The Bulk Way

UHV DC – the new dimension of efficiency in HVDC transmission

Answers for energy.

SIEMENS
Shape up for the future of power transmission

Siemens UHV DC helps meet the steadily rising energy demands

Throughout the world, the demand for power keeps growing at a scale and speed never imagined by past generations. For various reasons we also witness a strong push for renewable energy sources (RES), with power generation becoming increasingly distributed and a growing number of generation facilities located far away from load centers. At the same time, demanding economic objectives as well as obligations to reduce greenhouse gases have to be met.

To meet all these demands precisely, Siemens has taken great efforts to overcome the existing limitations in the technology available for high-voltage direct current (HVDC) power transmission. Thanks to Siemens Ultra HVDC (UHV DC), long-distance power transmission at a voltage level of 800 kV - providing power capacities of up to seven gigawatts and more - has now become technically as well as economically feasible for the first time ever. Both poles of the first 800 kV UHV DC system, ordered by the China Southern Power Grid Co. in Guangzhou, are in commercial operation since June 2010. Pole one already started operation in December 2009.

Reap more with less effort

Siemens UHV DC enables low-loss transmission of more than seven GW with a single bipolar line

Siemens UHV DC is a newly developed system that provides the key to increased performance and robustness of the transmission grid, to keeping pace with the steadily growing energy demand, and to a highly economical way of CO₂ emission reduction:

- single bipole power transmission capacity of more than seven GW at a voltage of ± 800 kV
- 60 percent reduction in transmission losses and CO₂ emissions with UHV DC compared with standard ± 500 kV HVDC
- significantly smaller footprint and lower OHL costs compared with 800 kV AC solutions
- ideally suited for bulk power transmission over very long distances of 2,000 kilometers and more for infrastructure upratings
- capable of interconnecting large grids and stabilizing the surrounding AC systems
- advanced high-speed control system with Win TDC
From Smart Grid to Super Grid – Master tomorrow’s challenges today

Siemens UHV DC will be the bulk power energy highway and security backbone of the power grids of the future

In view of the rapidly growing demand for power, it is clearly evident that the power markets will undergo enormous changes in the years to come. Many existing AC transmission systems are about to reach their capacity limits, and new transmission technologies are required for bulk power point-to-point long-distance transmission from generation to energy-hungry load centers, which are growing at breathtaking speed.

In many countries, there will be a need for bulk power transmission corridors able to handle up to 60 GW of electric power. For various reasons, however, conventional AC transmission has proven unfeasible for this task. Here, Siemens’ ultra-high-voltage direct current (UHV DC) power transmission technology is thrust into the spotlight.

The next level of HVDC technology, Siemens UHV DC, is characterized by its innovative 800 kV voltage level, its transmission capacity of up to 7,200 MW, and a substantial loss reduction. Thanks to thorough R&D efforts, Siemens is able to produce the entire range of components required for 800 kV DC power transmission and supply complete UHV DC systems from a single source.

Benefit from innovation and expertise

Siemens offers single-source supply for all UHV DC components and services

UHV DC converter station

A converter station links the DC transmission line at each end to the AC grids. It consists of a number of components that have reached a high degree of maturity. However, for UHV DC application, innovative solutions have been implemented to fully meet the extended requirements for ultra-high-voltage bulk power transmission.

UHV DC converter transformer

The converter transformers connect each pole of the UHV DC converter to the AC grid in an economical way. With UHV DC, transformers show very impressive dimensions, especially their bushings. Local transportation restrictions and converter configuration determine their type and size; for example, for the world’s first UHV DC project Yunnan-Guang in China, a total of 48 transformers (plus eight spare units) had to be transported to the site.

UHV DC converter

A UHV DC converter performs the AC to DC conversion and vice versa. It consists of a number of thyristor modules that are connected in twelve-pulse groups. In the figure, a view of the new six-inch thyristor (8 kV, 4.5 kA) and the thyristor valve tower is shown.
UHV DC voltage divider

The UHV DC voltage divider from Siemens provides the DC-voltage measuring signal to the UHV DC control system. It is based on technology used in high-voltage test fields all over the world. The high accuracy of the divider is linear for almost the whole operating voltage range and above and extends over a large ambient temperature range. The challenge of developing an UHV DC voltage divider was to cope with the high internal and external dielectric stress, which is reflected in the dimension of the end-to-end composite insulator and the huge corona shield.

UHV DC bypass switch and bypass disconnectors

Both the UHV DC bypass switch and disconnector provide an option for more flexibility of the whole transmission scheme. For example, for a bipolar 800 kV DC transmission, two 400 kV converters at each pole are connected in series, and each one can be bypassed without interruption of the DC current whenever required. The assigned DC line is then operated at a reduced voltage level of 400 kV, and the redundancy of the transmission system is increased.

UHV DC disconnectors

The UHV DC disconnectors have to provide a safe isolation of all equipment in case of system shut-down, including during maintenance. The mechanical layout shows these requirements in an impressive way. Examples of the impressive testings of the UHV DC disconnectors are also highlighted in the figure.

UHV DC surge arrester

Insulation coordination of the protection levels of the UHV DC system determines the reliability of the whole transmission scheme. Surge arresters are the key elements for system security, for example, in case of line faults caused by lightning strikes, which are a typical and unavoidable natural phenomenon.

Additional UHV DC main equipment

- UHV DC wall bushing: as impressive as the transformer bushings due to its extended dimensions for the required insulation levels
- UHV DC smoothing reactors: current-sourced converters use a reactor as a smoothing element for the DC current
- hybrid optical UHV DC measuring system: ohmic shunt for measuring UHV DC current on high-voltage potential transmitted to ground via fiber optics
- UHV DC PLC capacitor: used to prevent high-frequency noise from entering the DC overhead line, and provides a connection path for the DC line-fault locator signal
- UHV DC post insulators: different technologies on the market, all using silicone housings, provide hydrophobic behavior on the surface of the insulators, which greatly reduces the risk of flashovers due to pollution
Siemens’ system design expertise is based on more than 30 years of building HVDC transmission systems. Just as Siemens products improve from year to year, the company’s system design experts push the limits of design to create ever-larger HVDC transmission systems.

Siemens has the knowledge at highest expert level and provides system design, station layout, and insulation coordination, including the design of arresters and flash and clearance-distance calculations. Its expertise also includes AC and DC filter design, AC and DC protection coordination, harmonic calculations, loss calculations, radio interference and noise calculations, reactive power management, frequency and voltage control, power oscillation damping, and system interaction studies, including subsynchronous resonances, to name just a few.

Both system design and component development evolve hand in hand, creating a constant development process that has always been driven by the goal of obtaining the maximum transmission capacity from an HVDC system of over 7,000 MW. Siemens system design experts contribute to achieving the perfect solution for their customers in each project, in close cooperation with them from the initial idea through the preliminary and final design, project execution, commissioning, and operation. And it doesn’t stop there. Transmission systems grow as power demand changes. Siemens is the number one partner of choice when such changes call for a transmission system to be upgraded or modernized. Siemens is on hand to identify the most efficient and economic solution to maximize its customer’s benefit and profit.

**Line arrester – special challenges**

<table>
<thead>
<tr>
<th>Development of an arrester housing</th>
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<tr>
<td>for upright installation</td>
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<tr>
<td>for maximum top deflection at specified seismic requirements and wind loads</td>
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**Tests at the HSP Hochspannungsgeräte GmbH in Cologne:**

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightning impulse voltage</td>
<td>2,400 kV</td>
</tr>
<tr>
<td>Switching impulse voltage in rain</td>
<td>1,770 kV</td>
</tr>
<tr>
<td>DC Voltage</td>
<td>865 kV DC</td>
</tr>
<tr>
<td>RIV test at DC maximum value</td>
<td>1,040 kV</td>
</tr>
</tbody>
</table>
System testing and commissioning

Siemens’ high quality assurance standards are fulfilled by intensive functional performance testing. Entire control and protection systems are connected to state-of-the-art digital real-time simulators (RTDS). All standard and customer-specific functions of the HVDC are verified in numerous transient and steady-state testing procedures. Physical limitations associated with carrying out on-site tests are a thing of the past, thanks to real-time simulator test facilities. The use of real-time simulators allows testing of all real system fault conditions in AC and DC that could possibly occur.

Finally, the on-site commissioning concludes the testing program and perfects the system to guarantee fail-safe operation at highest availability.

Capacitor-controlled wall bushing

<table>
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<tr>
<th>Technical data:</th>
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<tbody>
<tr>
<td>Rated voltage</td>
<td>816 kV DC</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>800 kV DC</td>
</tr>
<tr>
<td>AC Test voltage</td>
<td>1,100 kV</td>
</tr>
<tr>
<td>DC Test voltage</td>
<td>1,455 kV DC</td>
</tr>
<tr>
<td>Creepage path outdoor</td>
<td>42,500 mm</td>
</tr>
<tr>
<td>Creepage path indoor</td>
<td>26,630 mm</td>
</tr>
<tr>
<td>Rated current</td>
<td>3,700 A DC</td>
</tr>
<tr>
<td>Weight</td>
<td>5,600 kg</td>
</tr>
</tbody>
</table>
Furthermore, mechanical requirements refer not only to operational forces but also to seismic conditions and wind loads anticipated in the areas where the AC and DC stations are located.

By nature, ultra-high-voltage AC and DC equipment and suspension structure requirements are expected to be much higher than the requirements for existing voltage equipment. For this reason, both the electrical properties and mechanical stresses required careful consideration during equipment design.

For ultra-high DC voltages of 800 kV, external insulation of the equipment is a vital issue. In the past, HVDC was limited to maximum voltage levels of 500 kV to 600 kV. Today, in order to enable bipolar power ratings of 7,000 MW and higher, the operating DC voltage levels of all equipment has been increased to 800 kV. The impact of this increased steady-state and transient voltage on entire UHV DC stations had to be carefully investigated. To do this, the adequacy of existing technologies was evaluated and manufacturing capabilities were taken into account. The challenges for all of the DC components were huge:

- proper internal design of the equipment
- safe external insulation of the equipment housings
- adequate margin with respect to mechanical stresses, including seismic forces
- finding ways to transport equipment of these dimensions and weights

DC/AC yard – filters and reactive power compensation
Operation, maintenance, and contracting

UHV DC helps prevent bottlenecks and overloads in power grids through systematic power-flow control. As a result, the operation of UHV DC systems is basically similar to or even easier than the operation of a large power plant, with one important exception: the dynamic performance of the DC system is much more powerful than that of a standard power plant. This means that the DC transmission offers more features for dynamic system support through the injection of reserve capacity, based on its short-term and permanent overload capacities. That can help enormously in the event of emergencies like system faults or outages.

The additional function of any DC system that is decisive for system security is an automatic firewall. This firewall function can prevent the spread of an AC disturbance within the system at all times. As soon as the disturbance has been cleared, power transmission can be resumed immediately at a predefined ramping speed.

In addition, the maintenance of UHV DC equipment and systems is much less complex than that of a large power plant. The customer’s own experts are trained intensively in system component technology and in relevant maintenance procedures, usually in two-year cycles. Along with test routines for system control, the training encompasses protection for the DC components and the DC line, the converter transformers, AC busbars, and AC feeder protection. It also includes the associated AC and DC measuring circuits together with the HVDC converter, the valve cooling, the converter transformer, and the DC and AC filter components.

Within its contracting framework, Siemens also offers complete maintenance contracts where necessary, including a 24-hour round-the-clock emergency service. As part of Siemens’ service portfolio, total system operation responsibility is also available on contract, and is carried out by Siemens appointed specialists.
Increase the capacity and efficiency of your network

Siemens UHV DC compels with an outstanding cost-benefit ratio in every respect

One of the biggest and most untapped savings opportunities lies in advancing energy efficiency. That’s exactly what makes UHV DC the option of choice for long-distance bulk power transmission. Generally speaking, with the innovative UHV DC transmission voltage of 800 kV, transmission losses are typically reduced by 60 percent in comparison with conventional 500 kV DC transmission. This means that UHV DC is ideally suited for the bulk power energy highways of the future Super Grid.

That’s why Siemens has made every effort to enter this new dimension of innovative ultra-high-voltage and bulk power transmission. With 800 kV UHV DC technology, both right-of-way requirements and transmission losses can be reduced significantly. It bears mentioning that for a n-1 redundancy criterion, bipolar DC transmission is equivalent to a double-circuit AC system, which means huge right-of-way savings on the DC system.

Of course, Siemens UHV DC also fulfills its environmental responsibilities. The Yunnang-Guangdong project is the world’s first 800 kV UHV DC system, transmitting large amounts of clean hydro power from western China to the load centers near Hong Kong since 2010 - and it prevents 33 million tons of CO₂ emissions each year.*

This multitude of economic and environmental benefits makes Siemens UHV DC ideally suited for the immediate and efficient enhancement of transmission infrastructures wherever required.

Win TDC

Siemens Win TDC is a state-of-the-art industrial standard control system for drives and many other applications, including HVDC and FACTS. Equipped with ultra-fast 64-bit RISC processors, flexible interfaces, and a specially designed HVDC trigger set, Win TDC is the ideal solution for UHV DC control and protection.

* Compared to local power supply, based on an average energy mix