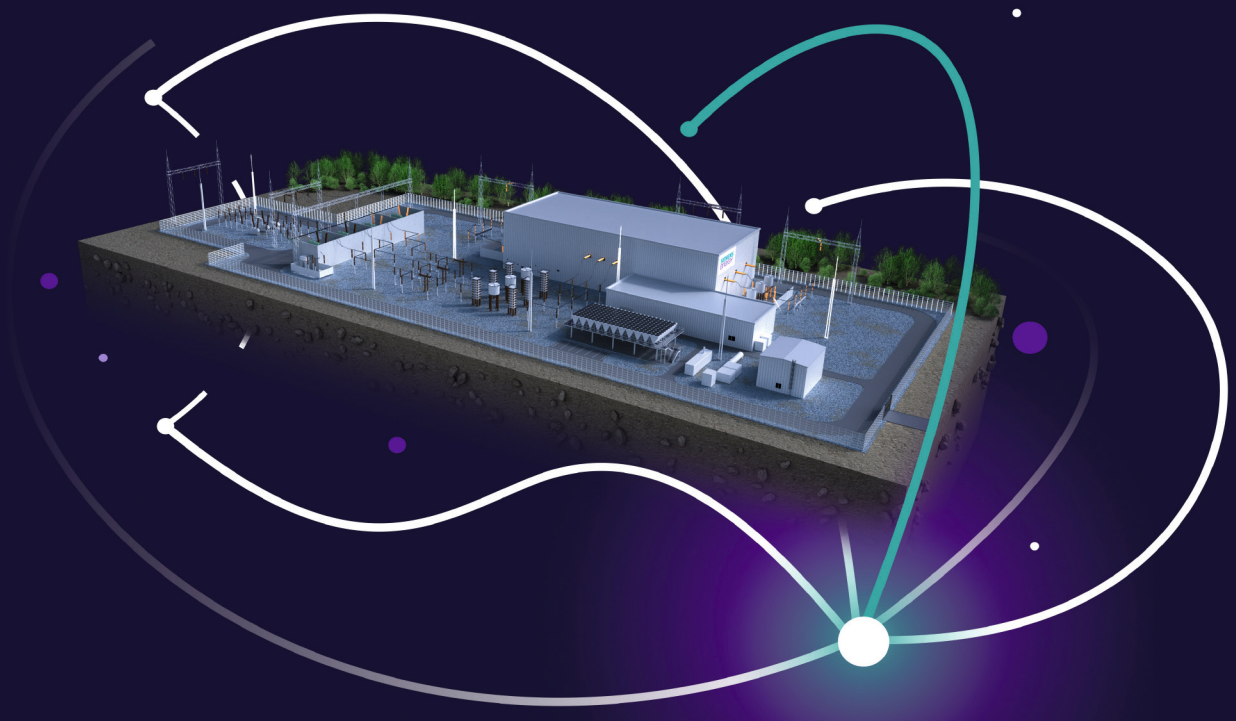
SIEMENS energy

HVDC PLUS® – the decisive step ahead

Stabilized power flows improve transmission grid performance



siemens-energy.com/hvdc



An unparalleled challenge:

keeping your grid performing predictably in times of unpredictable generation

An ever-increasing demand for energy, a steadily growing share of intermittent renewable resources and a decrease in conventional power generation are the challenges facing today's power markets.



Better grid performance

Grid operators are faced with ever-increasing requirements when it comes to grid stability, power quality, and reliability. In times of booming renewable power generation and decreasing conventional power generation, they need efficient, innovative solutions to keep the transmission system stable and reliable, and to maintain the safety and security of the supply at all times.

Managed grid complexity

With a multitude of intermittent power generators replacing a small number of highly predictable conventional power sources, grid operation has become very complex. It not only involves dealing with thousands of individual players while stabilizing the AC grid, it also means providing transmission capacity – wherever and whenever it is needed.

Improved grid access

Another challenge is providing grid access, either for remote renewable power generators such as offshore wind farms or for remote load centers like oil rigs. In all cases, transmission capacity is crucial for success, which means providing maximum availability, reliability, and flexibility.

Lowest CAPEX and OPEX

At the same time, customers need competitive solutions over the entire lifecycle. An optimal balance between functionality and performance on the one hand and investment as well as operational costs on the other hand is imperative.

Flexibility and power quality

In today's power grids, flexibility and power quality are in high demand. HVDC PLUS® can provide optimum solutions for your specific transmission tasks. This requires:

- Efficient use of HVDC PLUS® technology with project-specific adaptions, based on the Siemens Energy HVDC PLUS Reference Designs.
- An HVDC PLUS® point-to-point transmission system, which can optionally expand into a multi-terminal system with three or more converter stations.

Maintaining the highest standards

An HVDC PLUS® solution that improves your existing grid infrastructure needs to address the following aspects:

- Maximum availability
- Stabilization of the AC network
- Future-oriented, flexible solutions as a response to varying power market requirements
- Ability to provide grid access of renewable energy sources
- Power exchange between interconnected systems and between asynchronous grids
- Economic, adaptable, and compact solutions
- Maintenance-friendly, safe, and reliable design with comprehensive lifetime services









HVDC PLUS®:

the best technology for sustainable success

Versatility at your service

As an innovation leader, Siemens Energy has developed an advanced, universally applicable solution for power transmission with its voltage-sourced converter (VSC) technology HVDC PLUS®. The innovative solution offers a controlled power supply in either direction and is ideal as a "firewall" against disturbances developing in highly loaded AC grids. HVDC PLUS® technology is based on the trendsetting modular multi-level converters (MMC) and offers numerous technical and economical benefits.

Economical and environmental benefits

Environmental constraints play an important role in the development of power systems. HVDC PLUS® technology gives top priority to both, energy and resource efficiency. For example, the MMCs operate with low switching frequencies, which reduces losses. Due to generation of nearly ideal sinusoidal waveforms on the AC side typically the need for harmonic filtering is eliminated resulting also in less time and costs for planning, engineering, construction, and commissioning. And their compact design means lower space requirements and thus reduced property costs.

Siemens Energy has been a pioneer of HVDC PLUS® technology right from start and continuously driving technology further. HVDC PLUS® is our trend-setting development for ensuring economical power transmission and providing controlled power supply to the connected networks.

The compact footprint can be further reduced, e.g. using gas-insulated DC compact switchgear, available up to +/- 500 kV. Compared with air insulation, the gas-insulated solution reduces space requirements for the DC switchyard by up to 90 percent.



Stabilization of AC network

HVDC PLUS® is completely appropriate for steady state and dynamic AC voltage control, independently on each station. Its typical advantages are apparent when weak AC networks are being connected:

- Low dependency on short-circuit power, voltage, and frequency of the AC networks.
- Reactive power can be generated or consumed independent of active power transmission.
- During AC transmission network restoration (for example, after a blackout), HVDC PLUS® can provide system recovery ancillary service (SRAS).

Prize-winning health and safety compliance

We have a clearly defined goal for all our HVDC PLUS® transmission projects: apply the highest possible safety standard in order to reduce the number of incidents to zero. Our HVDC PLUS® systems are designed using a risk-based engineering approach to assure a risk-free and safe design, a “safety-first” construction process, and the safe operation of the systems. All projects are executed with the highest health and safety awareness on the part of our management, employees, and partners. Our team on the NEMO Link project awarded the „Sword of Honor” of the British Safety Council and the ElecLink project team achieved five stars in the British Safety Council’s Five Star Occupational Health and Safety Audit.

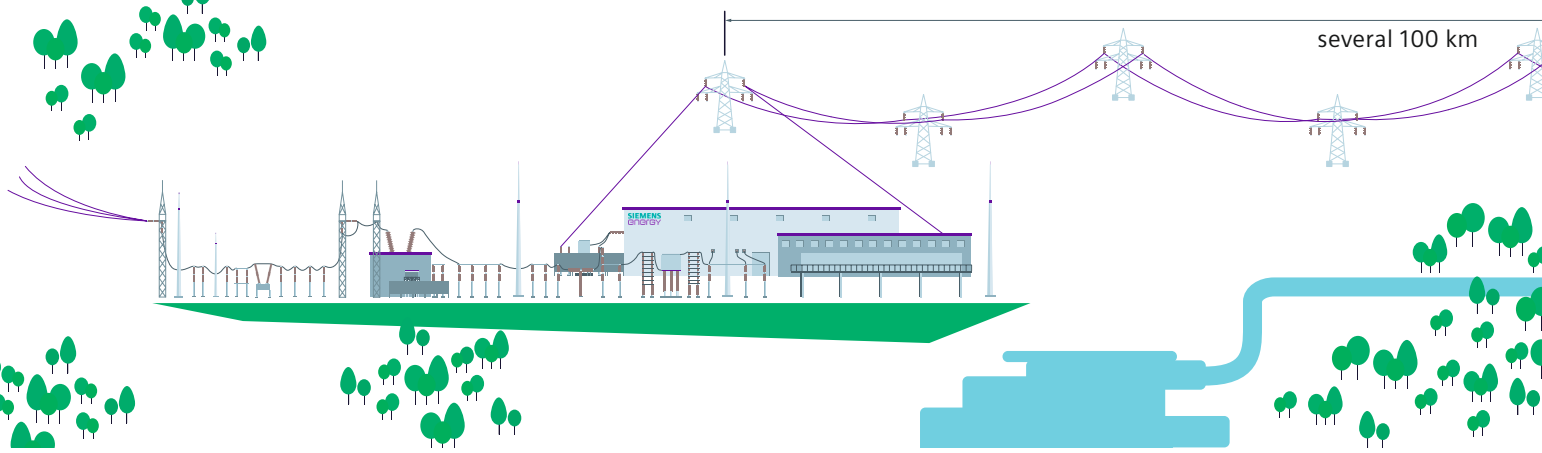
Operational advantages

- A very high level of system reliability, and redundancy for all key components of the converter control.
- Standard control and protection system; hardware and software in hot standby.
- Minimized maintenance and service requirements.
- Compact station design with typically no harmonic filters.
- Black-start capability to improve speed of recovery of interconnected grids.



HVDC PLUS®:

the solution for flexible DC power transmission systems



HVDC PLUS® 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.

HVDC PLUS® long-distance transmission

For covering long distances, HVDC PLUS® power transmission is often the most efficient and economic solution. In such cases HVDC PLUS® is the preferred solution where its superior features are benefical for the overall project. A variety of media can be used for power transmission: cables, or even existing overhead lines. There are numerous technical solutions that are best discussed with our experts to find the most appropriate configuration for your individual needs.

HVDC PLUS® interconnectors

HVDC PLUS® interconnectors connect independent national and/or regional grids regardless of their frequency. By converting the AC power into DC and from DC back to AC, the superior features of our HVDC PLUS® converters facilitate stabilization and improvement of grid operation. Grid code requirements are met. One example is a back-to-back interconnector where both converters are at the same location.

Long-distance

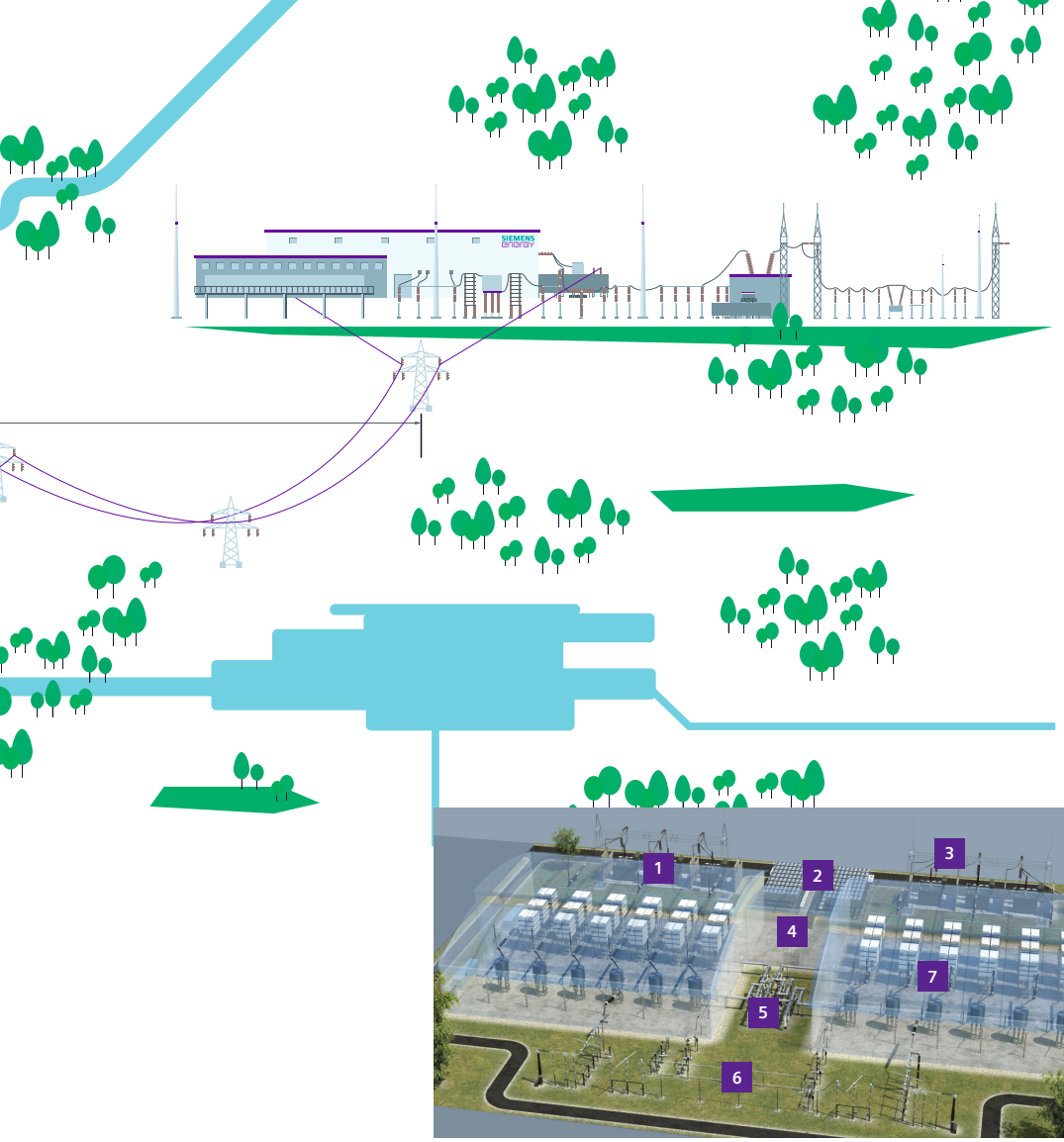


System A DC Line System B

Back-to-back



System A DC Circuit System B



1 Converter transformers
2 Cooling
3 AC switchyard
4 Control and protection
5 DC compact switchgear
6 DC yard
7 Converter hall

Grid Access

Siemens Energy offers perfect solutions for HVDC PLUS® offshore applications. HVDC PLUS® is the ideal space-saving solution to provide grid access to remote offshore wind farms with its dynamic fast control. This makes regenerative energy sources fit for the grid, and to connect them according to the conditions of each particular grid code by providing the required voltage quality at the grid coupling point.

Our DC Compact Switchgear offers additional space-savings on the platform.

HVDC PLUS® provides also power for connecting remote loads:

- from shore to offshore oil and gas platforms and
- for mines

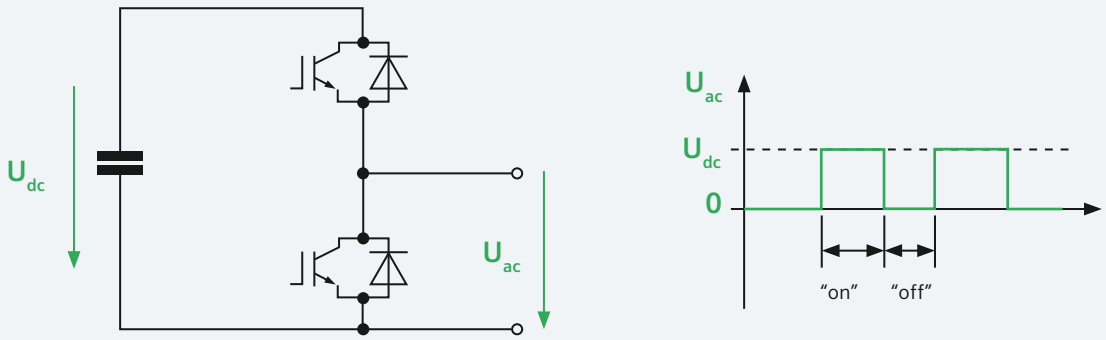
Multi-terminal connections and future DC grids

In addition to the most commonly applied point-to-point connections, HVDC PLUS® facilitate expansion to multi-terminal systems and further develop to DC grids in the future to back up existing AC grids.

Due to its operation principle to keep the DC Voltage constant in one polarity and to change direction of power transfer by reversing the current, HVDC PLUS® is ideally suitable for multi-terminal applications.

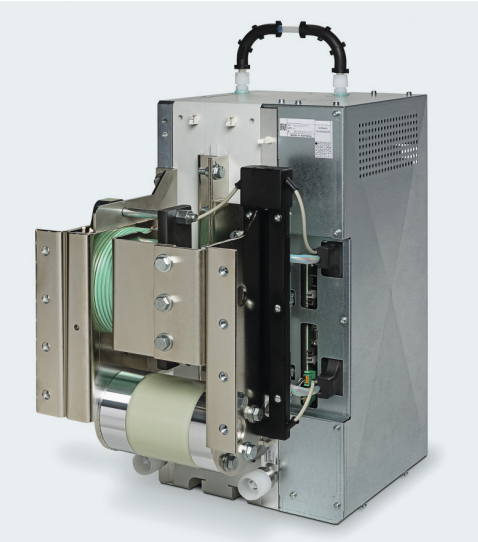
This enables to develop HVDC PLUS® transmisison solutions stagewise and provides high flexibility to expand existing schemes in case of future changes in power grids or load flow scenarios.

Half-bridge converter topology for utmost reliability



Half-bridge type MMC:

The power capacitor can be connected in one polarity to the terminals

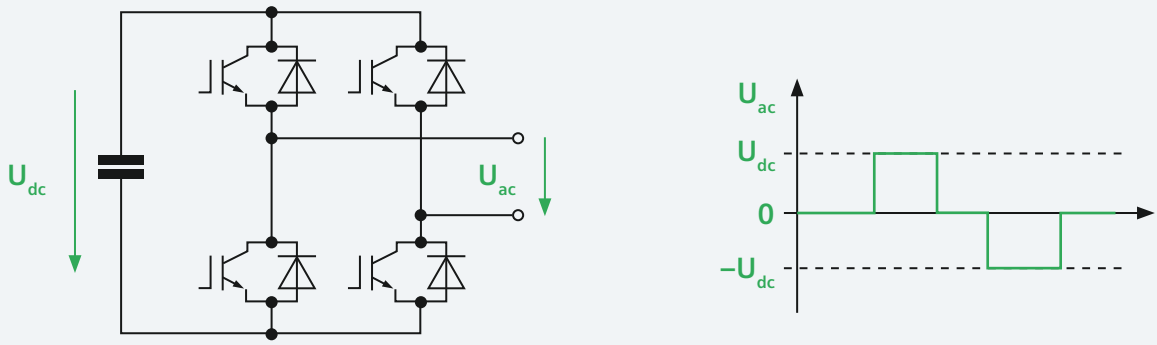


The next generation of power modules for more than 2 kA

The highly efficient HVDC PLUS® half-bridge topology is used for most HVDC PLUS® applications today. It has proven its excellent reliability in practice and is particularly suited for offshore applications.

This technology also features our latest innovation, the new half-bridge module based on cutting-edge IGBT technology with a DC current capability of more than 2 kA, which fits to the new development in XLPE cable technology. Its high power density results from its 6.5 kV voltage class and leads to reduced converter hall sizes. By a smaller number of submodule levels, losses are lowered even more.

Full-bridge technology for optimized power transmission



Full-bridge type MMC:

The power capacitor can be connected in either polarity to the terminals

For HVDC PLUS® overhead line configurations, MMC in full-bridge topology is the right choice, as this allows for selective clearing of DC line faults. The graph shows a typical HVDC PLUS® full-bridge topology design.

The power capacitors can be connected to the terminals at either polarity. This means that the DC voltage is independent of the AC voltage and can be controlled to zero or even be entirely reversed to maintain current control on the AC and DC sides and also under short-circuit conditions. The DC voltage can also be controlled over a wide range, including both polarities. Siemens Energy HVDC PLUS® technology is based on strategies proven in a wide range of industrial applications of VSC technology, and offers the following advantages:

- Immediate initiation of DC fault clearing by reversing the DC line voltage polarity for a short period of time in order to extinguish and de-ionize the electric arc followed by the possibility of multiple restart attempts
- Flexibly controllable DC voltage provides a voltage ramp-up characteristic, which takes into consideration project-specific AC conditions
- Flexible operation at a reduced voltage as a precautionary measure in adverse weather conditions and increased air pollution
- Minimized fault clearance time for multi-terminal systems, when combined with selective fault detection





Siemens Energy is not only the inventor of HVDC PLUS®, we are also the most experienced partner on the market today. And it shows – not just in our leading technology but also in comprehensive lifecycle support and individual services tailored to your needs.

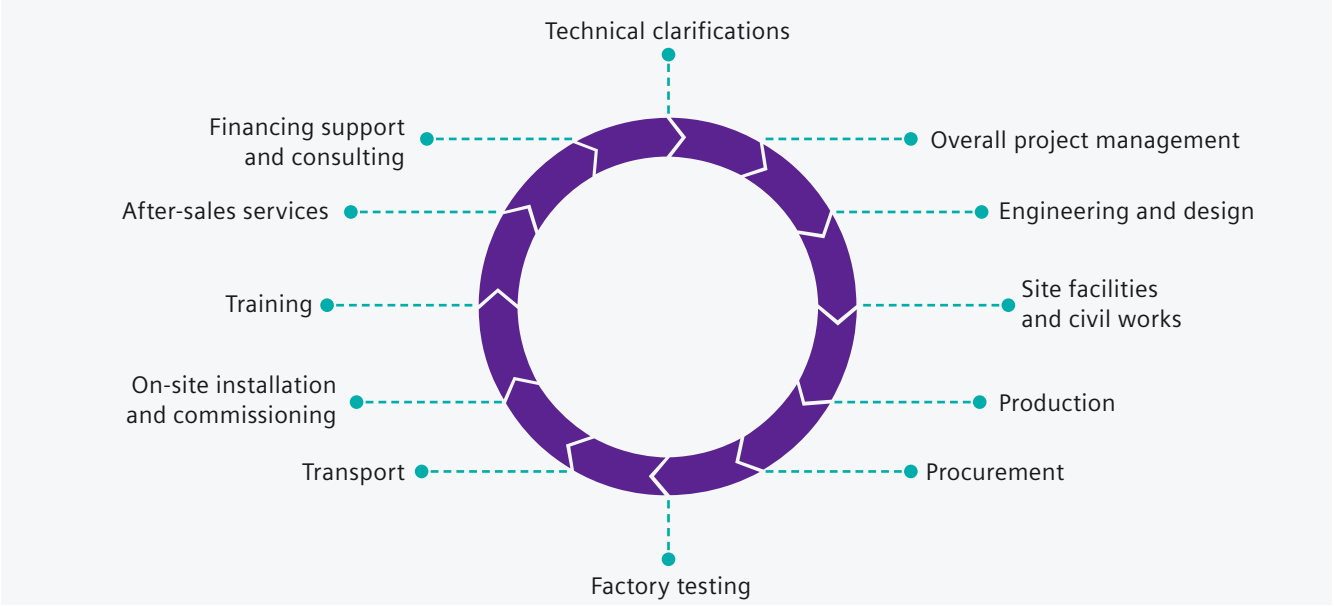
Turnkey solutions – the key to successful projects

If you are planning an HVDC PLUS® connection, you can rely on our unique expertise. This includes our continuous work to further advance the technology. As a result, we were the first to offer HVDC PLUS® in MMC technology, the first supplier of 2 x 1,000 MW with VSC technology, and the first to upgrade an existing HVDC PLUS® with black-start capability. This means that we can assume responsibility for the entire lifecycle of your project, from the first analysis through creation of an optimized solution to commissioning – including after-sales services from operation to the reliable supply of spares and more.

Our services span the entire lifecycle

As your partner, Siemens Energy offers the whole spectrum of HVDC PLUS® after-sales services to enable you to get the most out of your HVDC PLUS® assets. Our services range from standard preventive maintenance services to cyber security and asset management consulting. Retrofit and refurbishment services services assist you in extending the lifetime of your HVDC PLUS® assets.

Optimized support from your experienced partner



HVDC PLUS® after-sales services

Siemens Energy is an established service provider enabling you to obtain top performance and availability from your HVDC PLUS® system. This includes minimizing unplanned downtime through preventive and predictive maintenance. We provide a full range of valuable and reliable services.



To increase transparency of your assets:
- On-site condition assessments ("health checks")
- Condition monitoring and diagnostics
- Remote services
- Asset management and advisory services

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

To optimize asset performance:
- Refurbishment
- Upgrade and uprate

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

First HVDC PLUS® with modular multilevel converter (MMC) technology –

Trans Bay Cable



BorWin3 is the most recent project out of already 5 installed DC offshore grid connections. Operating since August 2019 and designed with float-over platform installation concept –

BorWin3



World's first HVDC PLUS® with full-bridge converter –

ULTRANET – A-Nord



Customer:	Trans Bay Cable, LLC
Location:	Pittsburg (California) – San Francisco (California), USA
Type of plant:	HVDC PLUS® in half-bridge topology connected via an 86 km submarine cable
Power rating:	400 MW, symmetrical monopole
Voltage levels:	± 200 kV DC, 230 kV/115 kV AC, 60 Hz

Operational highlights:

HVDC PLUS® enhances the performance of the transmission grid, improves reliability, and reduces maintenance costs. HVDC PLUS® is the preferred solution in space-constrained urban environments like San Francisco. After successful commissioning in November 2010, the Trans Bay Cable Project met the California Independent System Operator's (ISO) planning and reliability standards. The system was upgraded to black-start capability in 2016.

Customer:	TenneT
Location:	Emden, Germany
Type of plant:	HVDC PLUS® half-bridge topology, On-/Offshore cable, 160 km
Power rating:	900 MW
Voltage levels:	± 320 kV DC, 380/155 kV AC, 50 Hz

Operational highlights:

Compact DC solution for low-loss offshore-onshore power transmission and grid connection according to grid code. While grid fluctuations must always be taken into account in wind-based power generation, grid stability and reliability are significantly enhanced thanks to the Siemens Energy HVDC PLUS® technology.

Customer:	Amprion GmbH and TransnetBW GmbH
Location:	Philippsburg – Meerbusch – Petkum, Germany
Type of plant:	HVDC PLUS® converters in fullbridge topology connected via 340 km overhead line and 300 km DC cable
Power rating:	2,000 MW, bipolar
Voltage levels:	± 380 kV DC, 400 kV AC, 50 Hz

Operational highlights:

With its stabilizing functions, high availability for overhead line transmission, black-start capability, and full-bridge topology to clear faults in the DC sections quickly and flexibly, the bipolar ULTRANET HVDC PLUS® system will attain high reliability. ULTRANET will be the first link with DC lines placed on existing AC pylons, which will be provided by Amprion GmbH and TransnetBW GmbH.

With the DC cable extension A-Nord the system will be Germany's first HVDC Multi-Terminal system.

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