

# Three Gorges - Shanghai HVDC: Reinforcing Interconnection between Central and East China

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## **Summary:**

Three Gorges - Shanghai  $\pm 500$  kV DC Transmission Project is an integral part of the Three Gorges Hydro-electric power project. An additional DC transmission will be used to transmit the bulk power generated by its right bank power station to the Shanghai area in East China. The DC link will reinforce interconnection of Central power region of China, to which the Hydro-electric power plant will be connected synchronously, to the Eastern power region of China. The power will be transmitted towards the East during the high-water/flood season and towards the Centre in low-water/dry season. The 3 000 MW rated power will be transmitted to a distance of 1 060 km on one single bipolar DC line at  $\pm 500$  kV. This paper describes the detailed features of this project, which is scheduled to be commissioned in 2006-2007, with specific address to reinforcement in HVDC capacity in interconnection of these two asynchronous regions.

**Keywords:** HVDC, Three Gorges, Bipolar Transmission, Bulk Transmission, Interconnection

## I. Introduction

Being the most populous country of world and with continuously growing economy, one major concern of China is how to meet the ever growing energy demand. In spite of manifold growth in power generation, the challenge is enormous. To make the energy available to the power deficit area, with secured availability and reliability, interconnections are indispensable. Realising economic and technical advantages of High Voltage Direct Current (HVDC) transmission technique, Chinese electric power system planners have been successfully pursuing HVDC projects for over 2 decades. With several integrated HVDC links, Three Gorges project in China is one successful step towards turning problems (like flooding) to opportunities (meeting energy demand by power generation).

### 1. The Three Gorges Transmission

The Three Gorges hydro-electric power project has a planned ultimate power capacity of 18 200 MW. Fourteen units on the river's Left Bank, each 700 MW, are already in operation and completion of the whole Three Gorges hydro-electric power project is scheduled for 2009, with addition of twelve more unit, each 700 MW, on river's Right Bank. Through four HVDC transmissions (3 x 3 000 MW and 1 x 1 200 MW), this power will be made available to the load centres in East and South China, some 800 – 1 100 km away, together with several other 500 kV AC lines. Three of these HVDC projects are now already commissioned successfully and the fourth one, Three Gorges - Shanghai (3GS) Project (also known as San – Hu Project) is under construction with completion scheduled for 2007, see Fig. 1.

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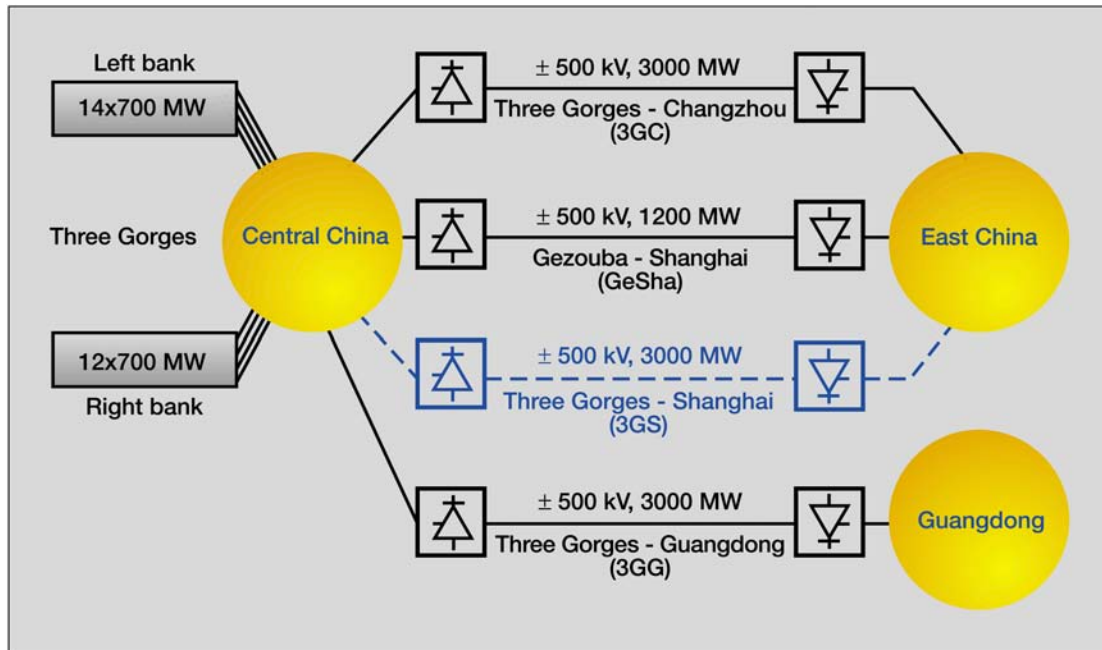


Fig. 1: Four HVDC links will carry hydroelectricity from the Three Gorges power plant to the industrial regions of Shanghai and Guangdong

## 2. Nodal Points of the Three Gorges – Shanghai Project

The 3 000 MW Three Gorges - Shanghai  $\pm 500$  kV DC Transmission Project is a bipolar transmission having one converter station in Yidu (in Yichang County in Hubei Province) and another in Huaxin (in Qing Pu within the city of Shanghai) in Peoples Republic of China.

The Yidu rectifier converter station (also known as Cai Jia Chong station) is located approximately 50 km from the site of Three Gorges hydro dam. Yidu will be connected to Three Gorges power station by three 58 km long 500 kV AC lines while Huaxin (also known as Bai He station) will be connected by two 5 km long 500 kV AC lines to station Huangdu, which is part of the 500 kV AC ring around Shanghai city.

## II. Design Features

### 1. Power Transmission Capacity

The single line diagram of Three Gorges – Shanghai HVDC Project is shown in Fig. 2. The bipolar system is rated for a continuous power of 3 000 MW ( $\pm 500$  kV DC, 3 000 A) at the DC terminal of the rectifier converter station. The transmission is designed to transmit full rated power up to specified maximum ambient temperature and with out any redundant cooling in service. With redundant cooling in service, a continuous overload of 105% and 2 hour overload of 113% of rated power is achievable. With lower ambient temperature, the overload can be even higher i.e. for an ambient of 20°C, a continuous overload of 115% and 2 hour overload of 131% of rated power is achievable.

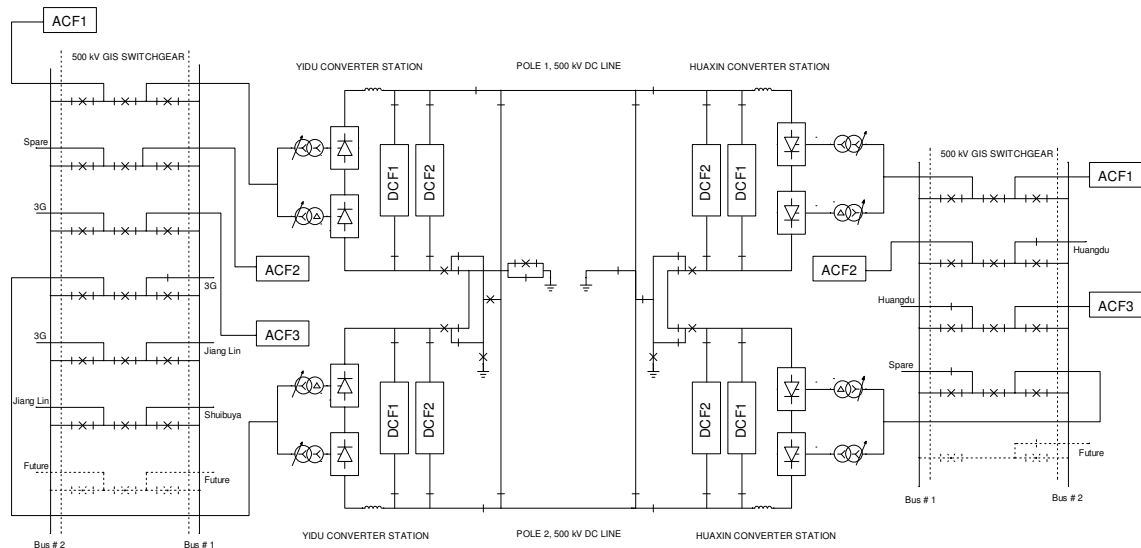


Fig. 2: Over-view single line diagram of Three Gorges – Shanghai  $\pm 500$  kV DC Transmission Project

The 3GS HVDC link is capable of operating continuously up to a reduced DC voltage of 350 kV (70% of rated) and any voltage between 350 kV and 500 kV can be selected by the operator. An optimised converter transformer with extended range of the on-load-tap-changer together with a design of thyristor valves operating at high firing angles makes this mode of operation possible. This facility makes it possible to keep the 3GS DC transmission running, even during a case of partial loss of DC line insulation.

## 2. Reactive Power and AC Filters

Since Yidu converter station is directly connected to Three Gorges right bank power station, part of the reactive power requirement (up to 500 MVar, at rated power) will be met by these generators. Huaxin station on the other hand is self-sufficient and provided with full compensation. Sufficient reactive power supply equipment will be available, meeting these design criteria, even when one sub-bank is out of service. High firing angles are used to meet the specified reactive power absorption requirement i.e. beyond 100 MVar at Yidu and 350 MVar at Huaxin, which connected AC network can absorb.

AC filter:	
Type	Passive
Yidu, no x type; MVar	3xHP11/13, 3xHP24/36, 2xHP3, 1xSC; 1371
Huaxin, no x type; MVar	5xHP12/24, 4xSC; 1890

Three AC filter banks, each having three individually switchable sub-banks are provided in both stations and configured as shown in Fig. 3 and Fig. 4 for Yidu and Huaxin respectively.

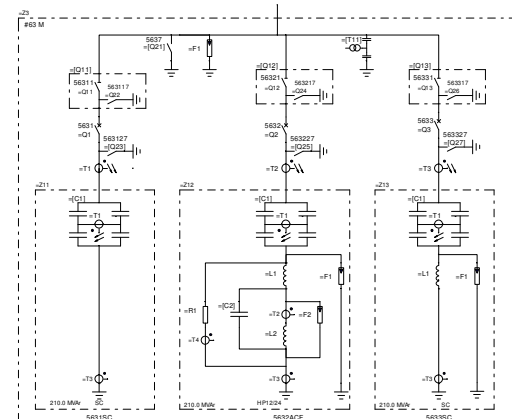
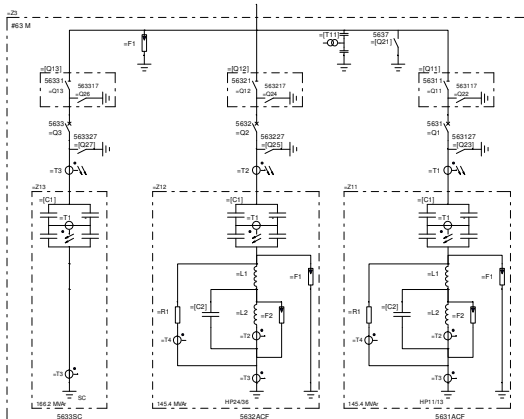
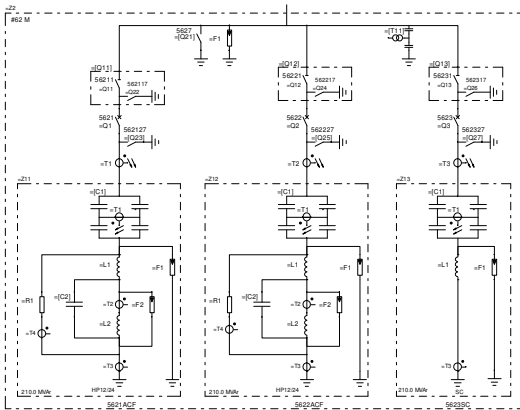
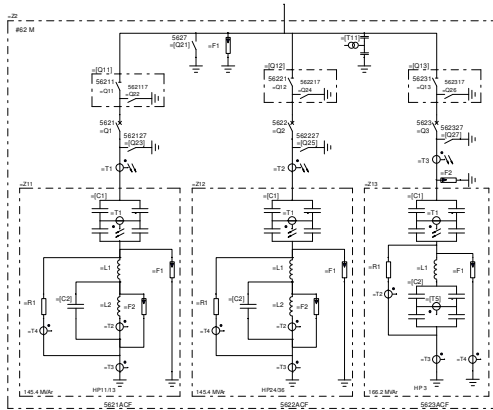
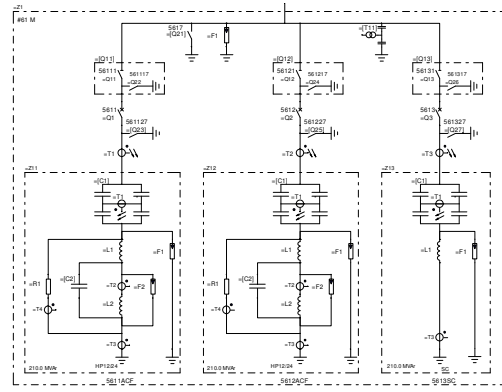
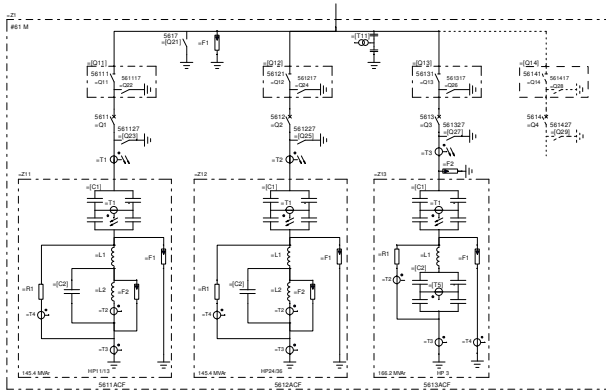


Fig. 3: Configuration of AC filters at Yidu – 9 sub-banks are arranged in 3 banks

Fig. 4: Configuration of AC filters at Huaxin – 9 sub-banks are arranged in 3 banks

### 3. Reliability & Availability

High availability and reliability performance has been one of the most important design criteria of 3GS project. On one hand high quality products together with redundant control system is used to secure higher reliability, while on other hand fast fault detection and effective maintenance management is basic tool to keep high availability. For both converter stations, the forced energy unavailability is guaranteed to be less than 0.5%. While pole forced out rate is guaranteed to be less than 5 outages per pole and per year.

The basic design principle has been that no single contingency within the converter station shall cause a shut down of complete Bipole. To achieve this target, a high level of redundancy has been built into almost all sub-systems, for example:

- ❖ 500 kV AC Switchyard (GIS) with one-and-half breaker scheme
- ❖ Redundant ac filter sub-bank
- ❖ Redundant dc filter sub-bank
- ❖ Redundant cooler bank on converter transformers and smoothing reactors
- ❖ Redundant thyristors in the thyristor valves
- ❖ Redundant pumps and cooling towers in the valve cooling system
- ❖ Redundant auxiliary power supplies
- ❖ Redundant ventilation system for control room and valve halls
- ❖ Redundant control and protection systems

#### **4. Audible Noise – One of most Critical Issue**

Audible noise design of the converter stations has been one of the decisive design factors for station layout design as well for design of many equipment. Considering its location in urban area of Shanghai, extra emphasis has been provided to the design of Huaxin station with regard to the outdoor audible noise and a design target of 45 dB(A) has been used for Huaxin; against a design requirement of 50 dB(A), at 20 meter outside boundary wall (for both stations).

Many different noise-reducing measures have been employed for the components used, to maximally decrease noise impact on the adjacent area. Some of attenuations measures used at Huaxin station include:

- ❖ The station layout has been acoustically optimised within the areas allocated by the Owner for converters and filters;
- ❖ The single filter location and layout has been acoustically optimised within the entire filter area;
- ❖ Converter transformers have been “boxed-in”, in appropriate designed compartments;
- ❖ Converter transformer and smoothing reactor's tanks have been provided with special beams, which are prepared to be filled with sand at site;
- ❖ All filter components are designed to be as quiet as possible. Furthermore, alternative attenuation measures have been used for example, some of the filter reactors have been provided with in-built noise screens; AC filter capacitor stacks have been divided in order to limit their height and certain capacitors units (e.g. 6/12 DC) use integrated internal damping elements design;
- ❖ All fans used in valve cooling system have been acoustically optimised and special noise dampers have been employed on the cooling towers;
- ❖ All cooling fans used for other cooling equipments have been acoustically optimised;
- ❖ Height and properties of the station perimeter wall have been adopted, to be used as an acoustical screen for the outside area;

In addition to above, space for future sound screens in filter areas has been reserved.

### **III. Main Equipment and Major Technical Features**

Air insulated, water cooled thyristor valves, arranged in double valve configuration are suspended from the ceiling of valve hall. Each single valve consists of 90 numbers in Yidu and 84 numbers in Huaxin YST90 (5”) type thyristors. Major part of thyristor delivery is manufactured locally and all thyristor modules are assembled in China.

In 3GS project, single-phase two-winding converter transformers are used. Half of the transformers are manufactured in China and half in Sweden. Cooler bank are mounted on tank itself for Yidu transformers while for Huaxin transformers, coolers are self standing due to audible noise mitigation arrangement adopted in this station. Both wye and delta valve winding bushings protrude inside the valve halls. Main data of converter transformer is as given in Table 1.



Factory testing of first converter transformer was completed in 9 months

	<b>Yidu</b>	<b>Huaxin</b>
Rated Power [MVA]	297.5	283.7
Rated Voltage [kV]		
- Line winding	$525/\sqrt{3}$	$525/\sqrt{3}$
- Valve wye winding	$210.4/\sqrt{3}$	$200.6/\sqrt{3}$
- Valve delta winding	210.4	200.6
Leakage Reactance [%]	16.0	16.8
Tap Changer Range [Steps]	+25, -5	+26, -6
- Step Size [%]	1.25	1.193
Insulation Level [kV]		
- Line side LIWL	1550	1550
- Valve wye side LIWL	1675	1675
- Valve delta side LIWL	1175	1175

**Table 1**

Smoothing reactor is oil insulated type and one unit per pole is installed on the high voltage side. Like converter transformers, half of the smoothing reactors are manufactured in China and half in Sweden. Valve side bushing protrude inside the valve halls, while line side bushing is outdoor and arranged vertically. Main data of smoothing is as given in Table 2.

	<b>Yidu/Huaxin</b>
Nominal Incremental Inductance [mH]	290
Rated Voltage [kV <sub>dc</sub> ]	500
Rated Current [A <sub>dc</sub> ]	3000
Insulation Level [kV]	
- LIWL, terminal to ground	1950
- LIWL, terminal to terminal	1950

**Table 2**

## IV. Reinforcing Regional Interconnection

Three Gorges - Shanghai DC Transmission Project is the 3<sup>rd</sup> HVDC project, which will be connecting Central China and East China asynchronously, See Fig. 1. The first transmission is 1 200 MW,  $\pm 500$  kV Gezhouba - Shanghai DC Transmission, which is operating now for almost two decades. A second 3 000 MW,  $\pm 500$  kV Three Gorges – Changzhou DC Transmission [1], which is operating successfully since 2002/2003. Another 3 000 MW DC transmission is

transmitting power from Three Gorges to Guangdong region [2] since 2003/2004, thus interconnecting South China network also with the Central and East.

A major part of system design were performed jointly by ABB and Chinese engineers, which made it possible to specify requirement specification of involved equipment at very early stage of the Project. At the time of writing this paper (June 2006), the installation at both stations is now at last stage, while commissioning activities for the equipment has already begun. The present target is to complete commissioning of both poles by month 31 i.e. 5 months ahead of contractual schedule with integrated project management and extensive cooperation within various involved parties.

Commissioning of this Three Gorges - Shanghai project will further reinforce HVDC capacity in interconnection of two asynchronous regions and will serve as a dedicated transmission high-way between current power hub of the country, Central China and power deficit East China region.

## V. References

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## VI. Biographies



**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 Systems AB in Sweden first as the Technical Manager for The Three Gorges - Changzhou  $\pm 500$  kV DC Transmission Project and presently as the Lead Engineer cum Project Manager for The Three Gorges - Shanghai  $\pm 500$  kV DC Transmission Project in Sweden.



**Ma Weimin** was born in China in 1966. He received his Ph.D. in High Voltage Engineering and Equipment from Wuhan Institute of Hydraulic and Electric Engineering in 1990. His working experiences include HVDC, overhead power transmission line design and high voltage testing. He is main author and contributor to the Technical Specification and system design of many of the large scale HVDC projects in China, such 3GC, 3GG, 3GS and LB BtB, etc. Since 2000 he is the Chief Engineer of Beijing Wanglian HVDC Engineering Technology Co. Ltd. (BDCC).



**Gou Ruifeng** was born in Shaanxi, China in 1959. He obtained his degree in Electric Engineering from Xi'an Jiaotong University in 1982. From 1982 to 1996, he was mainly engaged in the research of high voltage apparatus testing techniques & external insulation. Since 1997, he has been working on the HVDC Transmission Project, especially on the insulation coordination for HVDC Converter Stations in Xi'an High Voltage Apparatus Research Institute (XIHARI).