Three Gorges - Changzhou HVDC : Ready to Bring Bulk Power to East

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Abstract

Three Gorges - Changzhou ±500 kV DC Transmission Project is an integral part of the Three Gorges Hydroelectric power project. The DC transmission will be mainly used to transmit the bulk power generated by this project to the Shanghai area in East China. The project interconnects Central power region of China, to which the hydroelectric power plant will be connected synchronously, to the eastern power region of China. The power will be transmitted towards the East during the peak generation period and towards the Centre when water need to conserved in the dam reservoir. The 3000 MW rated power will be transmitted to a distance of 890 km on one single bipolar DC line at ±500 kV. The paper describes the detailed features of this project, which is successfully commissioned and is now ready to transmit the clean hydro-power from People's Republic of China's prestigious Three Gorges Project.

1 Short Description of the Project

The 3000 MW Three Gorges - Changzhou ±500 kV DC Transmission Project is a bipolar transmission having one converter station in Longquan (in Yichang County in Hubei Province) and another in Zhengping (in the city of Changzhou, Jiangsu Province). The Longquan converter station is located approximately 60 km from the site of Three Gorges hydro dam. The normal receiving station Zhengping is located approximately 160 km from the city of Shanghai.

Three Gorges - Changzhou DC Transmission Project is the 2nd project, which connects Central China and East China asynchronously. The first transmission is 1200 MW, ±500 kV Gezhouba-Shanghai DC Transmission, which has been operating for more than 10 years.

2 Basic Design of HVDC Project/Equipment

The HVDC link is designed for continuous rating of 2x1500 MW under relatively conservative conditions specified for the system, ambient and outage. It has overload capability for temperature being lower than the extreme value, redundant cooling equipment being in service, and allowance in equipment design. The bipolar link has a continuous overload capability of 3480 MW and 5 second overload capability of 4500 MW. The bipolar HVDC link has three possible connection modes, bipolar, monopolar ground return, and monopolar metallic return mode.

In order to minimise bipole outage, the HVDC system can operate with balanced bipole currents, using the ground mats of converter stations as temporary grounding while ground electrodes or their lines are out of service.

The nominal reverse power transfer capability is 90% of the rated power. The HVDC link is designed to operate continuously down to a DC voltage of 70% of rated voltage.

The use of reactive power capacity of generator units at Three Gorges Power Plant at Longquan Converter Station is optimised. For rated DC power, AC system will supply 800 MVAr reactive power to the Longquan station. On the other hand, the reactive power requirement of Zhengping Converter Station at rated power can be fully balanced by reactive power compensation equipment in the station. The reactive power surplus flowing from Longquan and Zhengping Converter stations into AC systems is designed not exceed 150 MVAr and 350 MVAr respectively at minimum power.

2.1 System Design

2.1.1 Main Circuit Parameters & Connection

All factors, such as transmission directions, operation modes, control modes, AC system conditions, DC line parameters, ambient conditions, manufacturing tolerances, measuring and control errors were considered in determining the main circuit parameters.

The main circuit connection of DC side, is a typical one for an HVDC bipole with overhead transmission line. In order to meet the requirements of monopolar metallic return operation mode, and the capability for transfer without stop, DC circuit breakers Metallic Return Transfer Breaker (MRTB) and ground return transfer switch (GRTS) are included. Besides, Neutral Bus Grounding Switches (NBGS) are installed at the neutral buses of both stations to meet the temporary grounding requirement.

On the AC side, at both stations, one and a half breaker configurations are used. Five entries are designed for HVDC: two are for converters and three for AC filter banks. Longquan station is connected to five and Zhengping with two 500 kV AC lines. Two more lines in each station are planned to be added in near future.

2.1.2 Reactive Power Compensation

At Longquan, 8 switchable sub-banks (2x118+6x140) with a total capacity of 1076 MVAr have been installed and at Zhengping, 9 switchable sub-banks (4x190+5x220) with a total capacity of 1860 MVAr have been installed. Additionally, at Longquan, 4x50 MVAr switchable low voltage capacitors are installed on the tertiary of a 500/220 kV autotransformer.

Additionally low voltage 3x60 MVAr low voltage switchable reactors are installed on tertiaries of transformers in the AC systems. Under extreme condition of either AC system or DC system, use can be made of the inherent capability of the converters to absorb more reactive power, if required.

2.1.3 Insulation Co-ordination

A typical arrester protection scheme for bipolar HVDC converter stations with one 12-pulse converter per pole were used in the design. The AC bus arresters are designed as 7 matched, individually housed arresters distributed near converter transformers and at filter buses. At Longquan, arresters are also installed close to the HP3 filters to limit the stresses across the circuit breakers.

Since Zhengping Converter Station is in an area with very heavy industrial pollution, the required length of insulators for the DC pole is larger than equipment capability of the manufacturers. Co-ordination between external and internal insulation of extra long bushing is also a considered. Considering all the concerns, indoor DC switchyards were built. All high potential DC equipment are installed indoors and all DC neutral equipment are installed outdoors. Four separate halls are designed for each pole, one for switches, two for the DC filter capacitor banks, and one for the DC PLC capacitor bank. Special lifting facilities are provided so that repair of DC filters can be done without interrupting operation of the corresponding pole.

2.1.4 AC Filtering

At Longquan Station, all 8 reactive power compensation capacitor sub-banks were designed as AC filters. There are three types of filters: Three sub-banks are designed as double tuned filters tuned at 11^{th} and 13^{th} harmonic; three are designed as double tuned filters tuned at 24^{th} and 36^{th} harmonic. The other two are designed as C-type filters tuned at 3^{rd} harmonic. At Zhengping Station, 5 of the 9 capacitor sub-banks were designed as double tuned filters tuned at 12^{th} and 24^{th} harmonic; the remaining 4 banks are used as shunt capacitor banks.

2.1.5 DC Filtering

A passive DC filtering scheme were designed for meeting a performance level of 500 mAp (bipole)/1000 mAp (monopole). At each terminal pole, two filter arms are installed. Both designed as double tuned filters, one tuned at 12^{th} and 24^{th} harmonic and the other tuned at 12^{th} and 36^{th} harmonic.

2.1.6 Control and Protection System

Fully computerised hardware of MACH2 design is used for this project. It has very good features of high performance, high integration, no maintenance requirements, very powerful programming environment and close integration with SCADA system. The SCADA systems are designed in such a way that information of operation status, of each converter station can be accessed from remote dispatch and control centres through communication systems. Despatch centres have full control to regulate power transmission on the link from remote.

The terminal to terminal communication of this project is via Optical Fibre Ground Wire (OPGW). Beside the communication requirements for this project, the remaining capacity is used for dispatching and data transfer of the networks, and even could be used for other commercial communication.

Additional control functions, such as power ramping, frequency control and damping modulation are integrated in the control and protection system. The interface and parameters in this function can be adjusted according to the system requirement by the Station Engineer.

Design documents, drawings and diagrams, manuals of operation, maintenance and training are built in a database with flexible file managing software to make searching of those documents very easy and thereby shorten the time needed for maintenance.

2.2 Main Equipment

2.2.1 Thyristor Valves

Mainly because single-phase two-winding converter transformers are used, the optimised design resulted in a double valve scheme. Thyristors built from Ø125 mm crystal, with 90 cm^2 effective area are used in the project. The rated current and voltage are 3 kA and 7.2 kV. There are 90 thyristors per single valve at Longquan and 84 thyristors per single valve at Zhengping. Dry type damping capacitors and film DC resistors are used.

The bushings penetrating into the valve hall are of dry type. The valves are also of dry type design. In addition to this, comprehensive fire detection and protection system including very early particle sampling detectors has been incorporated in the valve halls.

2.2.2 Converter Transformers

The converter transformers are of the single-phase two-winding type with two wound legs. The nominal parameters of the Longquan transformers are 297.5 MVA, 525/210.4 kV, 16% reactance, with an OLTC tap range of +25/-5, each step being 1.25%. The nominal parameters of the Zhengping transformers are 283.7 MVA, 500/200.4 kV, 16% reactance, with an OLTC tap range of +26/-2, each step being 1.25%. The bushings penetrating to the valve hall are of the dry type. The converter transformers for Longquan are also equipped with ETCS (Electronic Transformer Control System) which includes analysis and reporting and intelligent fan control to minimise losses.

2.2.3 Smoothing Reactors

For this project, oil insulated smoothing reactors with a reactance of 290/270 mH are used in each pole at Longquan/Zhengping respectively. All bushings are of the composite type. The smoothing reactors are connected to the valves with the bushing penetrating through the valve hall wall.

2.2.4 MRTB and Other DC Switches

The breakers used in the high speed DC switches including metallic return transfer breaker, neutral bus grounding switch, neutral bus switch and ground return transfer switch are SF_6 breakers. Of all these switches, the ground return transfer switch is of conventional passive design. All the other switches are designed with active auxiliary transfer circuit consisting of a capacitor with a charger. This charger enhances the DC Switches current commutation capability up to the highest overload currents.

3 Successful Commissioning

Following erection/installation of equipment in the stations, pre-commissioning tests, sub-system tests, station tests and system tests were performed successfully in a planned and systematic manner within the available short time and respecting the AC system constraints for such work.

3.1 Pre-Commissioning/Equipment Tests

The pre-commissioning tests (equipment tests) were carried out on all equipment (e.g. breakers, reactors, dc voltage dividers etc.) to verify the proper condition of the equipment and the installation. The tests ensured that the equipment has sustained no damage in transit, has been properly installed in the field, is safe to energise, load or start-up, and will perform and operate as designed.

3.2 Sub-Systems Tests

After successful completion of the pre-commissioning (equipment) tests, all independent sub-systems (e.g. ac-filter, fire protection, station service power, control system hardware etc.) were tested to check the joint function of a group of equipment with interconnections and prepare for energisation/operation or system test of the sub-system. During the sub-system testing, complete control and protection functions are tested, normally built up by a number of equipment with their interconnections. The tests included off-line testing of all interlocking sequences, final protection trip testing prior to energisation, and low voltage energisation (firing sequence check) of valves.

3.3 Station Tests

After the successful completion of the pre-commissioning and sub-system tests, station tests were performed starting in September 2002. These tests involved:

- HV Energisation of AC Busses
- HV Energisation of AC Filters
- HV Energisation of Converter Transformers and Valves
- HV Energisation of DC Yard and DC Line (by means of Open Line Test)

3.4 System Tests

System tests were performed after the successful completion of the station tests at both ends, transmitting power first time on November 22, 2002. The tests involved end-to-end power transmission for Pole 1, Pole 2 and the Bipole at low and high power levels.

The operators and dispatchers need to perform the overall co-ordination and planning of power levels and system conditions during the system tests. During the system tests final adjustments to the equipment for satisfactory operation are made.

The successfully performed System Tests has demonstrated that:

- End-to-end HVDC power transmission works well and that the HVDC system meets the specified performance and operates correctly within the specified operating range (including overload and reduced voltage operations).
- The main circuit equipment and MACH2 control and protection system behaves satisfactorily as designed.
- There is proper inter-station co-ordination of control and protections.
- The HVDC control and protection functions are correct during steady state operation , system transients and faults.
- The HVDC switching sequences operate correctly.
- The transmission can be operated from remote despatch centres.

4 Conclusion

As Three Gorges Project and the associated transmission projects are extremely important to both sending side and receiving side power systems, high availability and low forced outage rate have been an important factor in the design stage of the project. Advanced technologies with operation experience in real HVDC projects are used in all important design aspects. Flexibility of operation is built into the design, and maintenance requirements are minimised. With specified AC system and other conditions given through wide and deep studies, as well as high and suitable performance requirements with adequate margins for robustness the purposes of this project are achieved.

After successful commissioning the HVDC Transmission now in May 2003 is ready to transmit the clean hydropower from People's Republic of China's prestigious Three Gorges Project.

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7 Biography

Abhay Kumar was born in Delhi, India in 1961. He obtained his degree in Electrical Engineering from University of Roorkee (now IIT) in 1982. He joined National Thermal Power Corporation Ltd. (NTPC) in 1982 and worked until 1995 as Deputy Chief Design Engineer. He has been involved in the design of Vindhyachal B2B HVDC and Rihand - Delhi HVDC Projects and many other EHV substations. He has also been consulting engineer for Chandrapur – Padghe HVDC Project. From 1995 to 2000 he worked for ABB Ltd. New Delhi as Senior Manager at Power System Engineering and Business Development department. Since May 2000, he has been working for ABB Power Technologies AB in Sweden as the Technical Manager for The Three Gorges - Changzhou ±500 kV DC Transmission Project.

Mats Lagerkvist was born in Sweden in 1956. He obtained his Masters degree in Electrical Engineering from Chalmers University of Technology, Gothenburg in 1981. He joined ASEA the same year and worked in managerial positions for HVDC Control & Protection department in Ludvika during the 1980's. He has been involved in the design and commissioning of several HVDC projects including the Quebec-New England Multi-terminal where he worked as Commissioning Manager. He has also been on the Board of Directors for Manitoba HVDC Research Centre in Winnipeg. From 1992 to 1999 he was Manager of the HVDC system department. Since 1999, he is ABB's Project Director for The Three Gorges - Changzhou ±500 kV DC Transmission Project.

Mårten Eklund was born in Stockholm, Sweden in 1969. He received his bachelor degree in 2001 at Mid Sweden University in Härnösand. He joined ABB Power Technologies AB the same year and has been involved in main circuit design of a several HVDC plants including the Three Gorges – Changzhou and Three Gorges - Guangdong HVDC Transmission Projects. He has been working as a Sub-Project Manager in the Three Gorges – Changzhou ±500 kV DC Transmission Project since 2002.

Yuan QingYun was born in PR China in 1963. She received her master's degree in 1997. She has worked as Vice President at Changzhou Company of CPG till 1996, then transferred to State Power Grid Development Co. Ltd. (SPG) in 1998. She is currently Division Director of the HVDC Converter Station Division 1 of Power Grid Development Branch of SPG.