SIEMENS energy

HVDC Classic – powerful and economical

High-performance power transmission

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HVDC – the silver bullet?

Optimized grid operation in the face of technical constraints and market development

An ever-increasing share of volatile renewable infeed calls for future-proof, flexible solutions that meet regional regulations and standards.

In more than 50 projects worldwide, Siemens Energy has proven its leading high-voltage direct-current (HVDC) technology to be the best solution for long-distance transmission, grid access, and grid stability.

High power transmission capability

The energy transition from fossil to renewable resources is dramatically changing load flows and requiring improvements to the existing power transmission infrastructure. Increasing distances between power generation and load centers means that higher transmission capabilities are essential. In addition, emerging international electricity markets call for improved transmission capacities and new corridors for power transfer and cross-border interconnectors.

Optimal efficiency in power transmission

It goes without saying that power losses must be kept to an absolute minimum in order to make efficient use of optimally designed transmission corridors with maximum power transmission capability. The ability to flexibly increase current or even temporarily overload power lines in the event of an emergency is another aspect of enhancing power grid efficiency, while the minimized right of way required for overhead lines and cables compared to AC systems reduces costs.

Safety and security for a reliable power supply

The impact of failures on security of supply and transmission capability must be limited and the highest safety standards in both, maintenance and operation maintained. What's more, the grid must have optimal resilience against natural disasters, terrorist attacks, and cyber attacks.

Flexibility for future challenges

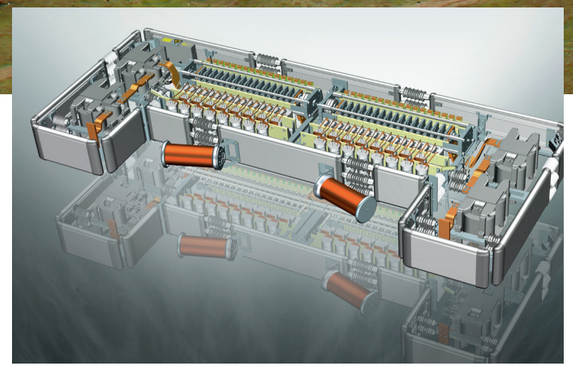
Another essential asset is a very fast and accurate power flow control as the infeed from intermittent renewable sources increases – and fluctuates with the weather. Power also needs to be transmitted in diverse directions and into different regions or even countries, depending on market requirements. Other challenges include more flexible grid configurations, redundancies, and more grid stabilizing functionalities.

Keeping costs low

In order to guarantee economic success, the lowest achievable CAPEX and OPEX are indispensable, possibly over the entire lifecycle of the investment.
During operation, this is mainly supported by high availability and a low-loss solution with minimized operating and maintenance costs for sustainable competitiveness.

Major challenges for grid operators

- Low investment and operation costs
- Highest efficiency with minimum losses
- Maximum operational availability and reliability and the best possible resiliency requirements
- Compact, adaptable, and economical solution
- Power exchange between interconnected systems and asynchronous grids
- Maintenance-friendly, safe, and reliable design with comprehensive lifetime services
- Future-oriented, flexible solutions for varying power market requirements



HVDC Classic:

Proven technology for sustainable performance

Lowest transmission losses – sufficient resources

While HVDC Classic features the lowest losses of all HVDC technologies, it's especially efficient in long-distance transmission over 600 km and more. In this case, HVDC transmission typically features 30 to 50 percent lower transmission losses than comparable HVAC (high-voltage alternating-current) overhead lines. It can also carry 30 to 40 percent more power given the same right of way. In addition, the HVDC transmission link offers an overload functionality that helps to supply sufficient power in emergencies and improves grid resilience without requiring more infrastructure investments.

Sustainable savings

Siemens Energys HVDC Classic technology offers the lowest CAPEX and OPEX and has set the efficiency benchmark in long-distance bulk power transmission. The HVDC Classic installations around the world are delivering substantial economic and environmental benefits – as well as transmitting large amounts of renewable power over long distances to the load centers. With a power rating of up to 6 GW at a voltage level of ±600 kV and up to 10 GW at ±800 kV, our HVDC Classic solutions offer very high power transmission capabilities that boost performance and provide a firewall against blackouts in existing overloaded AC grids.

Siemens Energys HVDC Classic (with line-commutated converter) technology helps grid operators to solve diversetechnical and economic challenges – while improving grid performance and stability and providing an outstanding control of power flows.

Enhanced grid stability

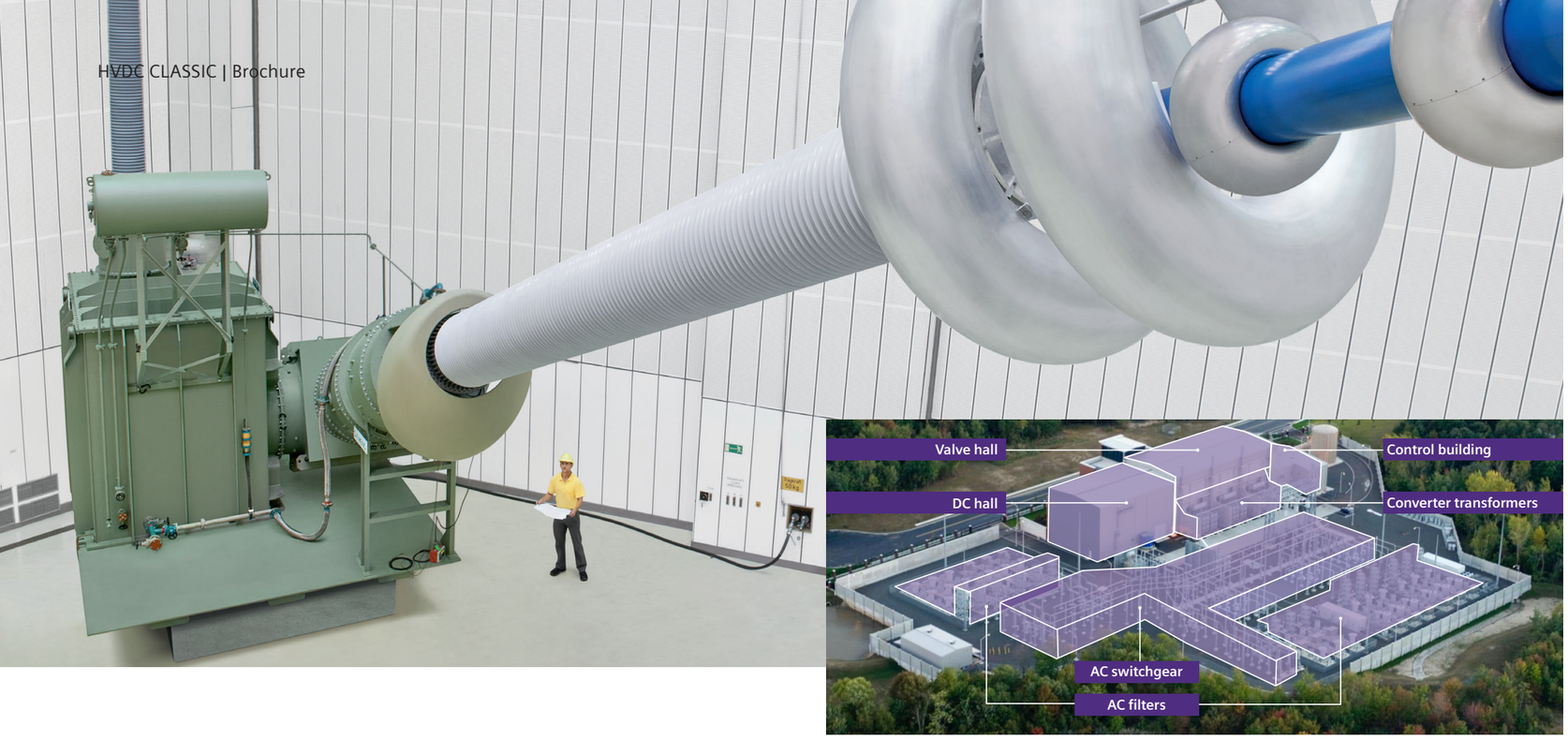
Any HVDC Classic system can improve grid stability. However, in special cases the addition of FACTS devices can enhance voltage stability even more. This optimizes grid stability such that it achieves the performance of Siemens Energys innovative HVDC voltage-sourced converter technology (HVDC PLUS). Increased security of supply can be achieved by arrangements of series and parallel connected converters in each pole. Multi-terminal setups take us another step toward connecting several stations: for example, across several countries.

Ease of maintenance and safety

Last but not least, the converter modules have been redesigned to facilitate easier, faster, and much safer installation, service, and maintenance activities. Thanks to the C-shaped design of these next-generation valve modules, all components can be accessed without having to leave the lifting platform.

Operational advantages

- High power and current transmission capability
- Optimized grid resilience thanks to sufficient transmission capacity to stabilize AC networks
- A very high level of system reliability and redundancy of all key components of the converter control
- State-of-the-art control and protection system; hardware and software in hot standby and proven in practice
- All current HVDC Classic systems are in line with latest cyber security standards (e.g. NERC CIP ready)
- Minimized maintenance and service requirements and the highest health and safety standards



A new dimension in power rating

Siemens Energy has developed a variety of technologies to meet the need for ever-higher power transmission capacities. One of them is the new six-inch thyristor with a rated current up to 6.25 kA. It has a high blocking voltage and the power density is also increased, which allows for a robust design with a minimum number of components.

This development opens up new horizons, enabling up to nearly 14 GW of power transmission in bipolar HVDC Classic systems.

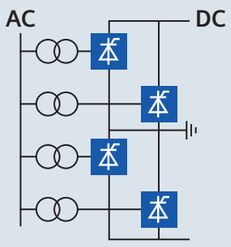
Siemens Energy is delivering the world's most powerful converter transformers to China in order to create the world's first 1,100 kV HVDC transmission link. This impressive component features 19-meter-long valve bushings that will enable the insulation clearance required in air.

The Changji – Guquan link is 3,284 kilometers long and has a transmission capacity of 12 GW. Its special converter transformers can be directly connected to China's 1,050 kV AC grid, another world's first.

Parallel converters

This solution is one answer to the increasing demand for large power transfers. It offers very high bulk power transmission, availability, and reliability due to its redundant design. It's also very flexible in operation, with an option to increase current ratings. Thanks to its very high currents and minimized height of the transmission towers and valve halls, these installations also enjoy improved public acceptance.

Parallel converters



HVDC Classic:

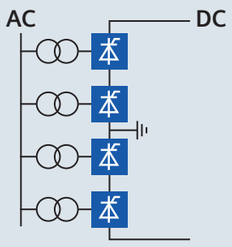
The latest developments are pushing the limits

HVDC Classic is a technological breakthrough for highly efficient power transmission. Available applications thus include long-distance transmission via overhead lines and cables as well as network interconnectors and grid access solutions.

Series converters

This design features improved redundancy and availability during converter failures. It enables grid operators to realize very high transmission voltages and power transfer, yet it's constructed using standardized components and designed to facilitate low investment and high cost advantages during operation. This is achieved by reducing losses and a simplified operation.

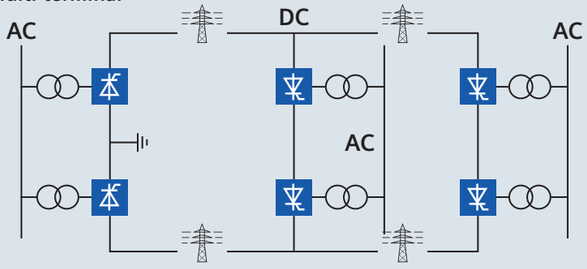
Series converters



Multi-terminal installation

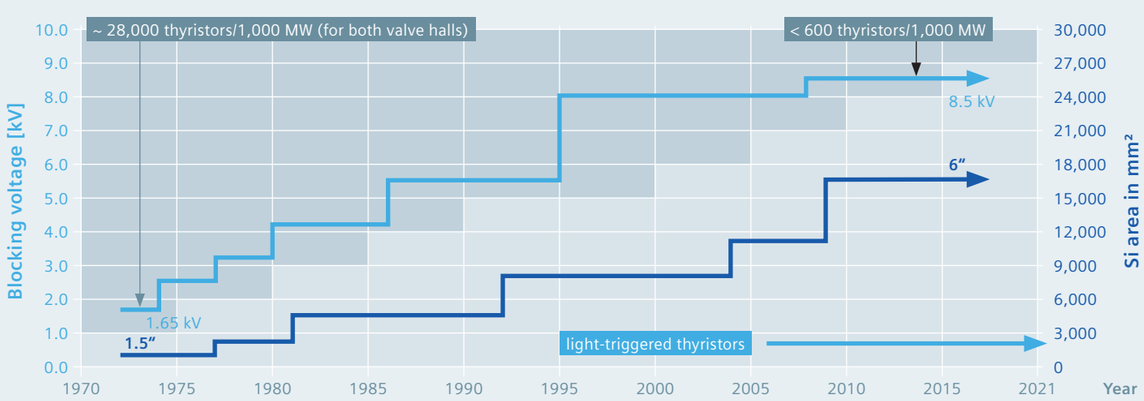
This system consists of three or more converter stations that can be built in different locations. As a result, a multi-terminal system offers highly flexible operation and adaptation to changing power flow needs. Therefore, it's the perfect solution for connecting AC grids, because it offers fast control and support for AC network stability and increased efficiency. In addition, a project can be developed in stages, allowing to achieve an early start of power transmission and revenues for the customer.

Multi-terminal



HVDC Classic:

Technology that explore new frontiers



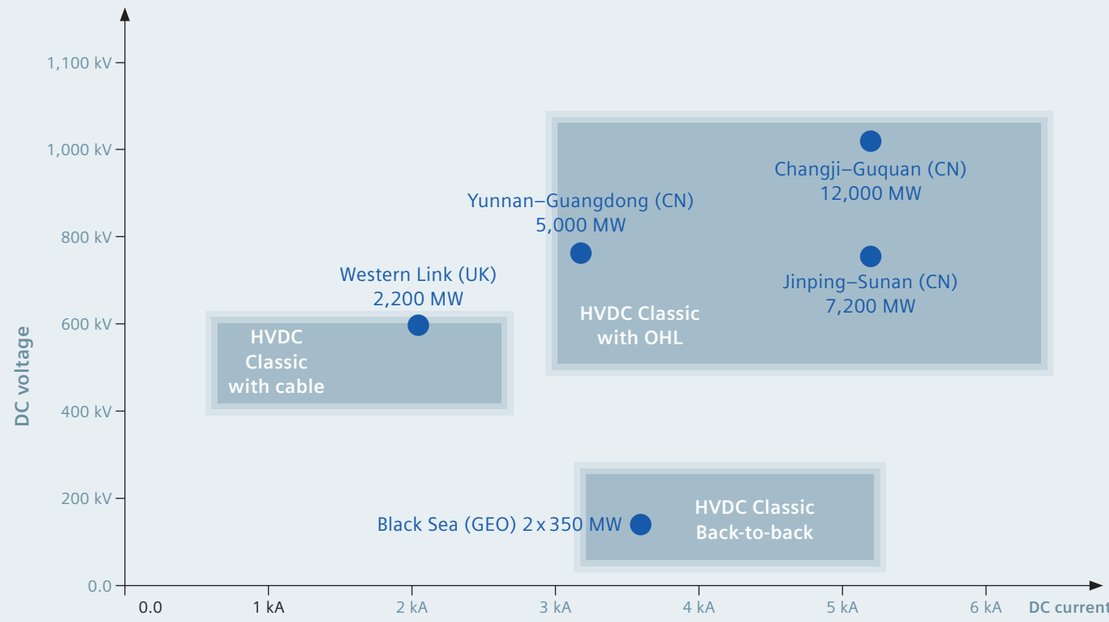
Continuous improvement of thyristor technology for maximum power density and compact design.

Siemens Energy is at the forefront of HVDC development and has set many milestones over more than four decades of research and practical implementation of this technology. Its overload capability, the advantages of Siemens Energy light-triggered thyristors, and the option to choose between voltage-sourced (HVDC PLUS) and line-commutated converters (HVDC Classic) are part of our HVDC success story.

Damping solutions for very high seismic requirements in New Zealand

An economical solution

Depending on system and ambient temperature and on the availability of redundant cooling equipment, the overload capabilities of thyristor-based HVDC Classic systems are an extremely economical asset. The cost benefits are amplified by the rugged system design, which allows for both, short-term and long-term overloads, if the appropriate cooling is installed. For grid operators, this means improved stability of the AC systems, shared spinning reserves, and reliable supply for peak loads. Even in the event of a pole outage, power reduction can be minimized.
The graph shows significant improvement in thyristor performance over the last four decades, resulting in ever-smaller numbers of thyristors carrying more and more power: With the latest generation, only 600 thyristors are required to transmit 1,000 MW of power.



Application range for HVDC Classic power transmission.

Light instead of electronics

The thyristor valves convert AC into DC – but while it is common to use electronics to trigger the thyristors, Siemens Energy has developed a more reliable trigger based on fiber optics and a light impulse. The advantage is obvious: The light-triggered thyristor (LTT) uses far fewer electronic components and is therefore more reliable.

Fire-retardant and self-extinguishing materials make our thyristors very robust and safer in terms of fire prevention. Parallel cooling of the valve levels with de-ionized water helps support maximum utilization of the thyristors.

Large range of high-power applications

HVDC Classic has been used to transmit the highest levels of power for decades.
The current carrying capacity of the thyristors, up to 6.25 kA, makes it possible to transmit power at high voltages and currents over very large distances, which cannot be achieved by any other AC or DC transmission technology. The HVDC Yunnan–Guangdong link in China was the first 800 kV project ever realized with overhead lines, and the Western HVDC link in the UK set a world record for 600 kV of power transmitted via subsea cable

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Investment in the transmission network are based on long-term calculations of power demand, mirrored in the life expectancy of the transmission equipment. Needless to say, Siemens Energy puts every effort into providing the best quality on the market; however, even high- quality installations require regular maintenance and other services to keep them perfectly efficient.

Get the most out of your assets

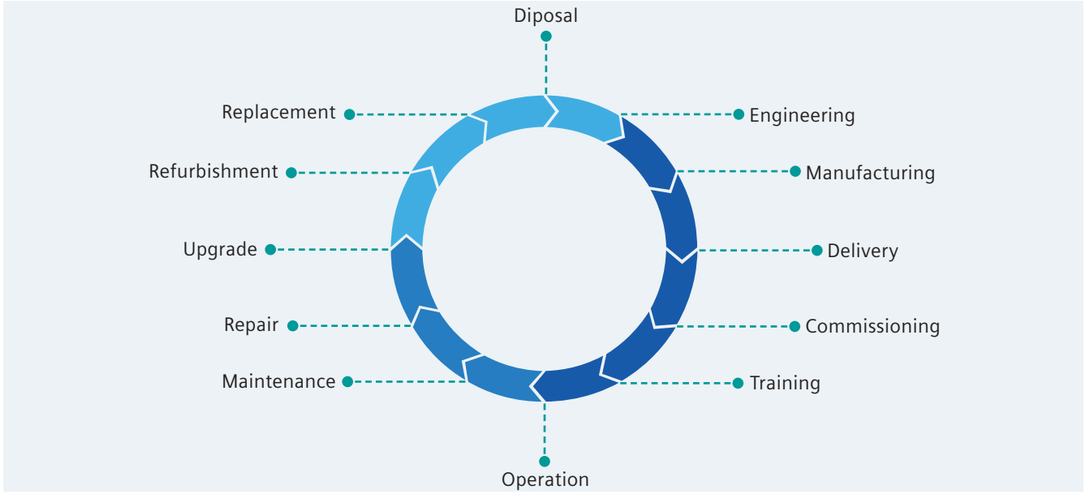
When the reliability and availability of the power supply is the essential factor for your customers, it's good to have Siemens Energy by your side. We help you obtain optimal performance, not only for your HVDC assets but for all your high-voltage equipment, based on our decades of field service experience and our pioneering work in both AC and DC technologies. In addition, we've developed dedicated services to best support your business goals, starting with on-site condition assessments of all your assets and complemented by continuous monitoring of critical systems, which minimizes unplanned downtime through preventive maintenance.

Made to order: Our HVDC after-sales services

As an established global service provider, Siemens Energy has developed a comprehensive understanding of after-sales services to provide customers with top performance and availability of their HVDC systems.
Profit from our in-depth analysis and service offerings to improve transparency and facilitate high asset availability and performance – today and for decades to come.

HVDC Classic Services

Partners for decades

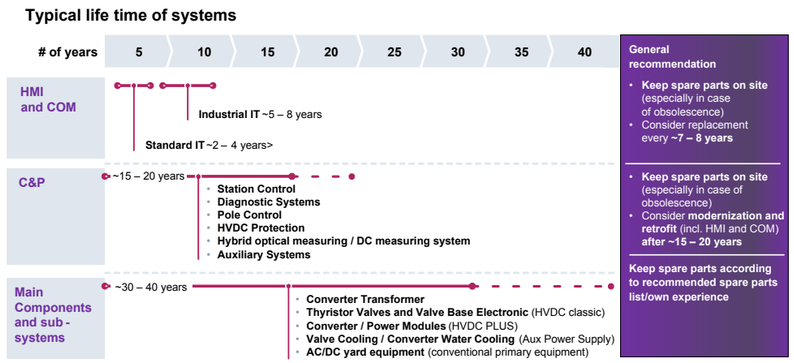


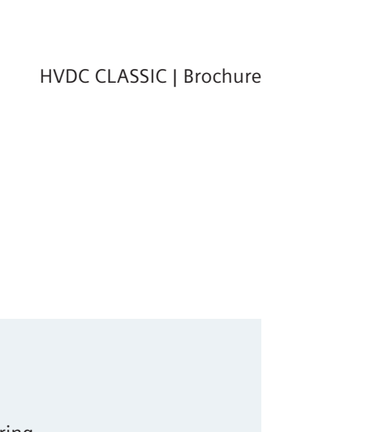
We make your assets more transparent:
- On-site condition assessments
- Condition monitoring and diagnostics
- Remote services
- Asset management and advisory services

We ensure high asset availability:
- Preventive maintenance
- Field service and repair
- Spare parts
- 24/7 expert hotline and technical support
- Obsolescence management

We optimize asset performance:
- Refurbishment
- Upgrade and uprate
- Patch management

We support you in operation management:
- Asset operation
- Spare-part management
- Customer qualification and training
- Cyber security services





HVDC Inter-Island link:

The backbone of New Zealand's power grid

**Since 1965, the power grids on New Zealand's North and South Islands have been connected across the Cook Strait by the HVDC Inter-Island link.
The comprehensive upgrade project, finalized 2013, included:**

- **The replacement of Pole 1 by a new Pole 3**
- **The replacement of the control system for the existing Pole 2, a third party system**
- **A new system for reactive power control.**

All installations fulfill the strictest seismic requirements ever implemented in an HVDC installation.

Safeguarding power in the Shaky Isles

Due to its geographic location on several seismic fault lines and the high number of resulting earthquakes, New Zealand is sometimes referred to as the "Shaky Isles." Haywards Substation, a key asset of New Zealand's transmission grid, is located directly on one of these seismic fault lines. Therefore, national grid operator Transpower demanded the strictest seismic requirements ever implemented anywhere in the world when preparing for the project to renew the HVDC Inter-Island link.

Over a period of four years, Siemens Energy designed, built, tested, installed, and commissioned a state-of-the-art thyristor-based HVDC converter and interconnector system at Transpower's Haywards site 25 miles north of Wellington, and at Benmore, the hydro power plant's substation in the far South Island. Both systems are capable of withstanding a one-in-2,500-years earthquake event.

Prepared for the future

The upgraded interconnector has a designed capacity of 1,400 MW at 350 kV, of which currently only 1,200 MW are being used due to the limited capacity of the submarine cables. This major upgrade to Transpower's high-voltage transmission system will secure New Zealand's electricity system for the next decades. The project also included a new reactive power controller, which controls reactive power flow and voltage in major parts of the 220 kV system of the northern island by direct control of existing and new reactive power sources.

The new Pole 3 has a continuous rating of 700 MW in both directions and, like Pole 2, is capable of operating in bipolar and monopolar configurations.

Further main advantages are increased reliability and the increased flexibility due to the new controls.

Designed and tested in every respect

The complexity of the AC sytem interfaces and the staged replacement of the existing third party control systems resulted in an unusually high number of different operational scenarios for which the system had to be configured and tested.

A very comprehensive on- and offsite test program was implemented in order to ensure that the HVDC Inter-Island link will be a robust and reliable backbone for New Zealand's power grid.

It will provide the required capacity to fulfill New Zealand's plan to achieve 90 percent renewable power by 2025.

Benmore Power Station – the start of the Inter-Island link Pole 3

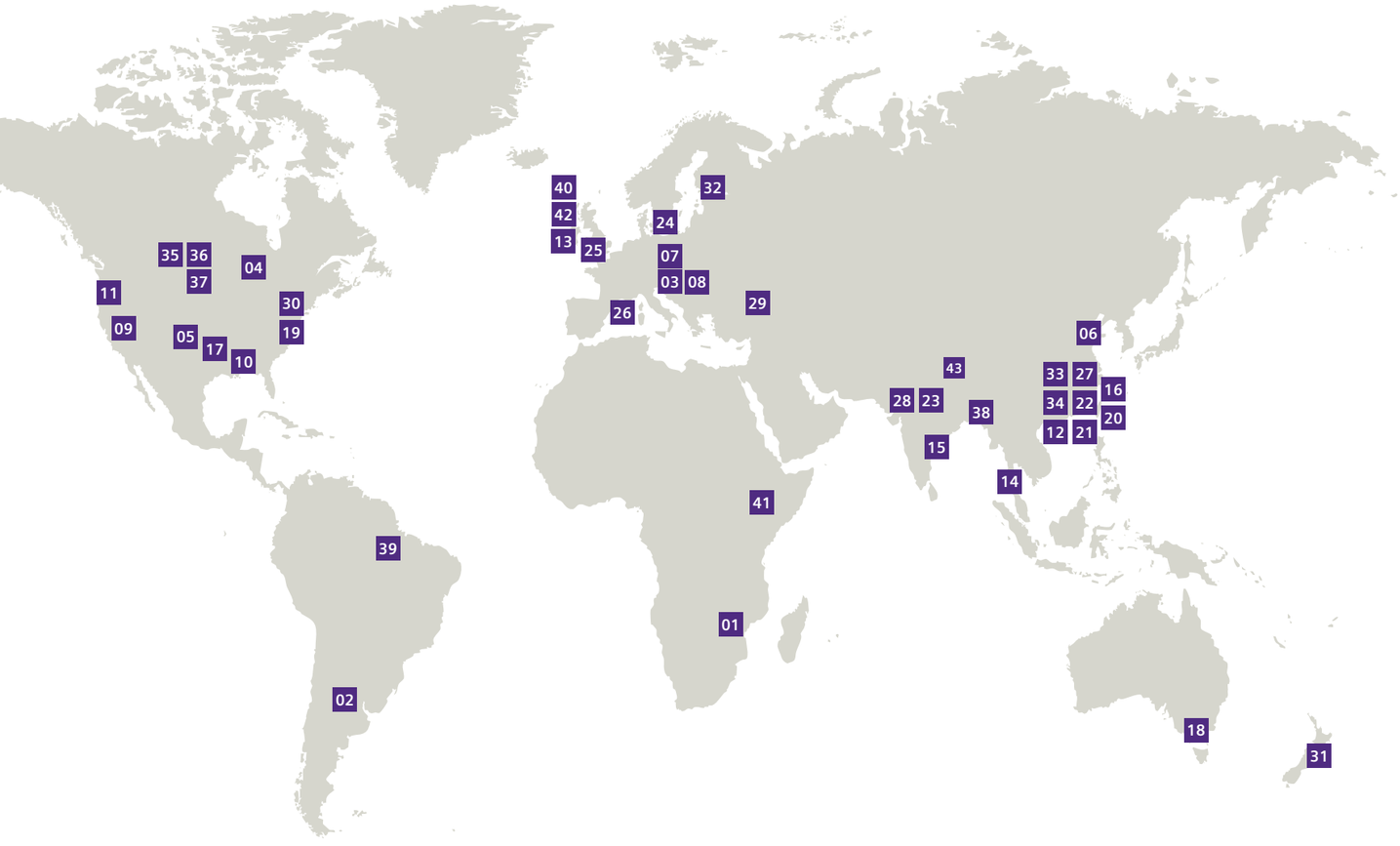
Seismic measures: rubber compensators for damping of vertical and horizontal oscillation of the complete valve hall/transformer foundation

Technical data	
Customer	Transpower New Zealand Limited
Project name	Inter-Island link Pole 3
Location	Haywards-Benmore, New Zealand
Power rating	700 MW monopolar 1,400 MW bipolar
Type of plant	Long-distance transmission, 649 m including 40 km submarine cable under Cook Strait
Voltage level	± 350 kV DC, 220 kV AC, 50 Hz
Thyristor type	Direct light-triggered, 8 kV
Other activities	Replaced Pole 2 control and protection system

HVDC CLASSIC | Brochure

Selected HVDC references

Siemens Energy is a reliable and experienced partner in the development, installation, commissioning, and operation of HVDC Classic solutions. Numerous references around the world demonstrate our role as a technology leader that offers highly efficient solutions for economical long-distance power transmission and interconnecting grids operating asynchronously or at different frequencies.



No.	Commissioning	Project name	Country	Power rating
01	1975	Cahora Bassa (1975/1998)	South Africa – Mozambique	1,920 MW
02	1981	Acaray	Paraguay	55 MW
03	1983	Dürnrohr	Austria	550 MW
04	1984	Poste Châteauguay	Canada	2 x 500 MW
05	1987	Virginia Smith	USA	200 MW
06	1989	Gezhouba – Nanqiao	China	1,200 MW
07	1993	Etzenricht	Germany	600 MW
08	1993	Wien-Suedost	Austria	600 MW
09	1995	Sylmar East Valve Reconstruction	USA	550 (825) MW
10	1995	Welsh 1995/2017	USA	600 MW
11	1997	Celilo 1997/2004	USA	3,100 MW
12	2000	Tianshengqiao – Guangzhou	China	1,800 MW
13	2001	Moyle Interconnector (2001/2022)	United Kingdom	2 x 250 MW
14	2001	Thailand-Malaysia	Thailand – Malaysia	300 MW
15	2003	East-South Interconnector II and Upgrade	India	2,000/2,500 MW
16	2004	Guizhou – Guangdong	China	3,000 MW
17	2005	Lamar	USA	210 MW
18	2006	Basslink	Australia	500 MW
19	2007	Neptune RTS	USA	660 MW
20	2008	Guizhou – Guangdong II	China	3,000 MW
21	2009	Yunnan – Guangdong	China	5,000 MW
22	2010	Xiangjiaba – Shanghai	China	6,400 MW
23	2010	Ballia – Bhiwadi	India	2,500 MW
24	2010	Storebælt	Denmark	600 MW
25	2011	BritNed	United Kingdom	1,000 MW
26	2012	COMETA	Spain	2 x 200 MW
27	2012	Jinping – Sunan	China	7,200 MW
28	2012	Mundra – Mohindergarh	India	2,500 MW
29	2013	Black Sea Transmission Network	Georgia	2 x 350 MW
30	2013	Hudson	USA	660 MW
31	2014	Inter-Island link Pole 3	New Zealand	700 MW
32	2014	EstLink 2	Finland-Estonia	670 MW
33	2014	Xiluodu – Guangdong	China	2 x 3,200 MW
34	2015	Nuozhadu – Guangdong	China	5,000 MW
35	2016	EATL	Canada	1,000 MW
36	2016	WATL	Canada	1,000 MW
37	2018	Nelson River, Bipole 1/2/3 (2004/1977/2018)	Canada	1,000/2,000/ 2,000 MW
38	2018	Bheramara BtB Block 1/2 (2013/2018)	Bangladesh	2 x 500 MW
39	2018	HVDC Brazil	Brazil	4,000 MW
40	2019	Western HVDC Link	United Kingdom	2,200 MW
41	2020	Ethiopia – Kenya HVDC Interconnector	Ethiopia - Kenya	2,000 MW
42	2020	Moyle C&P Refurbishment	United Kingdom	2 x 250 MW
43	2021	Vindhyachal Upgrade	India	2 x 250 MW

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Transmission
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91058 Erlangen
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Siemens Energy, Inc
Transmission
4601 Six Forks Road
Raleigh, NC 27609
USA

For more information, please visit our website:
siemens-energy.com/hvdc
or contact us: hvdc@siemens-energy.com

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