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ABB has commissioned the Rapid City DC Tie, a 200 MW back-to-back HVDC link connecting the eastern and western interconnections in the USA. The link will increase grid reliability, and features ABB's capacitor commutated converter technology.

Rapid City reliability

The benefits of interconnections between asynchronous power grids became obvious in the aftermath of the power outages in summer 2003. Interconnected power grids using a high-voltage direct current (HVDC) back-to-back system can transfer the power from one grid to another during emergencies as well as exchange economy energy between the systems. In addition, power flow can be controlled and both voltage and frequency stability is enhanced. These measures significantly increase grid reliability and help to prevent blackouts.

In the US, there are three main asynchronous grid systems: the eastern interconnection, the western interconnection and the Texas system. The Rapid City DC Tie is the seventh interconnection between the east and the west power grids and is owned by Basin Electric Power Cooperative and Black Hills Power. The HVDC system, called the "Rapid City DC Tie" because it is located close to Rapid City, South Dakota, carries 200 MW of power. ABB completed the $50 million contract in only 19 months – six months faster than the industry standard.

The HVDC back-to-back system was commissioned in October 2003. As the US HVDC interconnectors are located at the periphery of the AC networks, their ratings are relatively high compared to the available short circuit capacity at the point of interconnection. A new converter technology, however, allows higher converter ratings relative to the system strength at the point of connection thus opening up the possibility of transferring more power between networks with minimal need for new transmission lines.

Capacitor

The Rapid City DC Tie uses capacitor commutated converters or CCC technology. This technology combines series compensation technique with classical line commutated converter technique. Integrated series compensation provides a simple means of compensating for the converter reactive power demand without switching filters or shunt banks. It also allows larger converters to be used in relatively weaker network locations.

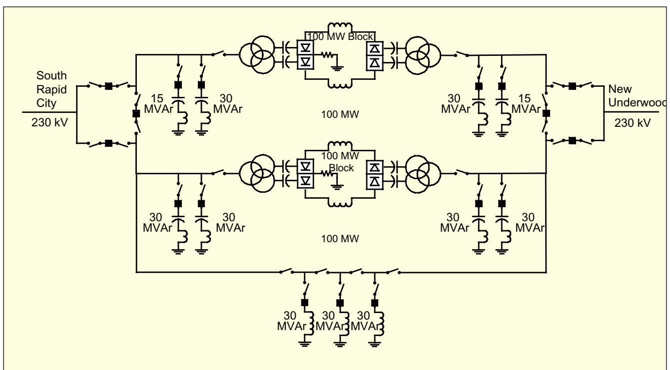

Figure 1. Single line diagram of the Rapid City DC Tie

The Rapid City DC Tie consists of two parallel 100 MW CCC back-to-back HVDC blocks fed from a single radial 230 kV line on each side. The same technology is used on a larger scale in the 4 x 550 MW Garabi interconnection between Brazil and Argentina.

The station is built on virgin soil at the outskirts of Rapid City, S.D., between the substations New Underwood, 30 km to the east, and Rapid City South, 6 km to the west. Basin Electric has built the two 230 kV lines connecting the converter station. Four filters are available on each side to reduce harmonics from the conversion process, besides providing voltage support to the AC system. Three 30 MVAr shunt reactors are possible to connect to either side of the station, providing a challenge in designing protections as well as interlockings for the Tie.

Converter

Maintenance will be handled by Black Hills Power, based in Rapid City. Operation is taken care of by the Western Area Power Administration from its dispatch centre in Loveland, Colorado.

The converter station not only performs the asynchronous frequency conversion, but is also the key to fulfilling the electrical performance requirements of the system. A simplified single line diagram of the station is given in Figure 1. It can be seen that there are two converter blocks of 100 MW each, ensuring the delivery of 200 MW, even under low voltage conditions. In order to optimize the rating of the thyristors, the direct voltage used is ±12.85 kV. The CCC capacitors are shown between the transformers and the valves, which provide stable operation of the converters at low short circuit levels. The harmonic filters are in two banks, each associated with a converter block.

The converter transformers are 109 MVA 3-phase, 3-winding units each weighing 210 t in oil filled condition. The rating of a CCC transformer is less than in the transformer of a conventional converter of the same DC power, because the flow of reactive power through the transformer is reduced due to the series capacitor.

A sophisticated switching scheme has been developed to allow connection of two blocks (two transformers) in parallel without using preinsertion resistors. Elimination of remnant flux is made possible by a special switching scheme at deenergization of a converter block. Then, synchronized connection results in very low in-rush currents without saturation.

Prefabricated enclosures, containing thyristor valves, valve cooling equipment and control equipment have been employed. This concept allows assembly and testing at factory to a large extent. Consequently, installation work and testing is reduced on site, enabling the short execution time of the project. A common feature of all enclosures is the VESDA (Very Early Smoke Detection Apparatus) fire detection system, enabling shutdown of a converter before a fire hazard develops.

"A sophisticated switching scheme has been developed to allow connection of two blocks (two transformers) in parallel without using preinsertion resistors"

Components

Thyristor valve enclosures: The converter valves are located in modular housings, factory assembled and tested, shipped to site ready for commissioning. In order to optimize the costs of the thyristor valves, as well as the DC side equipment, the DC current is kept as high as the thyristor rating allows, and the valve cooling system can handle. This means that the DC voltage is kept low. The low DC voltage means that the air clearance requirement is low, which is in favour of a compact design of the valve housings.

Each valve enclosure contains a complete 12-pulse converter. The thyristor valves are suspended from the ceiling, easily accessible for the maintenance crew. The enclosures also contain the surge arresters connected across the valves, and the valve control cubicle. For a better and more reliable supervision of the thyristors, electrically triggered thyristors are used.

Valve cooling enclosures: The valve cooling system for a modular back-to-back is located in a separate module, except for the cooling towers that are located outdoors. The thyristor valves are liquid cooled by means of a single closed loop system. The cooling liquid is a water/glycol mix to handle ambient temperatures down to -34.4° C

Control and protection enclosures: The ABB MACH 2 control and protection system is a fully duplicated system. High speed fiber optic buses (CAN, TDM) are used between the AC yard interface and the pole controls. The interface to switches and instrument transformers in the AC yards and filter is located in separate enclosures, located in the vicinity of the high voltage equipment, one in the west end, another in the east end of the switchyard. Besides controlling the converter process, the main computers of the pole control provide protection, internal supervision, transient fault recorder and sequence event recorder.

Operation: The Rapid City DC Tie will be unmanned, normally operated from the WAPA control centre at Loveland, Colorado. Supervision is also possible from Black Hills Power's control centre at Rapid City as well as from WAPA's centre at Watertown, S.D.

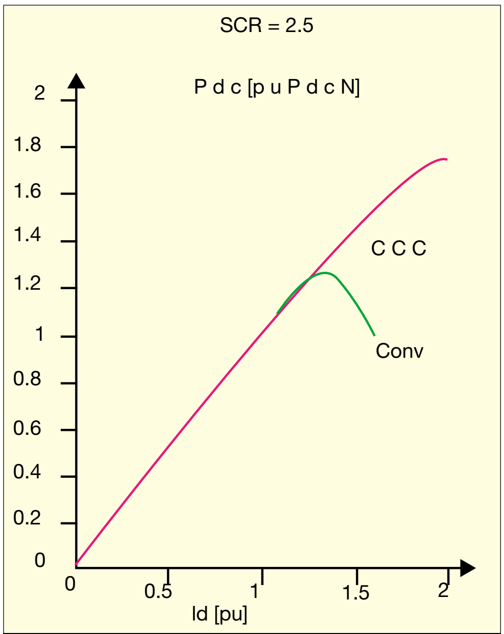

Figure 2. The CCC is in a stable situation, while the conventional converter is close to the stability limit

The owners will also have supervisory possibilities through remote workstations, connected to the station LAN. All locally available information is accessible, e.g. TFR and event recordings.

The main control mode is power control. Power modulations such as damping control and voltage support are included. The settings of these modulations can easily be changed by the owners. Pre-determined events in the adjacent networks will trigger run-backs to pre-set DC power levels.

The CCC concept

The commutation capacitors create the AC voltage to which the converter is commutating, hence these capacitors are called commutation capacitors, and the converter becomes a capacitor commutated converter (CCC). The steady state operating voltage of the commutation capacitor is defined by the direct current. The capacitors are protected against over voltages by parallel ZnO varistors. The voltage stresses on the capacitors are relatively low compared to the installed capacity, and consequently the commutation capacitors can be of compact design.

The commutation capacitors improve the commutation failure performance of the converter. Typically, a CCC can tolerate a sudden 15-20 per cent voltage drop on the network voltage. The contribution to the commutation voltage from the commutation capacitors results in positive inverter impedance characteristics for an inverter operating at minimum commutation margin control. An increase in direct current therefore results in a DC voltage increase rather than the opposite, which is the case for conventional inverters with commutation margin control. The dynamic stability of an inverter will thus be dramatically improved with a CCC.

Figure 3. ABB completed the $50 million contract in just 19 months