China's CNNC ACP100S and ACP25S Floating Nuclear Power Plant (FNPP) Concepts

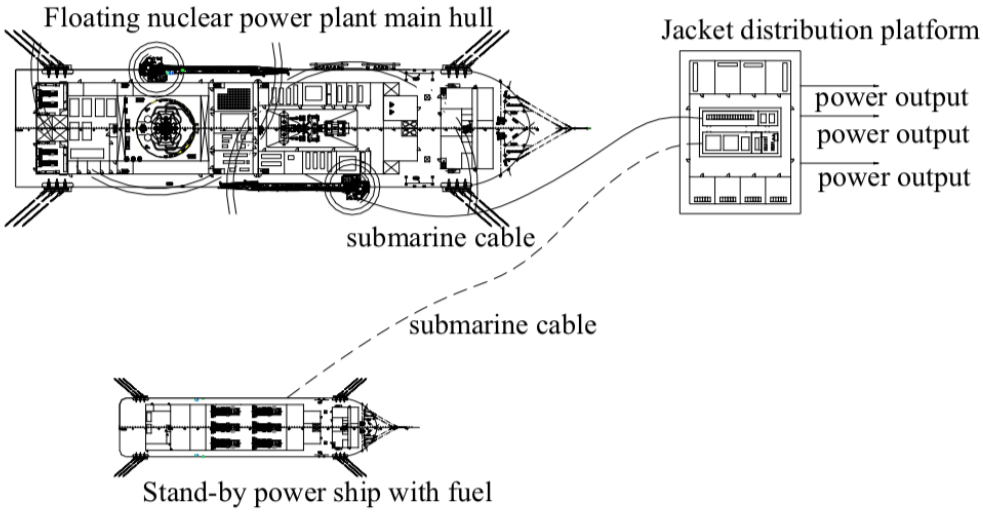
Peter Lobner, 15 May 2021

1. Introduction

In the Chinese domestic nuclear market, China National Nuclear Corporation (CNNC) and China General Nuclear Power (CGN) are competitor in many areas, including the development of small modular reactors (SMRs) and floating nuclear power plants (FNPPs). CNNC is developing two different small pressurized water reactors (PWRs) for use in FNPPs. These are the ACP100S and the smaller ACP25S marine reactors.

4. FNPP vessel design

The basic FNPP vessel will be a transportable double-hull, double bottom barge. It can be moored at a protected pier with interface facilities to connect to the local / regional electrical grid and other facilities for low-temperature process heat utilization and/or seawater desalination. The pier will provide secure multi-point mooring and protection during severe weather conditions.



FNPP multi-point dockside mooring. Source: Zhi Chen, et al., Nuclear Power Institute of China (2017)

The FNPP vessel houses the reactor systems, steam turbine generator(s) and thermal conversion system, control room, power supply system and other ship and auxiliary systems. A standby power ship provides backup power when needed and provides storage for nuclear fuel. Crew accommodations may be provided on the FNPP or a shoreside facility.

For offshore applications, the FNPP may be moored to a single point tower or deep water mooring buoy, where it also may require a dynamic positioning system.

General arrangement concepts for an FNPP with one ACP100S. Source, both graphics: CNNC

3. Reactor design

For more than a decade, CNNC has been developing SMR designs for both terrestrial and marine applications. Two of their small marine PWR designs seem destined for FNPP applications: the ACP25S and the larger ACP100S. Of the two, the design and development process for the ACP100S is further along than for the ACP25S. The basic technical characteristics of these two marine reactors are summarized in the following table.

Parameter	**ACP25S**	**ACP100S**
Thermal power	100 MWt	385 MWt
Electrical power	About 28 MWe	About 125 MWe
Reactor type	Loop type	Integrated
Refueling interval	1.5 years	2 years
Design life		60 years
Coolant avg. temp	280 °C (536 °F)	303 °C (577 °F)
Primary pressure	15 MPa (2,176 psia)	15 MPa (2,176 psia)
Pressurizer (PZR)	Separate PZR	Separate PZR
# fuel assemblies	25	57, CF3 shortened assemblies
Fuel enrichment		4.45%
Reactivity control	Control rods, solid burnable poison	25 x control rods, solid burnable poison
Steam generator type	2 x U-tube steam generators	16 x once-through steam generator (OTSG) modules
Main steam pressure	4.2 MPa (609 psia)	4 MPa (580 psia)
Main coolant pumps	2	4 x canned pumps
Safety systems	Active & passive	Active & passive
FNPP vessel type	Double hull, double bottom	Double hull, double bottom
Hull displacement	15,000 metric tons	40,000 metric tons

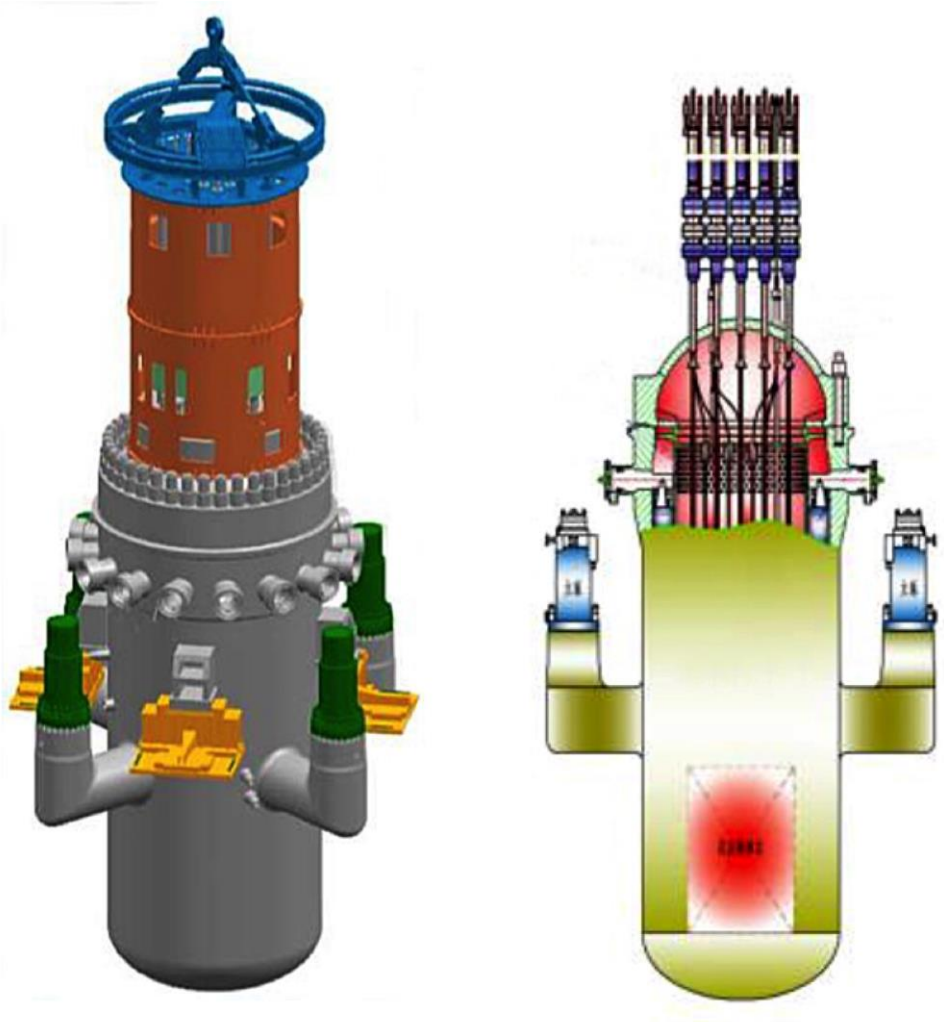
Source: Zhi Chen, et al. (2017)

ACP25S

The ACP25S is a 100 MWt / 28 MWe, two-loop PWR with U-tube steam generators. Few details have been released about this design. It appears to be in an early design stage, years behind the ACP100S. For FNPP applications, the ACP25S could be deployed in single and dual reactor configurations.

ACP100S

CNNC has been developing the compact 385 MWt / 125 MWe ACP100 integrated PWR since 2010 and the preliminary design was completed in 2014. The similar marine version is the ACP100S. The general arrangement of the integrated primary system is shown below.



Source: CNNC

ACP100 and ACP100S notable design features include:

- Integral reactor vessel housing the reactor core, which is located below 16 once-through steam generator modules.
- The vertical reactor coolant pumps are welded directly to reactor vessel via L-shaped coaxial nozzles.
- A separate pressurizer is connected to the integral reactor vessel via a surge line.
- The external control element drive mechanisms (CRDMs) are conventionally located on the reactor vessel head.
- The marine ACP100S does not use soluble boron reactivity control.

This design is generally similar to Russia's RITM-200M and the French K-15 integrated PWR marine reactors.

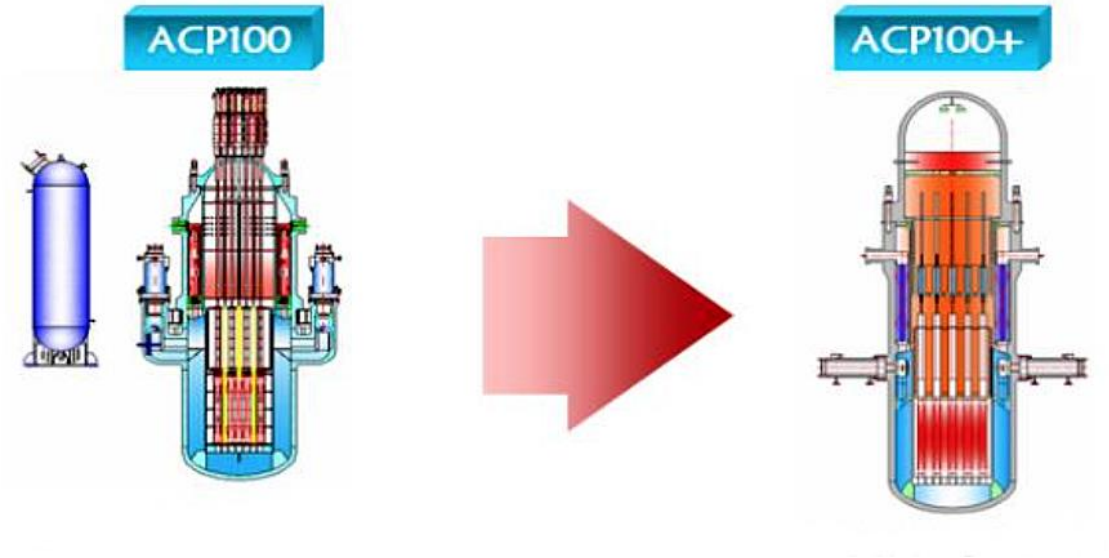
The ACP100 was identified as a 'key project' in China's 12th Five-Year Plan. In 2016, the ACP100 became the first SMR to pass a generic reactor safety review (GRSR) by the International Atomic Energy Agency (IAEA). CNNC reported that the National Development and Reform Commission (NDRC) approved the ACP100S variant for marine use late in 2016.

ACP100+

In about 2016, CNNC started developing the conceptual design of the more advanced land-based ACP100+, which incorporated the following major design changes:

- Larger reactor vessel with an internal pressurizer at the top of the vessel and internal CRDMs (housed inside the vessel).
- Horizontal canned-motor reactor coolant pumps welded directly to the reactor vessel.
- Smaller steel containment.

The key differences between the ACP100, with external pressurizer, and the ACP100+ primary systems are evident in the following CNNC diagram.



Source: CNNC

A marine counterpart for the ACP100+ has not yet been announced.

4. FNPP development plans

In July 2016, CNCC formed a joint venture with China Shipbuilding State Corp. (CSSC) and announced plans to develop floating nuclear power plants and a nuclear powered icebreaker.

In September 2017, China National Nuclear Power Co., Ltd. (CNNP) announced that Zhejiang Zheneng Electric Power Co., Ltd (ZZEC), Shanghai GuoSheng Group (a large investment holding and wholly state-owned capital operating company), Jiangnan Shipyard (Group) Co., Ltd, and Shanghai Electric, plan to jointly fund the establishment of CNNC-Marine Nuclear Power Development Co., Ltd. (provisional name).

FNNP shipbuilding was reported to have commenced in March 2018. The Qilu Evening News based in Jinan, Shandong, reported in November 2018 that the first CNNC floating nuclear power platform was expected to cost $2.1B (CNY14B).

Since late 2018, there has been almost no news on the construction status of a CNNC FNPP.

Rendering of an ACP100S FNPP at an offshore oil development site. Source: CNNC

Model of an ACP100S FNPP at a single-point mooring at an oil development site, displayed by CNNC during the China International Exhibition on Nuclear Power Industry in Beijing in April 2017. Source: AsianPower (25 Mar 2019)

5. For more information

- Xu Bin, “CNNC's ACP100 SMR: Technique Features and Progress in China,” CNCC & Nuclear Power Institute of China presentation to the IAEA, 18 – 21 October 2016: https://nucleus.iaea.org/sites/INPRO/df13/Presentations/011_CNNC%27s%20ACP100%20SMR-Technique%20Features%20and%20Progress%20in%20China.pdf
- Viet Phuong Nguyen, “China’s Risky Plan for Floating Nuclear Power Plants In The South China Sea,” The Diplomat, 10 May 2018: https://thediplomat.com/2018/05/chinas-risky-plan-for-floating-nuclear-power-plants-in-the-south-china-sea/
- Dan Robitzski, “China Is Building up to 20 Floating Nuclear Power Plants - They could be used to power artificial islands,” Futurism, 21 March 2019: https://futurism.com/china-floating-nuclear-power-plant
- Zhi Chen, et al., “The Study of Overall I&C System Scheme for Floating Nuclear power Plant ACP100S and ACP25S,” Science and Technology on Reactor System Design Technology Laboratory, Nuclear Power Institute of China, 2017: http://npic-hmit2017.org/wp-content/data/pdfs/189-19909.pdf