SIEMENS
Newsletter
Power Transmission
Issue 0910
HVDC/FACTS - Highlights

Ultra HVDC Transmission System

Increased capacity and efficiency for vast bulk power transmission systems

Introduction
Throughout the world, the demand for power keeps growing at a scale and speed never imagined in the past. 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 hitherto limitations in the technology available for high-voltage direct current (HVDC) power transmission.

The latest Ultra HVDC (UHVDC) is much more economical refering to the 800 kV AC solution. It is ideally suited for bulk power transmission over very long distances of 2,000 km and for infrastructure upratings. Transmission losses can be reduced by 60 % as well as CO_2 emissions compared with standard ± 500 kV HVDC. It is capable of interconnecting large grids and to stabilize parallel AC systems.

Challenges
This huge step in electrical power engineering was enabled by intensive R&D works over HVDC converter equipment design and long-term manufacturing experience.
The design of the latest UHVDC transmission system covers different requirements for external insulation, air clearances and corona performance. Some components of the main DC circuit did not require detailed investigations since the existing technology basically enabled to extrapolate from lower voltage applications. However, for other equipment more efforts were required to verify suitability of existing technology as well as know-how for the design and manufacturing process for UHVDC equipment (Background information: refer to newsletter 04.05).

For example especially for air clearances it becomes obvious that already a linear increase by 60% (comparing 500 kV to 800 kV) could be extremely difficult to realize from mechanical point of view. Considering that in the UHV range some effects become highly non-linear, extrapolation of existing design philosophies is not feasible. Manufacturing and finally transportation such large equipment to site would be extremely difficult. Hence, other solutions had to be found to balance electrical field strength and equipment dimensions.
Environmental conditions play an important role for equipment design. Even though this is not limited to the increased operating voltage level, it has to be considered thoroughly when converter stations may be located in areas: with considerable degree of pollution; or at altitudes of more than 1 000 m above sea level; or where transport limitations exist for heavy equipment; or with high seismic activities. It is worthwhile to mention that the above requirements cannot be regarded as independent of each other.

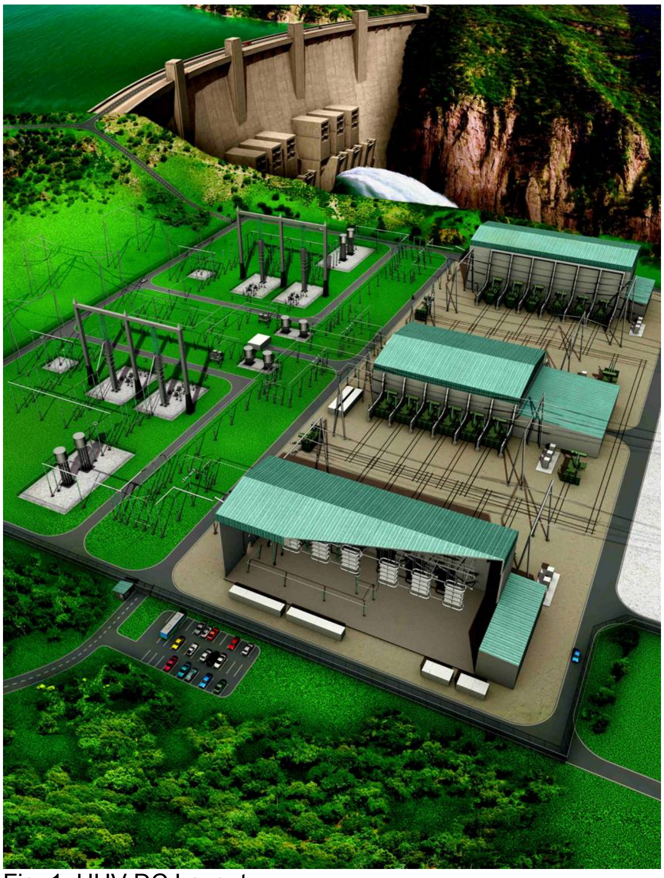
Fig. 1: UHV DC Layout

Let us now have a closer look to the first worlwide ordered 800 kV UHV DC by the China Southern Power Grid Co, the Yunnan-Guangdong project.
The project is designed to transmit a nominal power of 5000 MW over a long distance of 1418 km. The rectifier station is located at Chuxiong in Yunnan province where large amount of hydro power is available. The inverter station at Suidong is within the load centre in Guangdong province. The rated dc current of this UHVDC link was determined as 3125 A, which is a little higher than that of 3000 A in the existing ± 500 kV HVDC systems in China Southern Power Grid.
The altitude of Chuxiong Station above sea level is 1850 m. Though the altitude of Suidong Converter Statiuon is very low, the industry centre around Guangzhou city is the heavy pollution area. Both high altitude and heavy pollution level are challenges for external insulation of the 800 kV outdoor equipments.

Which solutions have been developed for the latest UHV DC?

Thyristor Valves

The valves are arranged as two 12-pulse bridges in series (400 kV bridge voltage each). Mainly due to the converter transformer arrangement, the valve hall length is pre-defined and allows arranging the MVUs (multiple-valve units) as double-valve towers. Each valve group can be put into or out of operation without affecting the current flow in the other group. This is accomplished by installation of bypass switches in parallel to the valve groups.

The MVUs are suspended from the ceiling including fibre optics for triggering as well as cooling water pipes. While the upper end of the converters is connected to the mid-point voltage of the corresponding group (i.e. 200 kV for the 400 kV group and 600 kV for the 800 kV group) the lower ends are connected to the terminals of the groups (neutral, 400 kV 800 kV respectively). During R&D stage shieldings on the upper and lower end were thoroughly investigated and verified in order to optimize required air clearances.

Fig. 2: Indoor photo of valve hall

The Yunnan-Guangdong Project is equipped with 5 inch direct light-triggered thyristors (LTT) which already have been installed in various applications up to 500 kV. Meanwhile, Siemens has already developed a new generation of thyristors, sized 6 inches, which enables to increase the dc current to values of 4.5 kA. In combination with 800 kV operating voltages this provides the capability to increase the bipolar power rating up to 7200 MW.

Protection scheme by additional arresters
The general goal of insulation coordination is to find an economically and technically optimized solution for equipment design. For –UHV applications this means that the arrester protection scheme, may include additional arresters to limit the withstand voltages to lower values and hence assist to optimize the equipment design without reducing proven safety margins. As an example additional arresters on the secondary side of the converter transformers have been introduced.

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New material for insulators and bushings
In recent decades application of other insulation materials has helped to dramatically reduce insulation problems caused by pollution flashovers. The first composite dry-type DC wall bushing at the 500 kV HVDC Nelson River Bipole 2 Project with silicone housing installed by the bushing manufacturer HSP is now in successful operation since 1991. The hydrophobic properties prevent building up a conductive layer on the polluted insulator surface. Based on excellent experiences gained in various converter stations, the creepage distance can be reduced to 75% of the corresponding value for porcelain. Meanwhile several other high voltage products are available with silicone housings. This included mainly the following components: busbar support insulators, DC disconnectors, DC bypass switches and DC plc capacitors.

DC wall bushing & transformer bushing
As already explained state-of-the-art technology is using composite housing and silicone rubber sheds for external insulation. The internal insulation design includes a condenser core of oil-free resin impregnated paper and SF6 for insulation between core and inner surface of the housing. Both parts of the wall bushing, indoors and outdoors, are of the same design and are connected by means of an SF6 filled duct.

Optimized shielding
Clearance distances in air depend strongly on the electrode shapes under consideration. These result in the so called “gap factors”. For indoor installations – namely the valve hall building – the influence from environmental-conditions can be well controlled and allows reducing air clearances to lower values by designing appropriate shielding electrodes. This has been applied for optimizing the valve tower shieldings.

Similarly, the transformer bushing terminals´ shielding was investigated. Double-toroids have been selected in order to improve the dielectrical strength of the air clearances to the valve hall building floor walls.

Converter equipment
The remoteness of the site is one of the challenges for UHV DC at the Yunnan-Guangdong project. “We specially designed the actual transformer units to fit through the mountain tunnels by train,” explains Marcus Häusler, Technical Director System & Equipment Engineering HVDC at Siemens. “The connector arms, the transformer bushings, as well as parts of the windings, were then installed on site.” In total, 24 transformers with four different types are installed at each station with one spare for each type. “If one of the transformers needs to be replaced, it could take months to get a new one out here, so we chose to keep one for each type in reserve on site.”

DC Smoothing Reactor

In the UHVDC projects under construction or design so far, dry-type, air core reactors are the preferred solution. They are a design family of coils without a magnetic core, with concentric multilayer windings, consisting of epoxy fibreglass encapsulated conductors regularly distributed along the vertical axis of the coil. After curing of the epoxy resin the winding constitutes a rigid, mechanically robust unit which is mounted on a number of support insulators to provide the clearance for the insulation to ground.
When being connected to the pole side terminal, the reactor is on full DC potential with respect to ground. The upgrade from existing dry-type smoothing reactor designs for 500 kV to 800 kV essentially concerns to the insulation to ground whereas there is practically no design change for the winding itself.

Fig. 3: 800 kV disconnector

This upgrade of the main insulation of a dry type reactor is relatively simple and is achieved in principle by just extending the length of the support insulators and by providing the coil with adequate shielding electrodes to meet surge voltage and RIV requirements. The coil is post mounted on 12 composite type insulators having a length of about 10 m. The weight of the coil is about 30 tons.

In case of such a heavy weighted coil mounted on long insulators the resonance frequency is well below the critical frequencies of earthquake vibrations which mitigates the seismic loading of the structure.

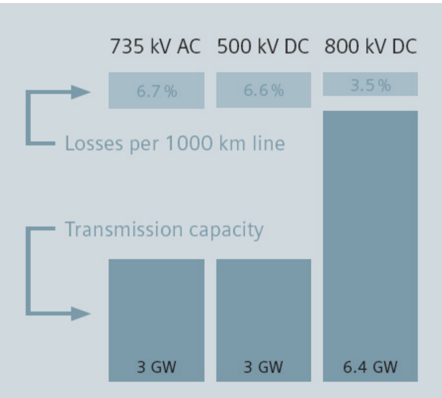

Fig. 4: Loss Reduction by means of UHV DC

Summary

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. The first 800 kV UHV DC system, ordered by the China Southern Power Grid Co. in Guangzhou, is scheduled to commence commercial service by mid-2010. It allows the country to tap more hydropower instead of adding new coal plants. The CO2 emissions offset amount to a whopping 33 million tons at the Yunnan-Guangdong project alone.