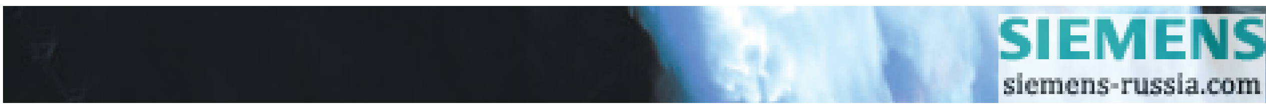
Transforming distance into daily life. Siemens Transformers.

HVDC transformers ensure efficient energy flow

Answers for energy.

SIEMENS



Efficient energy transformation with HVDC

Reliable electrical power supply is based upon highly developed power grids. That is why Siemens is right there wherever networks are being expanded, retrofitted, or newly built. As a world-leading manufacturer, systems integrator, and provider of complete solutions and services, Siemens enables power utilities to transport and distribute electricity reliably and economically from the power plant to the customer. Our comprehensive product range covers transformers for power stations, substations, and HVDC converter stations as well as transformers for industry and transportation, reactors, and accessories. For more than 100 years, Siemens transformers have been synonymous with top quality – as a result of ideas, know-how, and unequalled experience. All over the world, Siemens stands for highest quality and reliability in development, production, and installation as well as in commissioning and maintenance.

HVDC remote energy transmission – long distance with low losses

HVDC remote transmission makes it possible to transport electrical energy over long distances. The conversion of alternating current into direct current allows for transmission with comparatively low losses and for the interconnection of grids of different frequencies. Siemens is known for having developed unique new controls and instrumentation for HVDC transmission systems, and our transformers and smooth reactors have proven their outstanding performance for decades.

World-leading competence – always right at your doorstep

As an internationally networked provider with a strong local presence and a tight sales and service network, we are always on the spot – where- and whenever you need us to master a challenge successfully. Because for us, being a dependable, long-term partner for our customers is just another aspect of the reliability Siemens is noted for.

The importance of HVDC applications

With the rising energy price, power exchange between large grids will become more and more common.

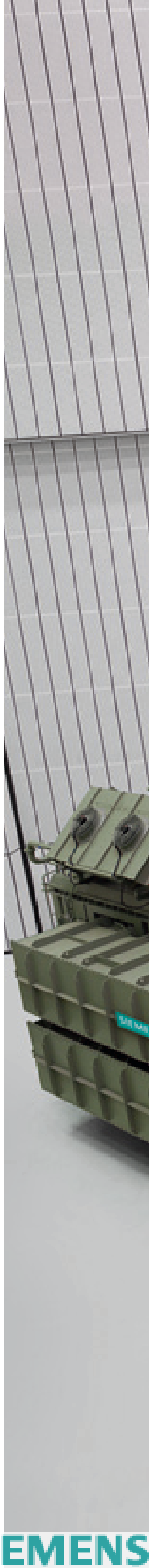
For example, an area (A) with abundant hydro power in a cold region may rely on another area's (B) coal-fired energy in winter since the frozen river cannot produce power. While in the rest of the year, the region B may rely on region A's hydro power to meet the peak demand in summer.

New HVDC applications are seen between existing, well-established networks. A back-to-back link can easily combine two different AC networks together, even with different frequencies. Both network users are able to take advantage of balanced load / output due to different time zones or different living behaviors that are causing delays in peak load. Such solutions can also help customers to strengthen and optimize their networks. The changing environment provides more and more opportunities to HVDC solutions, and Siemens is prepared to provide its customers with either our solution or with converter transformers as a loose component.

800 kV UHVDC converter transformers for China

In 2007 Siemens contracted the first two Chinese 800 kV DC projects: Yunnan–Guangdong at 5,000 MW and Xiangjiaba–Shanghai at 6,400 MW.

Both projects are featured of long-distance transmission with large-capacity electric power. With increasing demand of power in coastal areas of China, the hydro power in the western area is an ideal solution with low impact to the environment. However, the challenge lies in the transmission of bulk power over ultra-long distances. The Siemens solution helped the customers to solve this problem. China Southern Grid awarded the 800 kV transformer contract of both terminals to Siemens in summer 2007, which is the world's first order of this voltage level. Furthermore, Siemens is committed to help the local suppliers to build the low end transformers in China. At the end of 2007, China State Grid also awarded their first order of 800 kV DC transformers to Siemens, which shows the great confidence in Siemens technology of two major utility groups of China.

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Special demands on transformers

HVDC transformers are subject to operating conditions that set them apart from conventional system or power transformers. These conditions include:

- combined voltage stresses with both AC and DC
- high harmonics content of the operating current
- DC premagnetization of the core.

The valve windings which are connected to the rectifier and the converter circuit are subject to the combined load stress of AC and DC voltage. Added to this stress are transient voltages from outside caused by lightning strikes or switching operations.

Special demands require special solutions

The high harmonics content of the operating current results from the virtually quadratic current blocks of the power converter. The odd-numbered harmonics with the ordinal numbers of 5, 7, 11, 13, 17 cause additional losses in the windings and other structural parts. Selection of the material for all parts as well as their design and shielding therefore require in-depth preliminary theoretical study and experimentation.

Everything starts with the core

HVDC transformers are normally single-phase transformers, whereby the valve windings for the star and delta connection are configured either for one core with at least two main limbs or separately for two cores with at least one main limb, depending on the rated power and the system voltage.

Appropriately sized return limbs ensure good decoupling for a combined arrangement of windings.

Demands determine design and production

The quality of the core sheet, the lamination of the sheets, and the nominal induction must all conform to special requirements covering losses, noise level, overexcitation, etc.

Special attention must be paid to the DC premagnetization of the core due to small asymmetries during operation and vagabond DC currents from the AC voltage network. The effects of DC premagnetization must be compensated by appropriate design and manufacturing efforts (e.g., additional core cooling ducts and avoidance of flux pinching in the core sheet).

Windings – always wound well

The large number of parameters concerning transport limitations, rated power, transformation ratio, short-circuit voltage, and guaranteed losses require significant flexibility in the design of windings.

In concentric winding arrangements, star or delta valve windings lying directly on the core have proven optimal in many cases. The line winding, normally with a tapped winding, is then mounted radially outside this core configuration.

A compact unit evolves

The valve windings with high test voltages and a large portion of current harmonic waves cause particular demands on the design and the quality of winding manufacture. Together with its pressboard barriers, each limb set including a valve, a high voltage line, and a tapped winding forms a compact unit, which is able to cope with the demands made by voltage stress, loss dissipation, and short-circuit withstand capability.

Tank – unconventional design

The unconventional tank design in HVDC transformers results from the following requirements:

- The valve-side bushings should extend into the valve chamber, nearly horizontally.
- The cooling system is usually mounted on the opposite side to facilitate erection on site.
- For HVDC transformers with delta and star valve winding in one tank, the valve bushings must be arranged so that their ends conform to the geometry of the power converter. This frequently leads to very high connection heights and the need to mount the tank oil expansion vessels at a significant height.

Silicon-shield bushings

Compared to porcelain hydrophobic silicon shields provide better protection against dust and debris. A 15% higher DC voltage testing level compared to the windings underscores the particular safety aspect of these components.

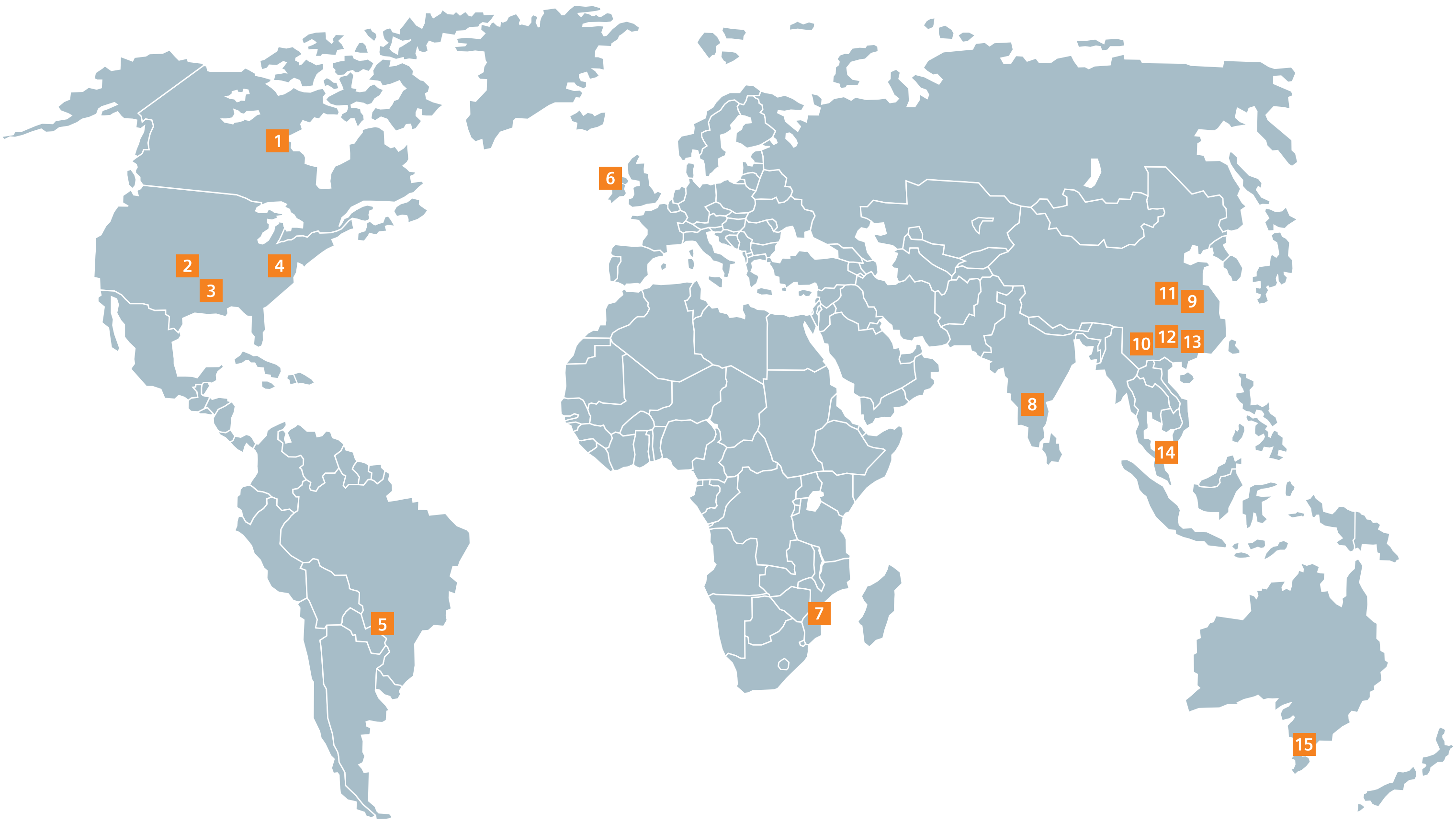
Smoothing reactors with independent inductivity

In the DC voltage line, smoothing reactors are necessary to reduce current harmonics. Electrically speaking, the reactor withstands the potential of the transmission DC voltage. Siemens employs both air-core coils with magnetic return paths and iron-core coils with air slots. In both cases, inductivity largely independent of the current must be guaranteed.

Testing the operating functionality

Special tests for verifying operating functionality are required for HVDC transformers. The applicable international standards are subject to constant further development. Separate tests with DC voltage, switching, and lightning impulse voltages cover the range of different voltage loads. The 2 MV DC voltage generator in the Nuremberg Transformer Plant is well-suited for all required DC voltage and reverse poling tests. The most important criterion is partial discharge. A maximum of ten discharges over 2,000 pC during the last ten minutes of the test is permitted.

Project references – in use around the world



Tried, tested, and proven

Wherever long cable connections, transmissions of very large volumes of energy over extremely long distances, or the coupling of networks of the same or different frequencies are needed, Siemens HVDC transformers and smoothing reactors deliver outstanding performance.

As a technology leader in HVDC, Siemens stands for experience, quality, and reliability and has always fostered further development, continuously introducing new cutting-edge details. That is why we are able to provide efficient solutions – worldwide and always tailored to our customers' needs.

1 Nelson River
2 Virginia Smith
3 Welsh
4 Neptune
5 Acaray
6 Moyle Interconnector
7 Cahora Bassa
8 East-South Interconnector
9 Ge-Nan
10 Tian-Guang
11 Three Gorges
12 Gui-Guang
13 Gui-Guang II
14 Thailand–Malaysia
15 Basslink

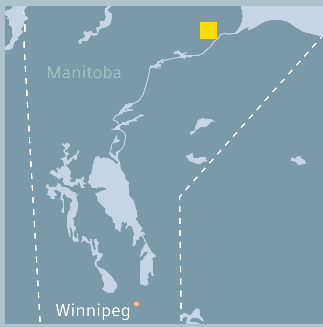
1

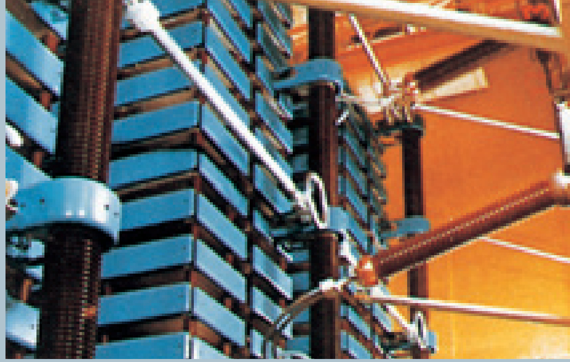
Nelson River, Manitoba, Canada

Introducing water-cooled thyristor valves

A double-bipolar 500 kV HVDC landline link delivers up to 2,000 MW from the power plants on the Nelson River in the north of Manitoba to the load centers in the south of the province, about 1,000 kilometers away. Bipole 2 was the first HVDC system using highly efficient water cooling for the thyristor valves, a technology which in the meantime has become standard.

Siemens supplied all thyristor modules and all four smoothing reactors, 0.65 H, 500 kV.





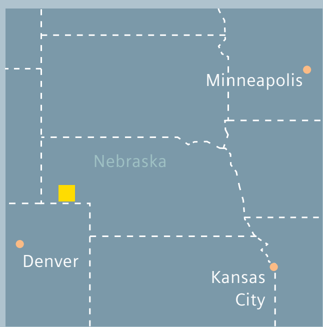
2

Virginia Smith, Nebraska, USA

Linking the asynchronous US networks

The 500 kV HVDC back-to-back tie at Virginia Smith Converter Station links the asynchronous networks in the east of the United Stated with those in the west. The station itself is controlled via WAPA from the load control center in Loveland, Colorado, 150 miles away. The converter station allows the transmission of up to 200 MW in either direction.

Siemens contributed seven transformers, 90 MVA, to the system.



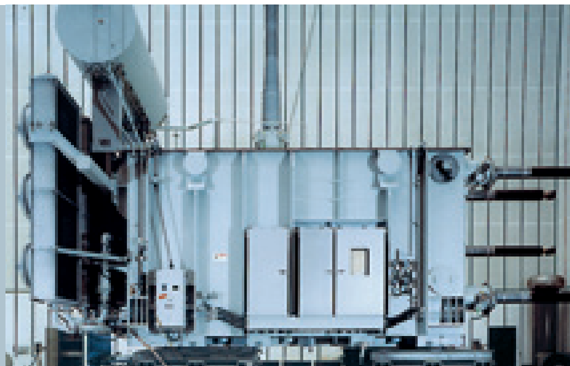
3

Welsh, Texas, USA

Connecting Texas to the Southwest Power Pool

The 170 kV DC Welsh Converter Station in Texas links the network of the Energy Reliability Council of Texas with the Southwest Power Pool of the eastern US network.

The back-to-back tie is equipped with seven Siemens 246 MVA DC transformers. It operates at a power rating of 600 MW at a voltage level of 345 / 345 kV, 60 / 60 Hz.



4

Neptune, USA

HVDC via subsea cable

The purpose of the 105 km 500 kV DC undersea and underground cable link is to transmit 660 MW of power from the Sayreville substation in New Jersey to Duffy Avenue substation on Long Island, thus providing LIPA (Long Island Power Authority) with access to the very competitive PJM Interconnection, a multi-state energy market on the east coast of the USA.

Siemens supplied eight HVDC transformers, 245 MVA each, plus three units rated at 80–115 MVA.

5

Acaray, Paraguay

Enabling intelligent energy exchange

In times of low output from its hydropower plants, Paraguay needs to import energy from Brazil, while in times of water surplus the country is able to export energy. The 25 kV DC back-to-back tie in Acaray links the Paraguayan 50 Hz network with the Brazilian 60 Hz network and furthermore helps to stabilize the Paraguayan 50 Hz network frequency.

Siemens supplied eight HVDC transformers rated at 20.6 MVA for the back-to-back tie with a power rating of 55 MW.

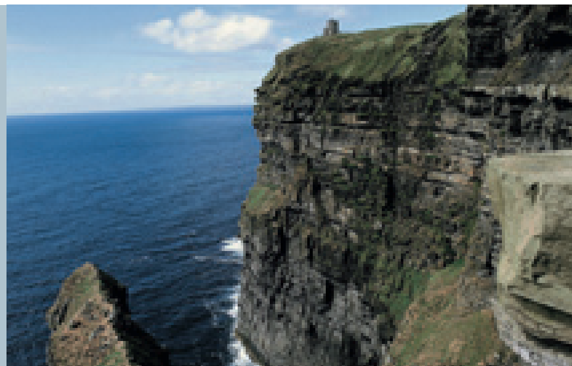
6

Moyle Interconnector, Northern Ireland–Scotland

Introducing LTT technology to HVDC

For the first time in a commercial HVDC system, the Moyle Interconnector, which connects the power networks of Northern Ireland and Scotland with a 64 km long submarine HVDC cable, employs direct-light-triggered thyristors with overvoltage protection. This reduces the amount of electrical parts in the thyristor valve and thus yields better reliability and longer maintenance intervals.

Siemens provided the 13 HVDC transformers, 96 MVA each, for the 2x250 MW interconnector.



7

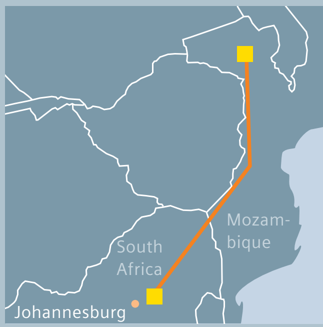
Cahora Bassa, Mozambique

The most powerful HVDC system in Africa

The Cahora Bassa project, which was originally commissioned in 1977, allows the landline transmission of 1,920 MW at 533 kV DC over a distance of 1,456 kilometers, from the Zambezi River in Mozambique to South Africa.

Siemens delivered 38 transformers rated at 90.8 MVA as well as four smoothing reactors, 0.7 A, 500 kV.

After civil warfare in the region in the 1980s, the most powerful HVDC system in Africa and the transformers were completely refurbished and updated by Siemens between 1995 and 1998.



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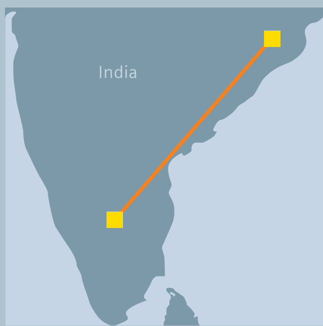
East-South Interconnector, India

Energy for the growing megacities

In India most of the energy is produced in the north-east, while consumption takes place in the south, in cities like Bengaluru or Chennai. The 500 kV HVDC East-South Interconnector transmits 2,000 MW of energy via landline from the province of Orissa to the southern province of Karnataka – a distance of 1,450 kilometers. The system also links two regional asynchronous networks. After three years, Siemens completed the project in India in 2003.

Siemens delivered 14 HVDC transformers, 400 MVA.



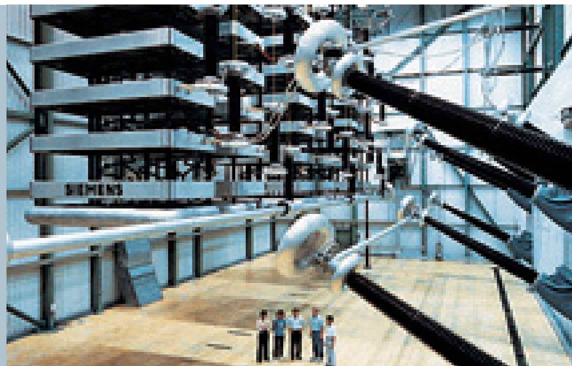
9

Ge-Nan, China

Hydroelectric energy for Shanghai

The Ge-Nan bipolar HVDC transmission system between Gezhouba and Nan Qiao transmits electric power via landline from the hydroelectric plant in Gezhouba in the Hubei province in central China to the Shanghai conurbation, which is about 1,000 kilometers away. The valve towers at the converter stations are suspended from the ceiling and employ water-cooled thyristors. This was the first project commissioned in China (1989) with a total power transmission capacity of 1,200 MW.

Siemens supplied seven HVDC transformers rated at 224 MVA.



10

Tian-Guang, China

1,800 MW over about 1,000 kilometers

The 1,800 MW 500 kV landline HVDC system which transmits energy from the Tianshengqiao hydropower plant to the Guangzhou region in the south of China employs water-cooled thyristor valves with the valve towers hanging from a special ceiling construction and active DC filters.

Siemens supported this project with 14 HVDC transformers, 354 MVA.

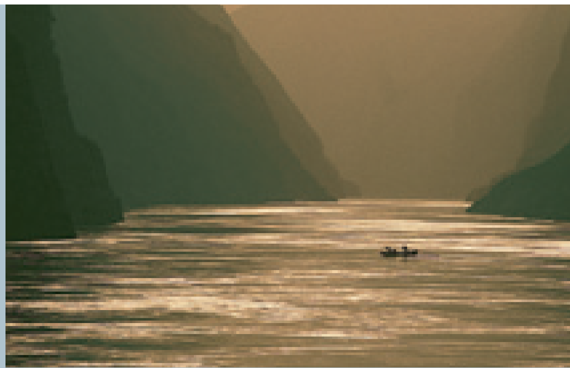
11

Three Gorges, China

Crossing inhospitable terrain

Transmitting energy over a long distance through nearly unaccessible terrain is a classic challenge in power transmission, and it is the field in which HVDC proves its high efficiency best. A characteristic example is the Three Gorges Project. The landline HVDC system covers a distance of more than 1,000 kilometers.

Siemens contributed 14 HVDC transformers, 283.7 MVA, as well as three smoothing reactors, 0.27 H, 500 kV, for the Zhengping converter station, which is situated between Shanghai and Nanjing.



12

Gui-Guang, China

Faster than anticipated

Six months ahead of scheduled time, the HVDC long-distance transmission system of Gui-Guang started commercial operation in 2004. The 3,000 MW landline system transmits power over about 1,000 kilometers.

Siemens delivered six smoothing reactors, 14 HVDC transformers, 297 MVA, and 14 HVDC transformers, 282 MVA, for 500 kV DC. Eight transformers and two smoothing reactors were built in China under supervision by Siemens.

13

Gui-Guang II, China

Expanding a successful system

In 2007, the Gui-Guang landline HVDC system, which transmits 3,000 MW of energy from the Anshun substation in southwest China across a distance of 980 kilometers to the Zhaoqing converter station near Guangzhou, was further expanded.

Siemens delivered a further six HVDC transformers at 297 MW, six HVDC transformers at 278 MW, and two smoothing reactors, 0.27 H, 500 kV DC, 1,500 MVA.

14

Thailand–Malaysia

Linking Asian networks together

The 110 kilometers HVDC long-distance transmission system interconnects the 230 kV AC network of Thailand with the 275 kV AC network of Malaysia. In its first stage, which started commercial operation in 2001, it is implemented as a 300 MW monopolar metallic return scheme.

Siemens delivered eight HVDC transformers.

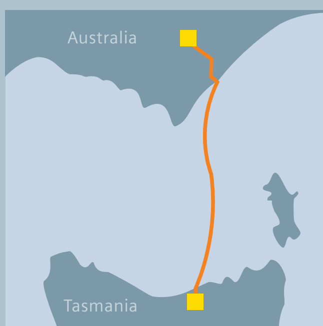
15

Basslink, Australia–Tasmania

Green power for Victoria

In 2005 the longest submarine HVDC link worldwide started its commercial operation. The 295 km long Basslink crosses the Bass strait, delivers hydro-electric power from Tasmania to the Australian State of Victoria, and also allows the import of base load from Victoria to Tasmania. The project was approved after extensive environmental impact studies in 2002, and consortium leader Siemens consigned the 500 MW HVDC system in 2005.

Siemens provided eight HVDC transformers rated at 196 MVA each.



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