Construction of CANDU® in China
A China–Canada Success Story

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Abstract

Qinshan III CANDU® Nuclear Power Plant consists of 2 x 728 MWe units constructed by Atomic Energy of Canada Limited (AECL) and the Third Qinshan Nuclear Power Company Ltd. (TQNPC) at Qinshan in Zhejiang Province, P.R. China. The Contract Effective Date was 1997 February 12 and first containment concrete for Unit 1 was 1998 June 8. The scheduled in-service dates are Unit 1, 2003 February 12 and Unit 2, 2003 November 12. Construction and commissioning are on schedule and major project milestones have been met. Qinshan Unit 1 is the first CANDU® in China and has been constructed to the shortest construction schedule of any nuclear power plant built in China. The reasons for this are modern project management tools and construction methods that included heavy lifts and modularization, together with an excellent working relationship and partnership between the Chinese and Canadian project participants. This paper describes the status of work, successes achieved, special experiences and looks ahead to the successful completion of the Project.

1. Introduction

TQNPC and AECL have forged an effective partnership in the construction and commissioning of the 2 x 728 MWe CANDU® station located on Hangzhou Bay at Qinshan, Zheijiang Province, P.R. China. The 2 units form part of an impressive nuclear complex that has two units operating and three under construction. The Reference Plant design is the design of Wolsong 3 and 4 CANDU 6 units in the Republic of Korea, for which TQNPC has implemented specific design improvements. Qinshan III is an international project with financing of the respective scopes coming from China, Canada, Japan and U.S.A.

2. Major Participants and Roles

AECL is overall project manager, designs and supplies the Nuclear Steam Plant (NSP) and manages NSP construction. (NSP equipment supply is subcontracted, in part, to Canadian, U.S., European and Korean suppliers.) TQNPC as owner manages the Balance of Plant (BOP) construction and executes commissioning. Construction is by Chinese Construction Contractors: China Nuclear Industry 23rd Construction Company (CNI 23), Hua Xing Construction Company (HXCC), China Nuclear Industries 22nd Construction Company and Zhejiang Thermal Power Construction Company. A consortium of Hitachi/Bechtel provides BOP design and supply under subcontract to AECL.

TQNPC's role includes: prepare Site; provide permanent site facilities (offices, warehouse) at start of construction for improved productivity; manage BOP construction by subcontract to Shanghai Nuclear Engineering and Research Institute, with technical assistance by Hitachi/Bechtel; provide local staff to AECL Site Project Management Organization; manage licensing; provide Quality Surveillance (QS) of NSP and BOP offshore equipment during manufacturing; provide added site QS of NSP construction through an independent QS company;

execute commissioning with guidance and direction by AECL and provide fuel after the first fuel load. China has established the capability of manufacturing CANDU fuel. AECL's role covers: overall project management; design and supply of NSP equipment; site management by subcontract with Canatom NPM (Canada); training by a subcontract to Hydro-Quebec (Canada) Gentilly 2 CANDU® 6 station; design and supply of BOP equipment by a subcontract with Hitachi/Bechtel (Japan/U.S.A); NSP construction and site excavation by subcontracts to Chinese Construction Contractors; supply of initial load of fuel and heavy water, and guiding and directing commissioning.

3. Project Management Tools

The Project features state-of-the-art engineering tools: three dimensional Computer Aided Design and Drafting System (CADDS); an Integrated Electrical and Control (IntEC) database for wiring, cable, connection and equipment information, which have been successfully used by CNI 23, the nuclear installation contractor and Commissioning; the CANDU® Material Management System (CMMS), which identifies and tracks equipment and material from the design phase through the supply chain, to construction and operation of the station; Asset Information Management (AIM) which manages, on line, all formal project records in electronic format; TRAK, an electronic document control system; a Weld Information System (WIS) developed by CNI 23 to electronically record quality information of all pipe welds; Primavera P3 , a planning and scheduling tool. These tools are integrated for maximum benefit and efficiency.

Design information in CADDS and IntEC has been integrated with other AECL electronic management systems for controlling and managing materials and documentation. Material and equipment information extracted from CADDS and IntEC carries a stock code number designation and a physical description that are linked with CMMS to produce bills of material. Accurate material identification is achieved, which is particularly important for materials requiring quality assurance documentation and traceability. The material in CMMS is bar coded for inventory control and allows the construction contractors to produce construction work packages by area. AIM provides real-time access to official drawings and documents by all parties, thus improving quality and efficiency and reducing costs. A key feature of AECL's production of electronic design documents is electronic approval of documents, which means that project official records can be completely electronic. TRAK accesses information from AIM to facilitate the scheduling, issue, distribution and shipping of documents and drawings (including those from suppliers). Real-time status reports and documents are accessible to all project participants at Site and in Canada through Local Area Networks (LAN) and by digital communications to off-shore locations.

TQNPC as owner supported the use of the new electronic tools, which has contributed to the successful management of the Project. The simplification of storage, accessibility, and upgrading facilitates configuration management from design to construction and operations – all to the benefit of Project stakeholders.

4. Construction

Construction of the plant is by Chinese contractors. Excellent co-operation among AECL, TQNPC and Chinese contractors has resulted in the introduction of modern construction management techniques, some of which were not previously used on other CANDU® projects. China is a large country and with an intensive nuclear power plant program, experience and personnel from Daya Bay were not readily available to Qinshan III. AECL's decision to place in

its construction team "hands-on" construction specialists successfully provided "on-the-job-field" training, which greatly contributed to the success of the project. The introduction of new techniques was achieved by marrying conventional AECL practices with working experiences in China.

Open top construction was implemented for the first time on a CANDU® Project by TQNPC and AECL with a Very Heavy Lift (VHL) crane (Liebherr 1650/1800) supplied by TQNPC which provided schedule flexibility and reduced labour, and allowed work access from top and bottom. More than 70 lifts were made using the VHL crane and major lifts (metric tons including lifting gear) included: Steam generator – 220; Temporary roof – 150; Pressurizer – 103; Reactivity Mechanism deck – 43; Feeder Header frames - 40 each; Condenser shells - 270 each, and Turbine Generator stator – 280. AECL will continue to optimize and further exploit open top construction based on the Qinshan experience. Together with heavy lifts, the construction at Qinshan continues the successful evolution of CANDU® 6 design by Chinese contractors and AECL through modularization (dousing steel, piping, valves and electrical, lower dome steel formwork and spent fuel transfer assembly).

TQNPC has responsibility for BOP construction management. A key feature of the site was four undersea intake cooling water ducts averaging 50 meters long that were constructed in water having a high silt content and with current velocities reaching 4 meters per second with the daily inflow and outflow of the tide into Hangzhou Bay where the Qinshan site is located. This very difficult work was completed by TQNPC and Chinese contractors to support the project schedule.

A special challenge on Qinshan III was the small site with water on three sides. Some of the site area had to be created using retaining walls, which limited space especially in the first part of the project, and the restricted access required detailed planning and coordination of common systems in the ring trenches around the site to meet the schedule. Another success of the Chinese-AECL team was the achievement of the lowest leak rate recorded for a CANDU® 6 containment from the Unit 1 Reactor Building leak rate test. Lessons learned will reduce this even further on the second unit. The learning experience was visibly demonstrated in going from Unit 1 to Unit 2, with construction durations for many Unit 2 activities being significantly lower than for Unit 1.

5. Quality

AECL's Quality Assurance Program at site was implemented to meet both ISO 9002 and Canadian Standards Association requirements. AECL's construction contractors have implemented quality programs to international standards and used quality trend analysis to improve their work. An excellent working relationship was established between TQNPC and AECL using joint audit/evaluation teams, which gave better problem resolution and synergy. AECL has carried out over 100 audits on the project to continuously place quality as its first requirement.

6. Commissioning Team

TQNPC (1000 staff) executes commissioning with AECL (46 expatriate advisors) providing guidance and direction. Two hundred and thirty-two TQNPC staff were trained at Gentilly 2 NPP in Canada. AECL has provided a full scope CANDU® 6 simulator on site to support the training of operators who are licensed by the Chinese regulator, NNSA. The TQNPC commissioning team has quickly absorbed and applied commissioning/operations skills. The key factor in the commissioning of Qinshan III is the use of Canadian management processes and

procedures to specify, document and verify the individual steps in the commissioning program. TQNPC and NNSA have effected a smooth licensing process supported by the quality, comprehensiveness and detail of the commissioning procedures and processes.

7. Schedules

The Qinshan CANDU® project represents the first CANDUs® constructed in China and with Qinshan Phase III being built on a small site surrounded by water on almost three sides, detailed planning and strong project management are required. The heart of this planning and management is a detailed 8500-activity Level 2, or Project, Co-ordination and Control schedule that sets the work requirements of all major Project participants and includes design deliverables, equipment deliveries, and construction and commissioning activities. The Level 1, or Contract schedule has 76 milestones. Level 3 schedules were produced by the Chinese Construction Contractors.

The following world records were set by Chinese NSP Contractors CNI 23 and HXCC, including:

- Slipforming Unit 1 18 days
- Slipforming Unit 2 14 days
- Fuel Channel installation Unit 1 69 days
- Fuel Channel installation Unit 2 64 days
- Steam Generator installation 8 hours
- Pressurizer installation 8 hours

8. Current Status

Unit 1 is at month 52.5 of construction. Owner's staff is about 1300. Contractor direct site labour force is at 3500 (down from 8000 peak). AECL and its off-shore subcontractors have 140 expatriates on site (peak of 180). Civil work is largely complete. Unit 1 commissioning is 90% complete and in Unit 2, turnovers from construction to commissioning are 95% complete. Project milestones to date have been met.

9. Summary

The China-Canada partnership has successfully integrated the multi-national project expertise of the participants on the Qinshan CANDU Project and has evolved CANDU® 6 construction methods and design. Advanced project management methods and tools have been adopted by TQNPC and Chinese Construction Contractors. Improved construction technology, coupled with hard work, has achieved many installation world records. TQNPC and AECL are working together to achieve a world construction schedule record for the first-of-a-kind NPP in any country – 51.5 months from first concrete to criticality and 54 months from first concrete to 100% power (forecast December 2002).

New Record for Chinese NPP Construction

Unit	First Concrete to Criticality (Months)	Criticality (Year)	First Concrete to 100% Power
Qinshan I	77	1991	87
Qinshan II Unit1	66.5	2001	70
Daya Bay Unit 1	71.5	1993	75.5
Daya Bay Unit 2	69.5	1994	71.5
Lingao Unit 1	56.5	2002	59.5
Lingao Unit 2	55.5	2002	-
Qinshan III CANDU Unit 1	**51.5**	2002	

Qinshan III will become the future CANDU® 6 international reference plant and its construction advances will allow continued improvements for future "replicated" and "evolved" (enhanced modularization) units. Based on applying the lessons learned on Qinshan III, future CANDU® 6 units can achieve first concrete to 100% Power in 51 months, at a unit cost less than US1500/kW.

AECL and its Chinese partners will continue their long-term nuclear co-operation in China and will look for opportunities to work together internationally.

10. Site Progress Photos

- September 1998 Site View
- November 1998 Coffer Dam
- January 1999 Slipforming Unit 2
- March 1999 VHL – Temporary Roof
- June 1999 Unloading Calandria Unit 2
- December 1999 Site View
- April 2001 Site View
- September 2002 Site View

SITE PROGRESS PHOTOS


January 1999
Slipforming Unit 2


March 1999
VHL – Temporary Roof


June 1999
Unloading
Calandria
ALSTOM


December 1999


April 2001


September 2002