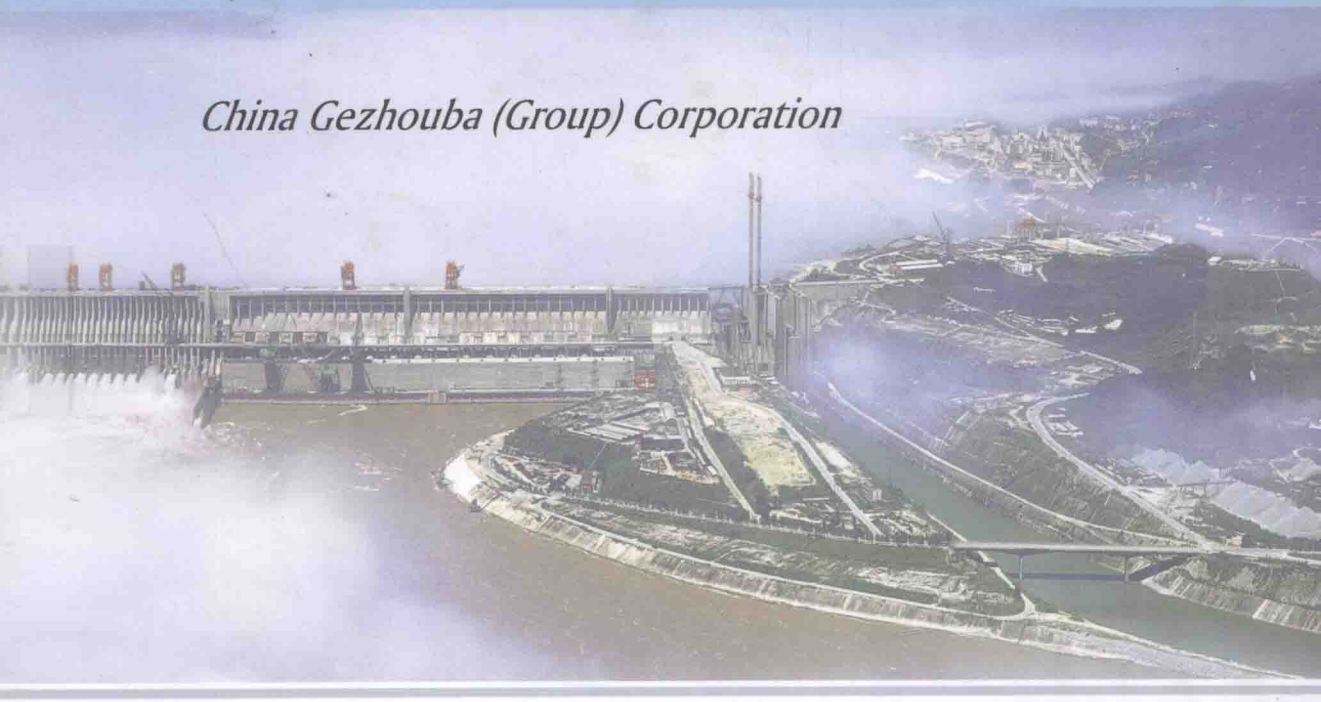
Installation Technology

in Great Turbine Generator Unit of 700MW

China Gezhouba (Group) Corporation



中国电力出版社
CHINA ELECTRIC POWER PRESS

Installation Technology

in Great Turbine Generator Unit of 700MW

China Gezhouba (Group) Corporation

中国电力出版社
CHINA ELECTRIC POWER PRESS

Abstract

The Yangtze River Three Gorges Project is a remarkably big project. After generations of research, survey, planning, designing and construction by Chinese people, the 700MW hydro-generator units have been installed in Three Gorges Project, Which is a significant breakthrough.

454 pictures were selected from tens of thousands of construction pictures and a few hundreds of videos showing the beauty of mechanical and electrical installation project for the book. The installation process of ALSTOM 700MW hydro-generator unit with words and pictures. It includes brief introduction on three gorges project, turbine installation, generator installation.

This is a practical and readable book for students and teachers in college and workers in this industry.

图书在版编目（CIP）数据

三峡700MW水轮发电机组安装技术 = Installation Technology in Great Turbine Generator Unit of 700 MW: 英文 / 中国葛洲坝集团公司编著. —北京：中国电力出版社，2012.1

ISBN 978-7-5123-2612-5

Ⅰ. ①三… Ⅱ. ①中… Ⅲ. ①水轮发电机-发电机组-机组安装-英文 Ⅳ. ①TV547.3

中国版本图书馆CIP数据核字（2012）第011340号

中国电力出版社出版、发行

（北京市东城区北京站西街19号 100005 http://www.cepp.sgcc.com.cn）

北京盛通印刷股份有限公司印刷

各地新华书店经售

*

2012年6月第一版 2012年6月北京第一次印刷

787毫米×1092毫米 16开本 20.75印张 375千字

印数0001—1500册 定价**95.00**元

Editor Committee

Editor's Office

Chief Editor	Jiang Xiaobing
Deputy Editors	Zhou Hui Qiao Xinyi
Reviewed by	Liang Weiyan
Co-authors	Jiang Xiaobing Zhou Hui Qiao Xinyi Chen Qiang Yu Jialian Lv Guiying Ma Jianghong Li Zhihong Li Jun
Photographed by	Jiang Xiaobing Li Sen Wang Zhifei Xu Yifu
Translators	Wang Zhifei Yu Jialian

Preface

When Jiang Xiaobing, chief engineer of China Gezhouba Group Corporation, forwarded me the manuscript for the book entitled with ***Installation Technology in Great Turbine Generator Unit of 700MW*** and asked me to write a ***Preface***, I refused at first for that was not my specialty. But after reviewing it, I got moved and couldn't help writing these lines.

With dedication and contribution from all those participating the project, the world-famous trans-century Three Gorges Project was realized with its three main targets of reservoir impounding, ship navigation and power generation in 2003; and the third phase project is under construction smoothly and expected to complete one year earlier than planned, which would add the final touch to the largest hydropower project over the world at present. To date, even those overseas who have prejudice to the project or even feel an antipathy against it, have to admit that: Chinese people have realized their dream cherished for a century – *'Wall of stones standing across the Yangtze River, to hold back Wushan's cloud and rain; and a tranquil reservoir looming in the deep gorges.'*(*It is part of a famous poem by Chairman Mao Tze-dong in 1956, in which he blueprinted The Three Gorges Project. - Noted by the translator*)

In the future, the Three Gorges Project shall bring more and more comprehensive benefits. The capacious reservoir shall ease the flood and relieve its tremendous hazard to Chinese people, which serves as the bulwark against the floods for the living and development of the residents along the middle and lower reach of the Yangtze River; through the permanent ship locks, ships with capacity of ten thousand tons could reach Chongqing Municipality from Shanghai, with the Yangtze River exhibiting its ability as the "Golden Watercourse"; but the most direct economic benefit from the Three Gorges Project is its power generation. 26 units of 700-MW-capacity shall be installed at the project (in addition, there are another 4200MW reserved for the underground power house); for the moment, the daily power output is more than 200 million kWh; after the completion of the Project, the annual output of electricity by both the Three Gorges Project and also its counter-regulation project - Gezhouba Power Plant shall reach above 100 billion kWh. The great potential not only makes it be able to return the loan in time, but also initiates the de-

velopment of the hydropower treasure along the upstream Jinshajiang River, which pushes forward the realization of the national grid integration and has a far-reaching significance. Under inspiration of the success made at the Three Gorges Project, unprecedented development occurred to China's hydropower industry, another 300 million kW of hydropower shall be developed in the coming 20~30 years. It is possible to develop all those economically feasible hydropower, which shall mitigate the shortage of energy in our country, optimize the energy structure, spur the economy, and improve people's life and reduce the pollution…what great importance in all aspects!

It is like a relay to build a hydropower plant which goes through various stages like planning, designing, surveying and constructing…; and at each stage, many different specialties are involved; none of these specialties or none of any step could be dealt by oversight. When we are visiting the Three Gorges Project, we are impressed by the lofty dam, the spectacular spillway like great dragon jetting out water, and the laddering up of the fleet with ships in ten thousand tons; but the generating units running around the clock are staying deep inside the power house, which are not obvious to the public. Actually, those of mechanical and electrical specialty also did indelible contribution for this undertaking. 700MW is the record unit capacity around the world for hydroelectrical generating unit till now. Many problems emerged during the construction, installation and operation of the Grand Coulee Hydro-electric Power Station in the USA; it was finally completed with numerous improvements. But the Three Gorges Project is facing more complicated operation conditions; therefore, during the feasibility study stage, the mechanical and electrical specialty has been taken as key field for further study. It proved that the mechanical and electrical industry in China has given a perfect answer.

Talking about the mechanical and electrical specialty, we first think of the manufacturing in unit components; we did make great achievements: by international bidding, technology import and Sino-foreign cooperation, the last two units among the 14 units for the left bank power house are mostly manufactured by Chinese supplier; and 8 out of the 12 units for the right bank power house shall be designed and manufactured by Chinese

supplier, which lets our hydropower unit manufacturing technology reach the world's advanced level. But the fact that our achievements and contributions in the installation of the hydropower units is also of the world's advanced level is less known to all. It only gradually comes to me to realize this point till I serve as quality supervision expert panel chief for the Three Gorges Project. Firstly, for such an complicated units in project like the Three Gorges Project, even supplied by the world's best suppliers, defects and design problems, or even hidden hazard may exist, which can only be detected and corrected by careful installation and commissioning. Without proper correction, it is impossible to guarantee the safe operation of the units. Many proposals for the correction of the defects during the installation and commissioning were accepted by foreign suppliers and they were impressed by our attitude and our ability. Secondly, installation quality is key to long term stable operation of the unit. We' ve set new standard for Three Gorges Project (known as the Three Gorges Standard), a standard with stricter requirement than that of the national, industrial or manufacturer's standards, which makes the precision and quality of the installation reach the world's advanced level. What impressed me most is the coin test for vibration—a coin erected on its side on the generator cover during unit operation and it did not fall—it is a miracle! Usually, the unit shall be handed over after 72 hours commissioning test. At Three Gorges Project, the unit can only be taken over when all the parameters meet the standards and without stopping the unit; what's more, a newly installed unit should pass the test of 100 days of continued stable operation. For a unit of this capacity, the result of success at first try, stable operation and realization of 100 days continued operation, has set a new world record. Thirdly, for such capacity unit, the originally planned installation duration is rather tight, but in reality, the installation time for one unit becomes shorter and shorter, and made an unprecedented record of putting 6 units of 700 MW each into operation within one year; as a result, all the 14 units had been put into operation in September of 2005, which is one year earlier than original scheduled and widely overtakes the speed for installation of such capacity units in the world! Those facts proved that we have reached the world's advanced level in hydroelectrical generating unit installation.

The installation of the left bank power house of Three Gorges Project was undertaken by China Gezhouba Group Corporation, Bureau 8 and 4 of Sinohydro. They are both competitors and companions. On the one hand, they competed with each other to set new records; on the other hand, under the coordination of the China Three Gorges Project

Corporation (the Employer), they cooperated with each other, worked together to realize the same target, which exhibits the characteristics and advantages of the socialist market economy. I hope those economists who simply emphasize "competition" and "market" but hedge "socialism" can go to the site of Three Gorges Project for a look and thought, I think it's will do them good.

This book is compiled by China Gezhouba Group Corporation. CGGC is a team capable of difficult missions, who undertook the installation and commissioning of 4 units and all the auxiliaries for the left bank power house. The authors and the compiler of this book are participators of Three Gorges Project; and most of them have participated 3~4 similar projects before and they are experienced; but they are not limited to their experience; they are ready to learn new technology, dare to master the top technology in installation. By the process of technology importing, absorbing, digesting and innovation, they have solved a series of complicated difficulties such as "turbine resonance", "change in distributor end clearance", "rotor rim shrinking", and the "unit axis alignment" , and made great contribution in the field. Under the leadership of Jiang Xiaobing, this book is compiled with careful analysis and summary, which is of great help in the guidance of the installation. To note, the feature of this book is that: it is compiled according to the intrinsic logic sequence of the actual installation: first with strict procedures, then brief introduction of the theory and method, and finally with pictures and concise description, which makes it easy to understand and pleased to read, it is a nice reference for the field in great hydroelectrical generating unit installation and even an excellent popular science book.

As an outsider, I'd like to show my respect and congratulation through these few words, and take it as the ***Preface***.

潘家铮

Pan Jiazheng

October 31, 2005

Pan Jiazheng, a well-known Chinese engineer and scientist in hydropower and water conservancy, served as Quality Supervision Experts Panel Chief for Three Gorges Hydropower Project. He is an academician of both Chinese Academy of Engineering and Chinese Academy of Science. He is currently the Honorary President of the Chinese National Committee on Large Dams.

Editor's Note

When I studied in university, I cherished the dream of participating the construction of Three Gorges Project, because it was proposed by Dr. Sun Yat-sen and blue-printed by Chairman Mao Tze-dong; It's a project for soaraway China like a great dragon, Which is beneficial to the decendants of Yandi and Huangdi Emperors, and a pride of Chinese nation. Once taking this field as my major, I should join Three Gorges Project, which is like a pearl on the crown of this field. Besides, I had a regret that I did not do well in a course called *Turbine Generator Installation*, because the textbook was dull and there weren't any reference books either, and most of my classmates shared the same opinion. As an ambitious student longing for clutching the pearl of the crown, what a shame to have done badly on a major course!

To pursue my dream, I joined China Gezhouba Group Corporation after graduation and became a member of hydropower construction team. For twenty years, I have worked at Gezhouba Project, Manwan Project in Yunnan Province, Ertan Project in Sichuan Province and other projects and I become matured. In 2001, I was the project manager for the hydroelectrical generating unit installation work in the left bank power house of Three Gorges Project for my company. My dream came true.

After generations of researching, surveying, planning, designing and construction by Chinese people, the world-famous Three Gorges Project is ready for M&E installation, the harvest season. Since hydroelectrical generating unit of capacity 700MW is unprecedented in China, and the first practice was just tried in the 80s of the 20th century abroad. Therefore, we have to start from scratch in the installation of the 700MW units. Based on our past experience, by careful study and organization, we solved many hard-nut problems and the first unit was a great success with all the operation parameters conforming to the requirements of the manufacturer's and the national standard. What's more, the progress is also unprecedented (for example: for unit No. 4, twenty days from runner installation to lowering the rotor, and 30 days from lowering the rotor to starting commissioning). During later installation, we kept on improving our procedures and methods, and make the installation technology of 700MW unit become matured and reach the world's advanced level.

In the process of the installation, besides my daily routines of organizing construction

and solving problems encountered, I was also considering compiling a book of the latest technology in the installation of the unit based on our actual experience, which is not only for the purpose of sharing experience with counterparts in this field, but also can serve as a textbook for university students in this major. If so, it is a comfort for my regret as a university student.

When planning for the book, I hope that the book should include both words and illustrations, because such a form can exhibit the beauty of the installation and motivate the student's passion to learn; it also provides an easy reading and understanding experience, which can inspire more people to master the technology. In order to better the book, we took photos and videos for every step of the installation, and accumulated tens of thousands of photos and hundreds hours of the videos, which provide rich materials for the book. Such materials cover the introduction of the Three Gorges Project as a whole, the technology in installation of such great capacity turbine and generator parts, which makes the book unique and rich in contents. I hope that we can provide a practical and readable book for students and teachers in college and workers in this industry. If so, I will be gratified.

Jiang Xiaobing
November, 2005

Jiang Xiaobing, born in 1956, graduated from Wuhan University with major in Hydropower Equipment in 1982. After graduation, he has been continuously engaging in construction work in hydroelectrical power project. He once organized construction works for several tens of hydropower projects in various kinds. He was project manager from year 2000 to 2004 for 700 MW generating unit installation contractor in Three Gorges Hydropower Project. He is currently chief engineer in China Gezhouba Group Corporation.

Table of Contents

Overview

1 Brief Introduction on Three Gorges Project

1.1 Brief Introduction

Major challenge in The Yangtze River is flood control. Three Gorges Project lies in Sandouping Town, Yichang City, Hubei Province, which is about 40 km away from the downstream Gezhouba Project.

Three Gorges Project has a comprehensive function of flood-prevention, power-generating and ship-navigation, it consists of the dam, power house and navigation structure. The dam cross the river is of concrete gravity type with a total length of 2309.47 meter; the elevation of the dam crest is 185 meter above sea. The dam consists of the spillway section, power house section and non-spillway section; the spillway section lies in the middle of the river bed, the contour length is 483 meters; there are 23 middle outlets and 22 crest outlets, and 22 temporary diversion outlets at bottom; in addition, there are 3 outlets for floatage discharging and 7 for sand discharging. The power house section and the non-spillway section lie on two sides of the spillway section, the left bank power house section is 581.5 meter long with 14 inlets; the right bank power house section is 525 meter long with 12 inlets.

The navigation structure lies on the left of the project; it consists of double five-stage ladder type ship locks and one vertical ship lift; during construction stage, there was one ship lock for temporary navigation, where now 2 sluice outlets are built.

There are two power houses located on both sides of the river at the foot of the dam, and 26 sets of 700MW turbine generators are installed with the total installed capacity

of 18200MW, among which, 14 sets at the left bank power house and 12 sets at the right bank power house. An underground power house with 6 sets of 700MW units is reserved at the right bank, which lies in parallel with the right bank power house. Of the 14 Francis units for the left bank, 8 are supplied by VGS, a consortium formed by VOITH, GE and SIEMENS, and the rest 8 are supplied by ALSTOM.

1.2 Main Parameters for the Project

Area of the upstream reservoir	1 million km^2	Flood limit level	145m
Average annual rainfall	1147.2 mm	Flood reserve level	135m
average annual temperature	16.9℃	Crest elevation	185m
Maximum high temperature	43.9℃	Maximum dam height	181m
Minimum low temperature	−9.8℃	Dam axial distance	2309.47m
Average annual water temperature	18℃	Installed capacity	18200MW
Maximum instantaneous wind speed	34m/s	Left bank power house	9800MW
Average annual flow	14300m^3/s	Right bank power house	8400MW
Design flood flow	98800m^3/s	Average annual power generation	84.7 billion kWh
Total reservoir capacity	39.3billion m^3	Maximum head	113m
Flood reserve capacity	21.15billion m^3	Minimum head	61m
Regulation capacity	16.5billion m^3	Rated head	80.6m
Normal water level	175m		

2 Major Technical Parameters for Turbine Generator

2.1 Turbine Major Parameters

In this section, the parameters are for units supplied by ALSTOM.

2.1.1 Technical Parameters (Refer to Tab. 1-2-1)

Tab. 1-2-1 Major Turbine Parameters

Item	unit	Value/Description
Type		Vertical shaft, Francis
Number of units		8
Runner Nominal Diameter	mm	9800
Maximum head	m	113.0
Rated head	m	80.6
Minimum head	m	61.0
Rated output	MW	710
Maximum continued output	MW	767
Maximum output when $\cos\varphi=1$	MW	852
Rated flow	m^3/s	991.8
Rated speed	r/min	75
Installation elevation (above sea)	m	57
Specific speed	m•kW	261.7
Rotational direction		Clockwise from above
Type of spiral case		steel

2.1.2 Elevations (Refer to Tab. 1-2-2)

Tab. 1-2-2 Elevations for Turbine

Item	Elevation (m)
Coupling flange of the turbine and intermediate shaft	64.5
Gallery to the turbine pit	61.24
Turbine installation benchmark	57.0
Spiral case manhole gallery	56
Draft tube cone manhole gallery	49.0
Draft tube expansion manhole gallery	44.0
Spiral case drain valve operation gallery	44.0
Foundation plate of the draft tube	27.0
Drainage gallery for maintenance	24.0

2.1.3 Dimensions and Weights for Major Parts (Refer to Tab. 1-2-3)

Tab. 1-2-3 Dimension and Weight for Major Turbine Parts

Parts Designation	Dimension (mm)	Parts No.	Single Weight (t)	Weight (t)
Bottom Ring	ϕ13270×700	4	28	112
Head Cover	ϕ13670×2275	4	95	380
Wicket Gates	1724×436×5710	24	9.5	230.4
Servomotor	4750×1460×1660	2	25	50
Runner	ϕ10600×5080	1	445	445
Turbine Shaft	ϕ4000×6680	1	110	110
Stay ring	ϕ15800×4640	6	65	390
Turbine Together	3308			

2.2 Generator Major Parameters

2.2.1 Technical Parameters (Refer to Tab. 1-2-4)

Tab. 1-2-4 Major Generator Parameters

Items	Value
Rated Capacity (MVA)/ Rated Output (MW)	777.8/700
Maximum Capacity (MVA)/Output (MW)	840/756
Rated Voltage (kV)	20
Rated Current (A)	22453
Current at Maximum Capacity (A)	24249
Rated power factor	0.9
Power factor at maximum capacity	0.9
Rated efficiency (%)	98.77
Efficiency at maximum capacity (%)	98.76
Weighted efficiency (%)	98.76
X_d' at rated capacity (unsaturated value)	0.315
X_d' at maximum capacity (unsaturated value)	0.340
X_d'' at rated capacity (saturated value)	0.20
X_d'' at maximum capacity (saturated value)	0.216

Tab. 1-2-4 Continued

Items	Value
Short circuit ratio at rated capacity	1.2
Short circuit ratio at maximum capacity	1.1
GD^2 (t·m^2)	450000
Stator slots number	540
Stator winding parallel branches and connection	5Y
Type of stator winding	wave
Stator winding rated current density (A/mm^2)	3.77
Stator winding maximum current density (A/mm^2)	4.07
Capacity of stator winding single phase to earth (μF)	2.03
Rated speed (r/min)	75
Runaway speed (r/min)	150
Allowable runaway time (min)	5
Type of cooling	Water cooling for stator winding, air cooling for stator core and rotor winding

2.2.2 Elevations (Refer to Tab. 1-2-5)

Tab. 1-2-5 Elevations of Generator

Item	Elevations (m)
Joint of the turbine shaft and generator shaft	64.5
Foundation for lower bracket	65.5
Stator pit	67.8
Generator floor	75.3

2.2.3 Dimensions and Weights for Major Parts (Refer to Tab. 1-2-6)

Tab. 1-2-6 Dimensions and weights for major parts

Serial	Parts designation	Dimension (mm)	Weight (t)
1	Stator frame (in 5)	ϕ22038×6035	206
	Stator core	ϕ19720/ϕ18800×2950.4	508
	Stator winding (1080 pcs)	4080.7×790 for one	90
	Stator complete	23100×6380	714

Tab. 1-2-6 Continued

Serial	Parts designation	Dimension (mm)	Weight (t)
2	Rotor hub and spiders (17 pcs)	Hub: ϕ5997×2690 Spiders: R8305/R2900×3190	394
	Rotor rim	ϕ18086/ϕ16650×3190	975
	Pole (80 pcs)	685×3480×326	410
	Rotor complete	ϕ18738×3600	1780
3	Generator shaft	ϕ4000×4935	112.8
4	Thrust collar and runner	Collar: ϕ5200×1100	68.27
5	Thrust bearing & bracket	Lower bracket: ϕ15100×4880	392
6	Upper shaft	ϕ2710×2215	27.55
7	Upper guide bearing & bracket	Upper bracket: ϕ23380×1875	140
8	Air cooler		7.5
9	Generator together (one unit)		3333.5

3 Structure of Turbine and Generator

3.1 Structure of the Turbine Generator set

The turbine generator Set for Three Gorges Project is vertical semi-umbrella Francis unit; the main shaft is in two sections; the thrust bearing is located in the lower bracket; there are three guide bearings; the cooling type is semi-water cooling. Refer to Fig. 1-3-1.

3.2 Structure of Turbine

The turbine consists of distributor, rotation part, guide bearing and shaft seal, servomotor and auxiliaries.

3.2.1 Distributor

The distributor consists of the bottom ring, the head cover, wicket gates and the operating mechanism.