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DESIGN FEATURES OF THE THREE GORGES - CHANGZHOU ±500 KV HVDC PROJECT

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SUMMARY

In this paper, the resulting design features of Three Gorges-Changzhou HVDC Project are summarized. In specifying performance requirements, the special features of this project, conditions and requirements of both side AC systems as well as environment conditions and requirements were considered carefully. The most up to date technology of HVDC and computerized controls are followed. Efforts have been paid to promote development of HVDC technology and to minimize the cost of the project with the basis of ensuring security and stability of the AC/DC systems.

Keywords: HVDC - Three Gorges - Converter Station - Power Transmission.

1. INTRODUCTION

The Three Gorges Hydroelectric Power Plant will be the largest of its kind in the world. It will consist of 26 generating units, each with a rated power of 700 MW. The total generating capacity of the plant will be 18.2 GW. After all these units are commissioned in 2009, 6 more units will be installed in an underground power house and the total capacity of the plant will then become 22.4 GW.

Fig. 1. Map

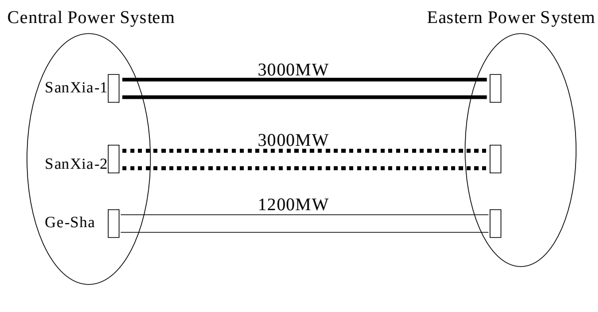

Fig. 2. Overview

Power and energy from this plant will be delivered to Central China and Sichuan-Zhongqing Systems by 500 kV AC transmission lines, and sent to East China by three HVDC links connecting the two large AC systems asynchronously. The total capacity of the HVDC transmission system will be 7200 MW, Figures 1 and 2.

The HVDC bipole reported in this paper starts at Longquan Converter Station in Yichang County, Hubei Province, and terminates in the East at Zhengping Converter Station in the city of Changzhou, Jiangsu Province. The transmission distance is 890 km. The rated power at the DC side of the normal rectifier is 3000 MW and rated voltage is ±500 kV. The first pole will be commissioned in 2002 and the second one in 2003.

The purpose of the link is to transfer electric energy from Three Gorges Power Plant to East China Power System during summer. In the winter it will be used as an interconnecting tie line between the two power systems, transferring power from Central to East China during peak hours and transferring electric power and energy in the reverse direction during valley hours.

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The sending side converter station of this project (Longquan) is connected to the 500 kV main network of the interconnected AC power pool composed of Central China Power System and Sichuan-Zhongqinq Power System which covers 6 provinces: Hubei, Henan, Hunan, Jiangsi, Sichuan and Zhongqing. The receiving converter station (Zhengping) is connected to the East China Power System which covers 4 provinces and metropolis: Shanghai, Jiangsu, Zhejiang and Anhui. Longquan will be connected to the Three Gorges power plant by three 500 kV AC line; Zhengping will have two 500 kV AC outgoing lines in 2003.

2. Conditions and Performance Requirements

2.1 Conditions

The steady state AC bus voltage ranges of converter stations are defined as follows:

	Longquan	Zhengping
Normal minimum	500 kV	490 kV
Normal maximum	550 kV	525 kV
Extreme minimum	475 kV	475 kV
Extreme maximum	550 kV	540 kV

The maximum short circuit capacity of both converter stations is 57 GVA and the minimum short circuit capacities of Longquan and Zhengping are 11 GVA and 22 GVA respectively.

The normal system frequency variation is specified as ±0.2 Hz. The dynamic frequency variations after disturbances are specified as +0.5 Hz and -1.0 Hz for Longquan and Zhengping.

The negative sequence voltages used for performance and rating of filters are 1% and 2% respectively. Measurements with corresponding statistical analyses have been done for the background harmonic voltages on the converter station AC buses. The magnitudes of background harmonic voltages (percent) were as follows:

Order	Longquan	Zhengping
2	0.21	0.5
3	2.5	2.0
5	0.90	1.43
7	0.32	0.17

The pollution levels of the converter stations were estimated considering industrial development and pollution distribution model. The results were:

Equipment	ESDD (mg/cm^2) Longquan	ESDD (mg/cm^2) Zhengping
AC suspension insulator	0.05	0.10
AC post insulator	0.03	0.06
DC post insulator	0.07	0.13

2.2 Performance Requirements

Comparisons among three alternatives, one 12 pulse converter unit per pole, two converter units in series per pole and two converter units in parallel per pole, were done and the scheme of one converter unit per pole was chosen due to technical feasibility and minimum investment cost.

Because the HVDC system connects two huge pools asynchronously, it was not considered necessary to design the link with specially increased overload capability. The link is designed for continuous rating of 2x1500 MW under relatively conservative conditions specified for the system, ambient and outage. It shall however have overload capability for temperature being lower than the extreme value, redundant cooling equipment being in service, and allowance in equipment design. For normal AC bus voltages each pole of the link shall operate with transmission power from minimum of 150 MW to 1500 MW with all specified performance requirements met. For extreme AC bus voltages the link shall be able to operate continuously.

Of four possible connection modes of a bipolar HVDC link, bipolar, monopolar ground return, and monopolar metallic return modes are required; monopolar ground return mode with both pole lines connected in parallel is not required for this project due to limitation of electrodes.

In order to minimize bipole outage, the HVDC system shall be able to 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 reverse power transfer capability shall not be less than 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 optimized. For rated DC power the sending side AC system can supply 800 Mvar reactive power to the station. On the other hand, the reactive power requirement of Zhengping Converter Station at rated power shall be fully balanced by reactive power compensation in the station.

The reactive power surplus flowing from Longquan and Zhengping Converter stations into AC systems at the minimum power of 300 MW is not permitted to exceed 150 Mvar and 350 Mvar respectively.

The specified AC filtering performance requirements are: individual harmonic distortion for even harmonics shall be less than 0.5%, those for the 3rd and 5th harmonics shall be no more than 1.25% and for all the rest of odd harmonics shall be less than 1.0%. The total rms harmonic distortion shall be less than 1.75% and the THFF shall be less than 1.0%.

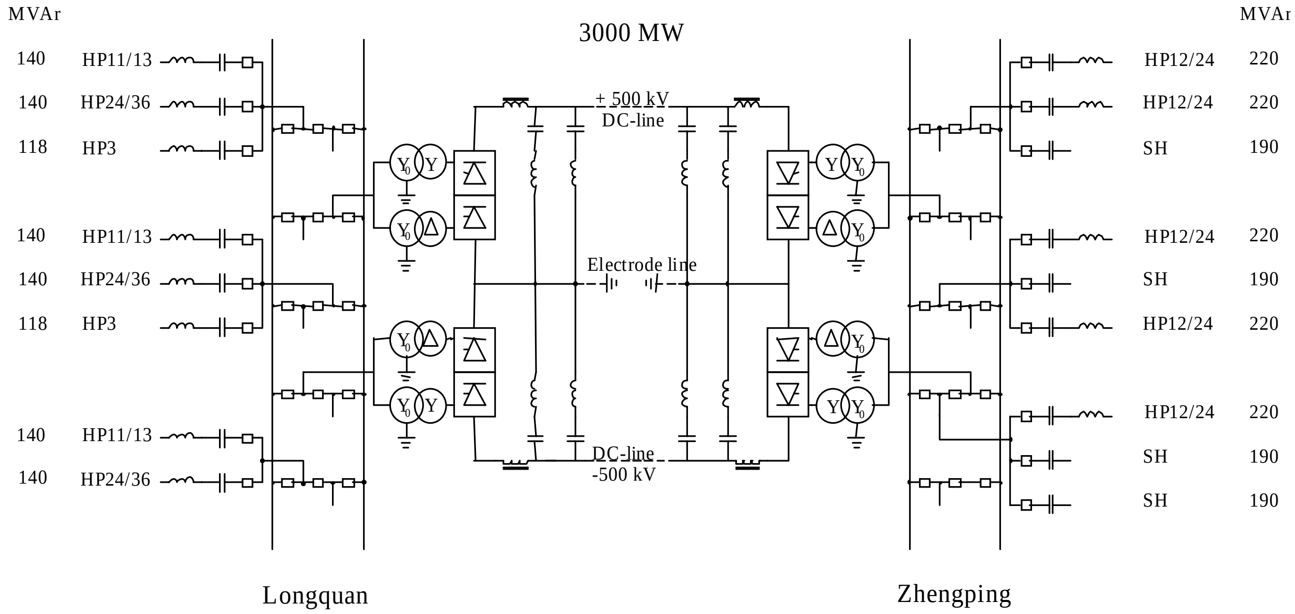

Fig. 3. Single Line Diagram.

Regarding DC filtering, both active and passive DC filter schemes were acceptable and two required performance levels were considered:250 mAp (bipole)/500 mAp (monopole) and 500 mAp (bipole)/1000 mAp (monopole).

3. FEATURES OF SYSTEM DESIGN

3.1 Main Circuit Connection

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 MRTB and GRTS are included. Besides, Neutral Bus Grounding Switches (NBGS's) 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.

3.2 Main Circuit Parameters

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. Main parameters are summarized as below:

	Longquan	Zhengping
DC voltage (kV)	500	476
α (°)	15	
γ (°)		17
Transformer Impedance (%)	16	16
Transformer rating (MVA)	297.5	283.7
Tap change range (in steps of 1.25%)	+25,-5	+26,-2
Valve Side voltage (kV)	210.4	200.6

3.3 Reactive Power Compensation

As shown in Figure 3, at Longquan, 8 switchable sub-banks (2x118+6x140) with a total capacity of 1076 Mvar will be installed and at Zhengping, 9 switchable sub-banks (4x190+5x220) with a total capacity of 1860 Mvar will be installed. Additionally, at Longquan, 4x50 Mvar switchable low voltage capacitors will be installed on the tertiary of a 500/220kV autotransformer.

Additionally low voltage 3x60 MVAr low voltage switchable reactors will be 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 converters to absorb more reactive power if required. This feature can be used to prevent the AC buses from reaching overvoltage.

3.4 Insulation Coordination

A typical arrester protection scheme for bipolar HVDC converter stations with one 12 pulse converter per pole is 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 will be 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 would be larger than equipment capability of the manufacturers. Coordination between external and internal insulation of extra long bushing is also a concern. Considering all the concerns, indoor DC switchyards were decided for the design. All high potential DC equipment will be installed indoors and all DC neutral equipment will be installed outdoors. Four separate halls are designed for each pole, one for switches, two for the DC filter capacitor banks, and one for the PLC capacitor bank. Special lifting facilities are provided so that repair of DC filters can be done without interrupting operation of the corresponding pole.

There will only be two AC lines connecting Zhengping Station with the AC system and during commissioning, there will only be one AC line connecting Longquan Station with the AC system. The overvoltage protection and insulation coordination of both converter stations were studied considering loss of connection to AC system when operating as inverter station.

3.5 AC Filtering

At Longquan Station, all 8 reactive power compensation capacitor sub-banks are designed as AC filters. There will be 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 2 are designed as C-type filters tuned at 3^{rd} harmonic. At Zhengping Station, 5 of the 9 capacitor sub-banks are designed as double tuned filters tuned at 12^{th} and 24^{th} harmonic; the remaining 4 banks are used as shunt capacitor banks.

3.6 DC Filtering

Both passive and active DC filtering schemes were studied and a passive one was chosen for meeting a performance level of 500 mAp (bipole)/1000 mAp (monopole). At each terminal pole, two filter arms will be 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. The specified performance requirement can be met with the designed filtering scheme.

4. CONTROL AND PROTECTION SYSTEM

4.1 System Hardware

Fully computerized hardware of MACH2 design will be 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.

4.2 Communication between Terminals

The terminal to terminal communication of this project will be OPtical fibre Ground Wire (OPGW). Beside the communication requirements for this project, the remaining capacity will be used for dispatching and data transfer of the networks, and even for commercial communication.

4.3 Remote Access of Information

The SCADA systems shall be designed in such a way that information of operation status, settings of control and protection systems, as well as fault records of each converter station can be accessed from the opposite terminal as well as from remote dispatch and control centers through communication systems.

4.4 Manuals in Data Base

Design documents, drawings and diagrams, manuals of operation, maintenance and training shall be 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.

4.5 Additional Control

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.

There is no special requirement to coordinate among the three HVDC links in the system, they can be coordinated by dispatch centers.

5. MAIN EQUIPMENT

5.1 Thyristor Valves

Mainly because single phase two winding converter transformers are used in the converters, the optimised design resulted in a double valve scheme.

Thyristors built from Ø125mm crystal, with 90 cm^2 effective area will be used in the project. The rated current and voltage are 3 kA and 7.2 kV. There will be 90 thyristors per single valve at Longquan and 84 thyristors per single valve at Zhengping. Dry type damping capacitors and film DC resistors will be used.

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

5.2 Converter Transformers

The basic design of the converter transformers is single phase two winding configuration as specified. The line side winding will be rated 500 kV, wye-connected, with the neutral terminal grounded, the valve side winding will be rated for 500 kV DC. Single phase three winding transformers were studied, but the capacity of a transformer unit would have been about 600 MVA. Though this poses no manufacturing problem, such a converter transformer would have been the biggest in the world, much higher than the existing record for converter transformers: If four wound limbs were used, the flux circuit would be of a novel design for converter transformers and if two wound limbs were used, the capacity of each wound limb would reach 300 MVA, exceeding the value for which reliable experience exists for converter transformers.

5.3 Smoothing Reactor

Oil insulated smoothing reactors with inductance of 270 mH will be used for this project. All bushings insulators are of composite type.

5.4 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.

6. HVDC TRANSMISSION LINE AND GROUND ELECTRODES

6.1 Transmission Line

The pole conductors have section area of 4x720 mm^2. The minimum distance to ground of the pole conductors for normal areas is 11.5 meters, one meter shorter than normal design in China. The resulting composite electrical field strength at ground level is 23.66 kV/m. Two ground wires are built through the whole distance of the line for lightning protection, of which one is OPGW. Conventional HVDC insulators will be used for most of the towers and some composite insulators will be used in heavily polluted areas. There are two long distance river crossing with spans of 1200 meters and 1910 meters respectively.

6.2 Ground Electrode

The ground electrodes are of shallow type. The one for Longquan side is designed with a single round loop with diameter of 800 meters and the one for Zhengping side is designed as double oval loop. The distances from the ground electrodes to the relevant converter stations are 41 km and 26 km respectively.

7. CONCLUSION

Because 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 are required. 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 minimized. With 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 will be achieved with acceptable installed and operation costs.

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