AP1000 Construction in China: A Progress Update

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Electricity demand in China is growing at a rate of 13 percent per year, a phenomenal rate of growth for such a large and populous country. This growth is fueled by the historic economic expansion taking place in China, with the country's gross domestic product rising at a rate of over ten percent, despite efforts by the Chinese government to slow the blistering growth to head off the risk of inflation.

Electricity consumption in China is the second highest in the world, behind only the United States, and rising each year. To support its new economy and demand for electricity, China is rapidly adding to its base of generating capacity, which currently stands at more than 625 GWe, to a projected capacity of more than 1400 GWe by 2020.

China is rising to this challenge not only through new fossil-fired capacity, but with an extraordinary expansion of its nuclear and renewable generating capacity. The country is developing new nuclear energy capacity at an almost unprecedented rate, with more than 20 plants now under construction and more than 27 additional plants in the planning stage, with construction to begin in the next three years. Through this expansion, China aims to achieve a nuclear capacity of over 86 GWe by 2020, and as much as 200 GWe by 2030, making China by far the biggest generator of nuclear power in the world.

The Westinghouse AP1000™ nuclear plant is China's announced Generation III+ technology of choice. Currently, four AP1000s are under construction, with the first to come on line as scheduled in 2013. China also plans to build many more AP1000s in the coming years and decades.

AP1000 China Project Background

In March 2006, China's State Council approved the Development Plan for Nuclear Power for the medium- and long-term (2005-2020). The plan states that the active development of nuclear power is an important energy strategy for China. The active development of nuclear power is also envisioned in China's 11th Five-Year Plan, which states that "China is to actively pursue construction of nuclear power, focus on building 1000 megawatt nuclear power plants, and gradually realize self-reliance in design, manufacturing, construction and operation."

In support of these goals, Westinghouse and its consortium partner, the Shaw Group, signed landmark contracts in July 2007 with China's State Nuclear Power Technology Corporation Ltd. (SNPTC), Sanmen Nuclear Power Company Ltd., Shandong Nuclear Power Company Ltd., and China National Technical Import & Export Corporation (CNTIC) to provide four AP1000 nuclear power plants in China, two each at the Sanmen site in Zhejiang and at the Haiyang site in Shandong.

The contracts were preceded by a framework agreement that paved the way for preliminary design, engineering and procurement of long-lead items to commence. By the time the contracts were signed, much of the early work was already well underway.

Site Preparation and Early Construction at Sanmen Unit 1

Several months of site preparation followed the contract signing, which included excavation of the area for the nuclear island. That excavation, which for Sanmen unit 1 commenced in February 2008, took approximately 12 months to complete, and created an approximately 12 meter (m) deep hole approximately 54 m wide by 78 m long, plus the rebar configuration and pipe-work required prior to basemat placement.

Placement of the basemat for Sanmen Unit 1 was concluded successfully on schedule on March 31, 2009, after nearly 47 hours of continuously pouring a total of 5000 cubic meters of concrete. Completing the basemat placement on time was crucial to keeping construction on schedule for completion and commercial start up of the first unit in 2013. The basemat concrete placement for all four units has now been completed andeach placement finished on schedule without any issues.

The AP1000's innovative basemat ties the nuclear island buildings into what is essentially one structure. The interconnectivity of these structures allows the basemat to be thinner than most conventional nuclear building basemats while still being able to fulfill the foundation functional requirements, saving considerable material and time-related cost while providing a sound structure.

The AP1000 design employs the use of many mechanical and structural modules. While the excavation was underway, the China-based module factory started fabrication of the major modules required for the early stages of construction, as well as the preparation of the containment bottom vessel head plates.

One of the largest of these modules is the auxiliary building. This particular module, set into place using the largest mobile heavy-lift crane in the world, weighs around 750 metric tons and is as tall as a five-story building. The setting of the auxiliary building has now been completed for the first three units with no lifting or setting issues. The fabrication and welding of the containment vessel bottom head has also been completed for the first three units with no issues. In each case the subsequent units have been manufactured in a reduced time, reflecting the learning process adopted by the project.

Other significant modules such as the reactor vessel cavity, steam generator and refueling canal module, and the access tunnel and walls module have also been fabricated and set, in addition to various other smaller modules. The first Sanmen unit has two of the four containment vessel (CV) rings in place. Haiyang unit one also has its first CV ring in place. The setting of the second ring at Sanmen was completed on schedule against the dates set in 2007; proving the advantages of the modular construction concepts incorporated into the AP1000 design and engineering. In fact, by the end of 2010, over 50 percent of the bulk materials are scheduled to be installed within the first Sanmen containment building. This rate of progress is necessary to enable installation of major equipment such as the reactor vessel, the pressurizer, and steam generators in 2011.

Enhanced Plant Design

The unique feature of the AP1000 is its use of natural forces to achieve and maintain safe shutdown conditions in the highly unlikely event of design-based accident. Rather than relying on active components such as diesel generators and pumps, the AP1000 relies on the natural forces of gravity, natural circulation, and compressed gases to keep the core and containment from overheating. Even with no operator action and a complete loss of all on-site and off-site AC power, the AP1000 will safely shut down and remain cool.

As a result, in the case of the AP1000, those active support systems no longer must be safety class, and they are either simplified or eliminated. With less safety-grade equipment, the seismic Category 1 building volumes needed to house safety-grade equipment are greatly reduced. In fact, most of the safety equipment can now be located within containment, resulting in fewer containment penetrations.

China has taken a leadership role in being the first country to implement AP1000 technology. Chinese engineers studied the AP1000 carefully before making the decision to proceed. The combination of a simplified design that benefits from modular construction techniques means that it will be possible to build a large number of AP1000 plants in a very short time. Thus far, the design and construction of Sanmen 1 is proving to be instructive as Westinghouse and Shaw proceed at the other three sites in China. After these first four plants are built, Westinghouse plans to realize certain efficiencies that would enable a decrease in construction time of at least 25 percent to be achieved.

Currently, construction at the Sanmen and Haiyang plants are on schedule, with the next first unit major milestone scheduled to be the installation of the reactor vessel and then steam generators at Sanmen 1 in 2011.

Building on Success

Excavation and site preparations for Sanmen Unit 2 were completed by the end of 2009. The first four AP1000 placements of the basemat structural concrete has been successfully completed in China, on two different sites and with different seasons of the year (hence differing curing temperatures). This has established a baseline, confirming the design and concrete formulation and the placement rate that can be reasonably expected. The bending and forming process for the containment vessel plates, particularly the more difficult CV bottom head plates, is completely established and proven. Similar observations can be made for modules – from the smaller equipment modules to the massive CA01 Steam Generator & Refueling Canal Module, which had a lift weight including rigging of over a thousand metric tons.

The difficulties associated with first-of-a-kind projects were understood and Westinghouse was well aware of the serious problems being experienced in the construction of new nuclear power plants elsewhere in the world. Therefore, particular attention was paid to risk management. The Westinghouse standard risk management processes focus on identifying events with uncertain outcomes that could affect negatively (threats) or positively (opportunities) the project objectives. When an uncertain event is identified the risk drivers are identified and attention is focused on the potential impact to project objectives if the uncertain event were to occur. Response plans and mitigation actions are identified to address the risk drivers. Risk management strives to prevent or minimize the potential negative impacts (threats), and exploit potential positive benefits (opportunities) with respect to project objectives.

With four units being constructed in China and contracts placed for the deployment of the AP1000 in the USA, it is essential that the lessons learned from the first build can be applied to subsequent construction. This is to ensure that (a) where difficulties have been experienced and resolved the actions are not repeated, and (b) successful methods are replicated. Westinghouse has implemented a state-of-the-art lessons learned system to ensure the capture of significant and minor lessons, experiences, or observations. Moreover, the staff working on the project are encouraged and obligated to actively support this lessons capture program.

As these four plants are constructed, the lessons learned are being shared with other organizations around the world. For example, the National Nuclear Safety Administration (NNSA) also has a very productive relationship with the U.S. Nuclear Regulatory Commission (NRC) and other regulators. Its representatives frequently meet with European regulators, and they are committed to sharing what they have learned as these projects continue to progress. The NNSA recognizes its responsibilities and takes very seriously the granting of licenses and assuring the safe design, construction and operation of plants throughout China.

Local Supply Quality is Imperative

Using local suppliers is a key component to keeping construction time and costs under control. The containment vessel, for example, was supplied locally, and Westinghouse worked with the supplier from the earliest stage to achieve American Society of Mechanical Engineers certification.

Bureau Veritas, a global company that specializes in quality assurance, is working with Westinghouse to help ensure supplier quality. This effort has been helpful in ensuring that supplier quality meets our overall standard of quality in plant design and construction.

When Westinghouse creates construction schedules for projects, we anticipate the need to factor in time for quality checking and occasional corrective action in order to satisfy our quality standards, before moving to the next step in the process. Interactions with the National Nuclear Safety Authority (NNSA), as well as SNPTC have been very productive, and both organizations are consistent in their commitment to safety and quality. Westinghouse and Shaw put safety and quality first, and this commitment has played a huge role in the ongoing success of these projects.

Looking Ahead

With the construction of these first four Generation III+ plants, China is leading the way in making its own nuclear renaissance a reality, and in turn, creating new opportunities around the world for nuclear power to help support economic growth and prosperity. The lessons learned in the design and construction of Westinghouse AP1000 nuclear power plants will undoubtedly provide valuable insight as the technology is implemented on a larger scale throughout China and the rest of the world.

China has opened its doors to the world, both as a developer of new energy production as well as an example for other countries to follow. Westinghouse is pleased to be an important part of China’s growth in electric power supply and a technology partner that the rest of the world can depend upon for the development of safe and reliable nuclear energy.

As the need for new nuclear generating capacity expands in the U.S., Europe, India and other parts of the world, the knowledge and experience gained from the construction in China will provide for increased efficiencies in the construction process, improved processes, and a broader, more localized supply chain. In the end, governments around the world will benefit from the cooperative environment we have created in China, where ideas and lessons are shared.

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