Experience Sharing of the First HPR 1000 Reactor Operation with High Quality

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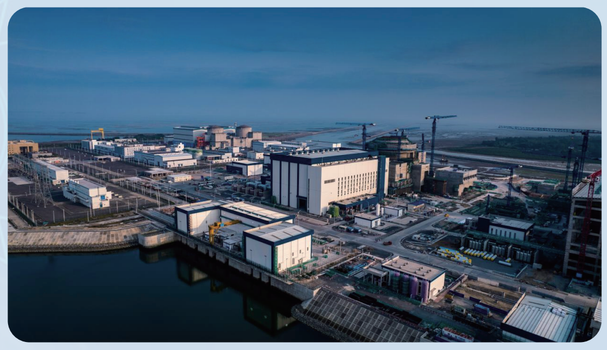
1.Overview



Guangxi Fangchenggang Nuclear Power Co., LTD. (hereinafter referred to as "Fangchenggang Nuclear Power") is a secondary subsidiary of China General Nuclear Power Group Co., LTD. (hereinafter referred to as "CGN"). As the first nuclear power project in western China and ethnic minority areas, it plans to build 6 nuclear power units with individual capacity of 1 million kilowatt. Among them, units 1 and 2 adopting CPR1000 technology were put into commercial operation in 2016; Unit 3 and Unit 4 adopt the third generation technology, HPR1000 with independent intellectual property rights of CGN. Unit 3 was put into operation with high quality on March 25, 2023. Unit 4 is expected to be put into operation in the first half of 2024. Moreover, Units 5 and 6 will adopt HPR 1000 technology, with preliminary work currently in progress. In recent years, the units of Fangchenggang Nuclear Power have maintained safe and stable operation, the WANO composite index has reached full score for 5 consecutive years, and the utilization hours have exceeded 8,000 in the past 3 years. The first cycle of the first HPR 1000 reactor maintains safe and stable operation, with the capacity factor of 98.4%.

Since 2010, building on the accumulated experience in multiple reactor model R&D, design, manufacturing, construction and operation, CGN has developed HPR1000, a third-generation nuclear power technology with independent intellectual property rights, which is achieved through independent innovation and industrial chain support. It takes the construction of Fangchenggang Phase II project as a demonstration project. On March 25, 2023, the first reactor of the demonstration project (Unit 3 of Fangchenggang NPP) was completed and put into operation, achieving four "zero" production goals of zero shutdown, zero scram, zero minor outage, and zero major equipment damage, and hitting a new record of high-quality production of the first reactor of the third generation technology. The high-quality operation of the first reactor of the demonstration project is another major milestone in the realization of China's independent innovation and development strategy for nuclear power in the new era, and also a good model for continuous innovation and improvement in the global nuclear power industry. In the process of project construction, Fangchenggang Nuclear Power has upheld “safety first, quality first”, adhered to the owner's full commitment to responsibilities, high-quality production, and the coordination across large teams, and formed a series of project construction experience with its own characteristics.

2.Construction experience

2.1 Upholding “safety first, quality first”

Quality acts as the foundation whereas safety is the guarantee.Fangchenggang Nuclear Power always adheres to the basic principle of "safety first, quality first" to ensure nuclear safety. The overriding priority is given to construction of nuclear safety culture, which is continuously promoted in line with the hierarchy, internal and external coordination, integration and grid management ideas; Fangchenggang Nuclear Power has jointly established a nuclear safety culture studio with regulatory authorities, worked with partners to promote the full coverage of the nuclear safety culture industry chain, and continued to enhance nuclear safety management capabilities. Fangchenggang Nuclear Power takes the initiative to embrace supervision in an honest and transparent manner, establishes a multi-level reporting and communication mechanism, and reports concerns in a timely manner. The management requirements raised by regulatory authorities must be analyzed and resolved from the management system. Fangchenggang Nuclear Power resolutely puts in place the latest regulatory standards, makes it the first within CGN to adopt Chinese technical specifications, and wins the trust of regulators with safety and quality effectiveness. Fangchenggang Nuclear Power adheres to the supreme standards and the most stringent requirements and strengthens the implementation of responsibilities. It does not trade quality for progress, nor safety for profit. A 3R dedicated team has been set up to carry out multiple DCS upgrades, take the initiative to fall back at the power grid window, and carry out the optimization of legacy items and the elimination of defects to ensure that the unit is in commercial operation in a good state.

The quality assurance system has been enhanced to cover the whole industry chain, pass the quality assurance requirements to all sub-suppliers in a level-wise way, and achieve holistic coverage. We have integrated supervision forces, strengthen the process oversight and management of the whole industry chain, give full play to the role of multiple supervision barriers, and ensure the effective operation of the quality assurance system of the whole industry chain. It is necessary to put in place the strict implementation of lifelong responsibility commitment in writing concerning project quality in the whole industry chain, permanent signs, quality information archives and other systems, strengthen the traceability of quality responsibility.

During the construction of the first reactor project, there were no work safety events (including minor injuries and above) or environmental punishment events. The overall clearance rate of the legacy items of the unit commissioning and start-up was 99.91%, making it the best in the history of CGN.

2.2 Adhering to the owner's full commitment to responsibilities

It is the underlying requirement of Nuclear Safety Law that owners fully fulfill their responsibilities. Establishing the EPC under the overall responsibility of the owner is an effective guarantee to promote the construction of nuclear power projects with high quality. Fangchenggang Nuclear Power Plant, as the owner company, has established the command and decision-making concepts of "the Party committee taking the primary leading role, business areas acting as the main implementation arena, and departments being responsible for main construction" in the operation of the company's management system. It has zoned out the "three business areas" of production, engineering and approval, established a resource-saving flexible organization, optimized the division of leadership responsibilities, organizational structure and operation mechanism, and mobilized more manpower and resources for the investment on the first reactor construction. In the engineering area, the EPC under the overall responsibility of the owner is established. The owner resolutely fulfills the full responsibility, and the decision-making mechanism with clear rights and responsibilities, standardized processes and classification is established.

Starting from the goal of safe operation over the full life, we have controlled safety and quality, comprehensively deepened the whole process of project construction, and consolidated the control from six aspects, covering safety, quality, environment, technology, progress, and cost, which ensured that the first HPR reactor construction was carried out with high quality. In terms of safety, quality management and environmental protection (SQE), we have consolidated the "four responsibilities" of leadership, management, supervision, and implementation through the effectiveness SQE system construction with quality assurance system as its core, dual prevention mechanism construction, SQE role-model construction and other work; we have proactively explore d the introduction of third-party independent supervision, controlled SQE indicators throughout the process, standardized the management of process activities, and strengthened the key control of critical parts, key processes, and important links. In terms of technical management, we have adhered to the "technology first", implemented the principles of analysis and control and hierarchical decision-making, optimized the review process of non-conformances, upheld the 100% review of major designs, set up a joint technical team with the owner as the core and a joint special team of important links to clear items, achieved 100% tracking and decision-making of technical issues, and promoted the realization of important milestones on schedule.

2.3 Sticking to high-quality production

We have focused on achieving the long-term safe operation goal of the unit. The high-quality production goal of zero shutdown, zero scram, zero minor outage and zero major equipment damage was proposed in 2019.

In 2021, the overall plan for the high-quality production project of HPR1000 unit was formulated to target CGN's deployment. Starting from the five areas of SQE, construction and safety engineering, handover & delivery, equipment management, and commissioning & start-up, we formed a total of 71 special projects, including "four zeros" and outage optimization projects, which were addressed one by one, featuring systematic planning as well as implementation with target, schedule and requirements.

With accurate positioning, we have been committed to zero shutdown and scram of the first reactor. We have taken the initiative to carry out investigation of hidden design dangers and SPV troubleshooting and invited fleet I&C experts panel to systematically carry out activities, such as investigation of hidden dangers to ensure the rationality of channel design, the survey of consistency between important logic DCS configuration parameters and design requirements, the rationality review of quality bit judgment and default value setting, the optimization of adjustment parameters for motor-driven regulating valves and the matching check of simulator drill parameters prior to RRC test to ensure the matching of control parameters. Besides, we conducted special operation guarantee for 3R and DCS equipment, which were incorporated to major risk projects of the plant for control, eliminated important equipment defects and common problems, and ensured the reliability of critical equipment. We have developed and applied the process control system featuring "3 exercises, 4 meetings, 5 sheets, and 6 controls " 1, which was intended to control high-risk operation tests and operations, the risk of temporary modifications in TCA, and implemented plant tests for important changes to ensure the standardization of risky operations. Moreover, we carried out important operations, turning and grid connection, offered the guarantee in the whole process, completed the treatment plan preparation and drill for 3R/DCS important equipment faults, and carried out DCS guarantee by working on shift to ensure the effectiveness of emergency plans. With multiple measures at the same time, we have performed each task in a solid way, and finally achieved the high goal of "double zero".

With full involvement, we have ensured zero major equipment damage. A "whole process management" system was pioneered from equipment design, manufacturing, storage and installation during the engineering construction stage, by which we comprehensively carried out SPV elimination, supervised manufacturing, unpacking inspection, installation and commissioning witness for major equipment, developed the control list of critical and sensitive equipment, promoted the implementation of experience feedback and technical problems in a holistic way, and ultimately ensured the smooth realization of the goal of zero damage in terms of important equipment.

With goal orientation, we have realized zero minor outage of the first HPR1000 reactor. Before and after the hot test, SG secondary side flushing and inspection were carried out several times. Following the cold and hot tests, four trains of electrical panels and main and auxiliary transformers underwent rectification troubleshooting in an active way, and non-nuclear turning was successfully performed in one time during the hot test, effectively testing the equipment status of the second circuit. We have carried out the project legacy items and defect elimination through campaigns to ensure it was free of defect backlog. We have taken the initiative to arrange the maintenance window in shutdown and disconnection, set up the plant FINT quick response team in advance, and vigorously carried out the special work of defect elimination.

2.4 Adopting coordination across large teams

For better cohesion and cooperation, we have centered on the construction of the first HPR1000 reactor and formed a multi-level coordination mechanism from the country to the industry, the industry to CGN, and then to the project, which effectively gives play to the Chinese characteristics of “concentrating resources for large undertakings". At the national level, a coordination group for the construction of HPR 1000 Demonstration Project was established in 2015 to ensure ministry-local-industry collaboration. At the industry level, the HPR100 Project High-Level Summit was launched in 2017, which adhered to the macro coordination of the whole industrial chain, focused on improving equipment quality assurance, boosting the level of project demand guarantee and response speed, and pushing forward the efficient progress of the project and the joint improvement of the industrial chain. Overall management was in place at the CGN level, which strengthened the support of internal and external advantageous resources, efficient linkage between the front and back offices, on-site support of technical experts and maintenance backbone teams. Platform companies

responded to project needs in a timely manner to ensure rapid decision-making and handling of problems. At the project level, full play was given to the leadership of the owner, who jointly established a large integrated team with all the participating units. Under the "one headquarter, one decision-making line", the project team was deeply integrated. The integration plan was coordinated to advance, with the management down to the frontline, and the command moving forward. We jointly fought risks, assumed responsibilities and resolved problems, which created a collaborative atmosphere of "mutual trust and close cooperation".

3.Achievements and prospects

The high-quality production of the first CGN reactor of HPR1000 has effectively proved the capability of independent R&D, design, and construction as well as operation management capability of CGN's third-generation nuclear power technology, marking that China's nuclear power technology level and comprehensive strength rank the first in the world,. It strongly supports China's leap from a country featuring many nuclear power units to one strong in nuclear power. As a large number of large-scale equipment and key technologies of third-generation nuclear power are developed and applied, it accelerates the improvement of the capacity of nuclear power equipment manufacturing industry, effectively promotes the technological innovation of the nuclear power industry chain, and provides a good model for continuous innovation and improvement of the global nuclear power industry. In the process of project construction, Fangchenggang Nuclear Power has gradually nurtured the innovative spirit of self-improvement, aggressiveness and pioneering. Besides, we have overcome difficulties and strived for the best. We stress unity and coordination. We uphold the spirit of the first reactor with dedication as its core, which has gradually been deeply rooted in people's hearts, and has become a strong support for promoting the company's sustained high-quality development.

Going forward, Fangchenggang Nuclear Power will comprehensively summarize and absorb the construction experience of the first reactor, adhere to the priority of safety and quality, and build a high-quality HPR1000 demonstration project with the goal of building a role-model project. Meanwhile, we will proactively cooperate with HPR1000 units to continue excellence, play a leading role in the first reactor demonstration, comprehensively strengthen experience feedback, jointly cultivate core capabilities, and promote joint construction and sharing for HPR1000 units under operation and construction, which contributes to the prosperity and development of the nuclear power industry.

Note 1: 3 exercises refer to simulator preliminary exercise, simulator operation shift combined exercise, and simulator strengthening exercise. 4 meetings refer to technical exchange/exercise meeting, preliminary pre-job briefing, pre-job briefing, and post-job meeting. 5 sheets refer to pre-job preparation sheet, simulator exercise tracking sheet, preliminary pre-job briefing sheet, pre-job briefing sheet, and post-job sheet. 6 controls refer to document quality control, risk identification control, human error prevention control, test condition control, unit transient control, and test feedback control.