China's commercial reactors

China's approach to civil nuclear power reactor development will determine the overall tenor of its nuclear power programme long into the future. Its approach, both domestically and through imports, is analyzed, with a focus on the next decade of deployment. By Jonathan Hinze and Yun Zhou

Considering China's place in the world today, it is worth noting that the pace of reactor technology development in China was rather slow from the beginning of the commercial nuclear power program in the 1980s through around 2000. An important early decision was to focus the commercial nuclear program solely on pressurized water reactor (PWR) technology – a decision that is credited to the "grandfather of China's nuclear program," former Premier Li Peng.

Early on, China was able to master its own smaller PWR design and also gained valuable experience through the first PWRs to be imported from Framatome (now Areva) at Daya Bay. The CNP-300 reactor deployed at Qinshan Phase I, which was based on the nuclear propulsion reactor designed by China's military for its submarines, was an important first step in Chinese reactor development and was led by Shanghai Nuclear Engineering Research and Design Institute (SNERDI). The localization efforts that began at Daya Bay and which were followed through to the latest Lingao Phase 2 project represents the first successful integration of nearly every aspect of modern nuclear reactor technology by China. The result of this two-decade localization process was the CPR-1000 design, also known as the M310+, which is a significantly advanced version of the 157 fuel assembly PWR series deployed at 34 reactors in France. In fact, the CNP-600 design, which was the successor to the CNP-300, borrowed numerous technical features from the early units built at Daya Bay. This cross-fertilization of reactor technology concepts between the imported designs and local designs is still happening today.

Current status

A crucial aspect of China's current reactor deployment approach is the fact that while standardization is viewed as an important element of an efficient and economic construction program, there are currently four different designs under construction and at least six different technologies envisioned for additional construction starts that will occur before 2020 (see Table 1). Thus, a simple conclusion would be that China values a reasonable level of diversity in its technology selections, but the reality is that there are numerous factors at play in deciding which designs are chosen for specific new projects.

This complex issue is not easily reviewed in this brief article, but there are some key factors that can be highlighted. First, the utility/owner of the project makes a big difference in the reactor technology selection. For example, China Guangdong Nuclear Power Company's (CGNPC) affinity for the CPR-1000 is natural given the many years of efforts it has placed in the localization process. This may also be the reason why it is now aggressively pursuing development of the Generation III advanced CPR-1000 (i.e. the ACPR-1000) with its French partners – Areva and EDF – as a result of the new post-Fukushima safety requirements. A similar approach can be seen with the China National Nuclear Corporation (CNNC) and China Power Investment Corporation (CPIC) utilities, which are focused primarily now on deploying additional AP1000s given the strong efforts made so far by their partner State Nuclear Power Technology Corporation (SNPTC) in localizing that design through technology transfers from Westinghouse.

Ultimately, the need for a rapid pace of deployment of reactors in China to keep up with additional energy demand has meant that we are currently seeing numerous designs being built by numerous entities around the nation. While the intent by the national planners was clearly to have a standardization approach similar to the monolithic French nuclear program seen during its rapid expansion in the 1980s and

Table 1: Civil nuclear power reactor designs in China, and their project status

Reactor Design	Type	Generation	MWe (gross)*	Designer/Supplier	Units Operating	Units Under Construction	Units Planned
CNP-300	PWR	Gen II	300	SNERDI/CNNC	1	0	0
CNP-600	PWR	Gen II	650	SNERDI/CNNC	3	3	0
CANDU 6	PHWR	Gen II+	728	AECL	2	0	0
CPR-1000 (M310+)	PWR	Gen II+	1,080	CGNPC (Areva)	6	18	~12
ACP-1000	PWR	Gen III	~1,100	CNNC (NPIC)	0	0	~20
ACPR-1000	PWR	Gen III	~1,100	CGNPC	0	0	~20
VVER-1000 (AES-91)	PWR	Gen III	1,060	Atomstroyexport	2	0	2
AP1000	PWR	Gen III+	1,200	Westinghouse/SNPTC	0	4	~20
EPR	PWR	Gen III+	1,700	Areva	0	2	~4
				Totals	14	27	~78

*Note that there are slight variations in electric power generating capacity among reactors of the same design depending on specific operating parameters and features at the individual power plants.

early 1990s, it is worth remembering that China is a much larger country with a different political environment and ideology, which could cause a much more complicated and opaque decision-making process.

Fukushima effects

China has clearly been on a steady development pace since it made the decision to deploy commercial reactors in the late 1970s. While the program has seen ebbs and flows over the years, the most recent history is clearly one of rapid expansion with significant resources put towards multiple new reactor designs. However, the Fukushima accident in Japan has clearly altered many of these plans. By halting all new construction projects since March 2011 and establishing new safety standards for all future reactor projects, China's government has indicated that the process envisioned prior to Fukushima can no longer be followed. Since operating reactors and those under construction appear to have been spared from any major re-engineering as a result of the Chinese post-Fukushima regulatory reviews, it is in the new reactor technology selection process where the critical shifts are being felt.

First and foremost, it is important to note that these are still uncertain times in the Chinese nuclear program, and it may not be until the new Chinese political leadership will be installed later this year that we know about the final decisions made in terms of which projects will be approved in the near-term as well as what the impacts of new safety regulations will be on China's long-term reactor growth prospects. It appears that a certain number of existing CPR-1000 (M310+) projects that have been planned for quite some time could still be approved, especially at sites where similar units are already under construction (e.g. Hongyanhe, Ningde, and Yangjiang). It also appears that CNNC's new ACP-1000 design will be given the green light, and CNNC is likely to pursue new projects with this design in the coming years with the first of these units at Fuqing 5 and 6.

The situation for the imported reactor designs is varied, but this is less likely to be determined by anything resulting from the new post-Fukushima regulatory regime. The two new Russian VVER-1000s recently contracted for the Tianwan plant will be grandfathered in due to geopolitical considerations and not as a top choice for additional future plants. In terms of the AP1000, there is obvious intent to deploy large numbers of additional units with SNPTC's localized Westinghouse design, but there are also concerns about beginning large-scale construction on new AP1000s before the first four at Sanmen and Haiyang are completed. CGNPC is also likely to agree to an addition two or four EPRs from Areva, but the same situation in terms of waiting for the first two Taishan EPRs to be completed applies.

Eventually, China will look to wean itself from purely foreign reactor technology, but the Fukushima effects mean that a reliance on these international vendors is unlikely to be as fast as it could have been prior to March 2011. Still, China will not import as many reactors as some international companies may hope, and in the post-Fukushima environment, it appears that the trend to shift from the older Gen II+ domestic designs to newer Gen III domestic designs might occur much quicker. Thus, one argument that can be made is that Fukushima will cause China's domestic designs to rise faster than what was expected prior to March 2011.

The other process that is still unfolding is the development of various advanced reactor designs based either on previous domestic technology or imported designs. There is a relatively long list of these concepts out there, and it is still a bit too early to tell the pace and success of each of these projects. Still, it does appear that the most aggressive activity will be on both the ACP-1000 and ACPR-1000 designs, which are basically enhanced versions of the current CPR-1000 (M310+) design, as well as the CAP-1400, which is basically an enhanced version of the current AP1000 design. It would seem that any discussion of even more advanced reactor designs (e.g. the CAP-1700, CPR-1700, etc.) is less connected to the current realities in China and expresses desires for long-term reactor technology development unlikely to be feasible in the coming decade.

One topic that we have not addressed is the development of various Generation IV designs in China. At the top of this list, the commercial deployment of the first HTR-PM reactors is looking quite positive. This small high temperature, gas reactor design based on an experimental pebble-bed reactor operating at Tsinghua University in Beijing, will likely see its first construction beginning later this year at the Shidaowan site in Shandong Province. While the HTR-PM may be deployed on a wider scale in the future, this process is likely to take more time than hoped for by the sponsors of the project, which is financed mainly by China Huaneng Group. Finally, the development of fast breeder reactors (FBR) in China is important to consider when looking at the long-term future of the country's nuclear power program. However, beyond the experimental CEFR unit currently operating and the prototype larger unit to be developed in conjunction with Russia, it appears that commercial-scale FBRs are far from becoming a reality. This is reflected in the Chinese authorities' own projections that FBRs are only meant to be used on a large scale in the post-2040 era.

Market report

In early 2012, the Ux Consulting Company (UxC) released a major new report analyzing the entire nuclear energy industry in China, with emphasis on analyzing the impacts of the Fukushima accident on China's commercial nuclear prospects. The report includes analysis of China's nuclear fuel supply, reactor construction pace and regulatory framework, among other sections.

Conclusion

There is so much happening in China that it is nearly impossible to do justice to all the important aspects of its nuclear power program. While the post-Fukushima standstill on new reactor deployment may be seen as having slowed the program, it has also offered opportunities for the main industry stakeholders to focus their attention on the critical technology issues associated with reactor designs. With nuclear safety as the paramount premise for all new nuclear plant projects, China's reactor selection process offers all of those looking to understand the future of this critical program many valuable insights.

There are still many questions about which reactor designs will take hold as the dominant options for the coming decade, but these selections will have ripple effects on all other aspects of China's nuclear program. The future direction of the country's nuclear fuel cycle will naturally be influenced, especially in terms of the fuel fabrication sector. The level of involvement of international vendors in the reactor supply chain will also be heavily determined by these design selections. Various aspects of the back-end of the fuel cycle will also be influenced.

Ultimately, given that there is no doubt about China's continuing efforts to expand its nuclear power capacity, we strongly believe that the choices made in terms of reactor technologies will be one of the most critical factors in determining the overall direction of China's nuclear power program long into the future. While the Chinese domestic efforts on reactor technology will be at the forefront of the nuclear program, we also anticipate that there will continue to be strong interaction with the global reactor design and supply chain industry to support a successful and sustainable growth path. ■