South Korea's Kepco E&C Floating Nuclear Power Plant (FNPP) Concept

Peter Lobner, 15 May 2021

1. Introduction

Kepco Engineering & Construction Company (Kepco E&C), a subsidiary of state-owned Korea Electric Power Corporation (Kepco), has been developing its concept for an FNPP for almost a decade. Their goal for the FNPP is to tailor it for applications in distributed electrical and heat supply systems, seawater desalination, and nuclear-renewable hybrid energy systems.

2. FNPP vessel design

The basic FNPP vessel will be an unpropelled, transportable barge designed to be moored at a protected pier with interface facilities to connect to the local / regional electrical grid and other user facilities. The pier will provide a secure mooring during all conditions, including severe weather. The Kepco E&C FNPP is expected to house one 200 MWt / 60 MWe BANDI-60S pressurized water reactor (PWR) with a 60 year operating life.

A concept for a BANDI-60S FNPP. Source: Kepco E&C

For use in offshore sites, such as oilfields, the FNPP vessel may be outfitted with a dynamic positioning system.

3. Reactor design

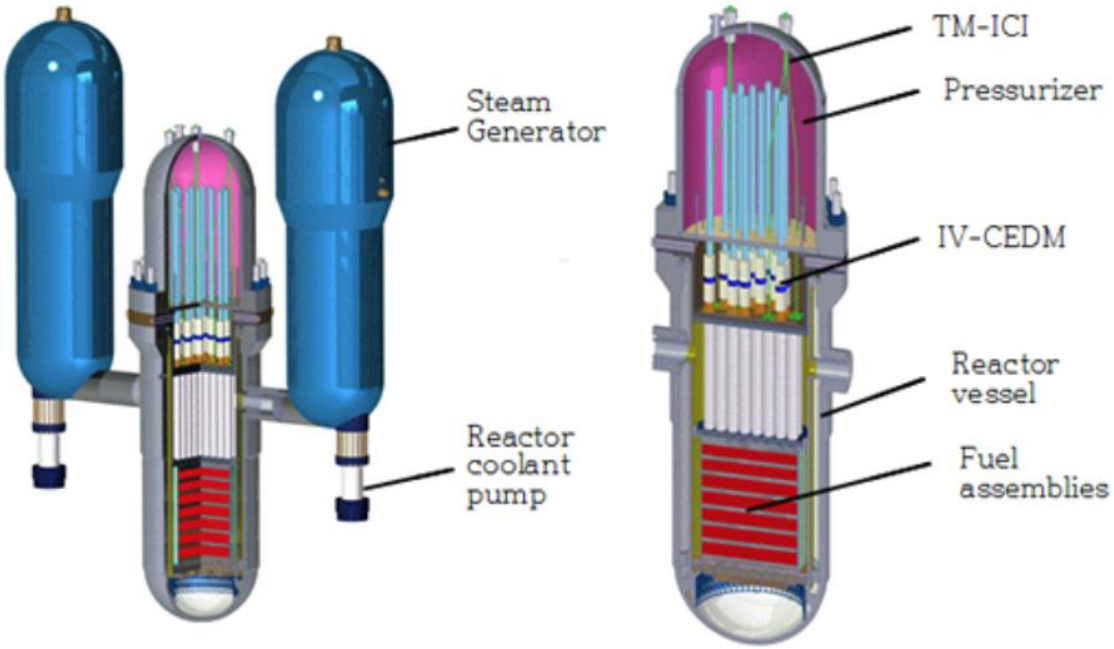
In 2016, Kepco E&C began developing their design for the 200 MWt / 60 MWe BANDI-60S small, modular PWR. In October 2020, Nuclear Engineering International reported that, “The conceptual design is underway. In the next phase, safety and performance analyses will be performed to assess the feasibility of the conceptual design and the sizing of the main components and systems, including passive safety features.” The BANDI-60S is being designed to comply with the design standards and regulations for land-based nuclear power plants as well as the regulations of the International Maritime Organization (IMO).

The BANDI-60S modular PWR includes the following notable design features:

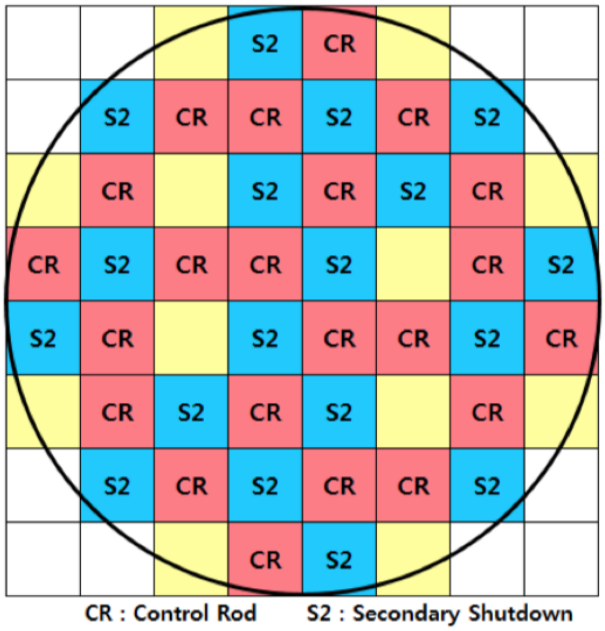
- The reactor and an integrate pressurizer share a common pressure vessel measuring 11.2 m (36.7 ft) tall and 2.8 m (9.2 ft) in diameter.
- In-vessel control element drive mechanisms (IV-CEDM) eliminate the possibility of a control rod ejection accident.
- Potential sources of reactor vessel leakage below the reactor core have been eliminated. For example, all in-core instrumentation (ICI) has been relocated above the reactor core.
- Short coaxial pipes connect the reactor / pressurizer vessel and a pair of U-tube recirculation steam generators.
- Integral, leak-tight, canned motor reactor coolant pumps are located at the bottom of the steam generators.
- There is no soluble boron in the primary coolant. Reactivity is managed with control rods and burnable neutron poison.

The U-tube steam generator was selected based on long experience with that type of design in Kepco’s larger, land-based nuclear power plants, like the APR1400. As an advanced design option for the BANDI-60S, Kepco E&C is now working on a new steam generator design based on plate-and-shell heat exchanger technology, which would significantly reduce the size of the steam generators.

The modular primary system design is expected to simplify manufacturing, operational surveillance and maintenance.



General arrangement of the Kepco E&C BANDI-60S modular primary system. Source: Kepco E&C

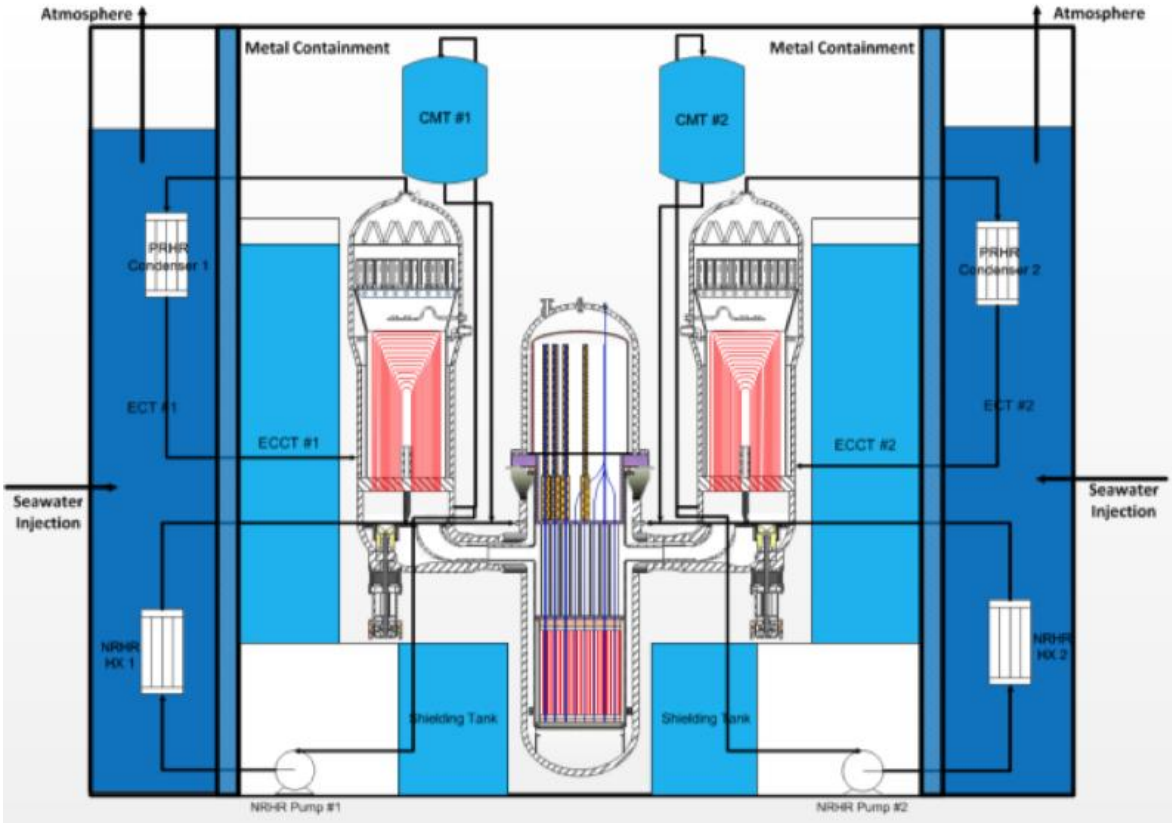


The reactor core is composed of 52 fuel assemblies, each with a 17 x 17 square array of fuel rods. Fuel is UO_2 enriched to 4.95% in a reactor core with an active length of 2 meters (6.6 ft). The basic core arrangement is shown in the adjacent diagram. Normal control rods are in the assembly positions labeled “CR” and the secondary shutdown (scram) rods are in the positions labeled “S2.”

Source: I. H. Kim, et al., (2019)

The reactor is designed to be refueled at an interval of 4 to 5 years during its design life of 60 years.

The BANDI-60S design incorporates passive safety systems for post-accident reactor core and containment cooling. These systems do not require safety-grade AC power, but do require DC power.



General arrangement of a Kepco BANDI-60S in an FNPP hull, highlighting passive safety systems. Source: I. H. Kim, et al., (2019)

- If forced cooling flow is lost in the primary system, passive natural circulation continues to transport heat from the reactor core to the steam generators. On the secondary side of the steam generators, the PRHRS establishes a natural circulation, closed loop heat transfer path to condensing heat exchangers in the emergency cooldown tanks (ECT), which can be refilled from the ocean. This passive heat transfer path provides long-term core cooling.
- If a primary coolant leaks occurs and power is lost to active systems, the large volume of the integral pressurizer is the first

line of defense. If primary pressure and water level continue to drop, the passive, pressurized core makeup tanks (CMT) inject water into the primary system. If primary pressure continues to drop, water from the large volume emergency core cooling tanks (ECCT) is injected by gravity and floods the reactor vessel and lower containment volume. Heat is passively removed from the containment volume by conduction through the metal wall between the containment volume and the ECT.

4. FNPP development plan

In June 2014, Kepco E&C signed a memorandum with Korea Institute of Machinery and Materials (KIMM) that defined their respective roles in the development of the FNPP:

- KEPCO would be in charge of system engineering for generating units and inland connections.
- KIMM was responsible for designing the floating structure and the main power generation facilities.

The government's 7th Basic Plan for Long-term Electricity Supply and Demand (2015-2029) issued in July 2015 envisaged 13 new nuclear power plants in operation by 2029. While the plan did not address FNPPs, this was a promising, pro-nuclear energy plan.

Kepco E&C and the Korea Research Institute of Ships and Ocean Engineering met in April 2016 to discuss the business model for FNPPs. Kepco E&C plans to target markets in coastal areas and islands where power grids are hard to install or power demand exceeds the capacity of the local / regional terrestrial infrastructure. The Kepco FNPP also has been mentioned as a future means to establish electric power infrastructure in North Korea while avoiding difficult issues associated with developing onshore nuclear power stations.

The South Korean government elected in May 2017 introduced a policy to phase-out nuclear power over a period of 40 years. By May 2020, the plan included provisions for reducing the share of nuclear power from 19% to 10%. Under this current plan, Kepco likely does not have a domestic market for their planned FNPP.

In October 2020, Kepco E&C, signed a memorandum of understanding (MoU) with Daewoo Shipbuilding & Marine Engineering (DSME) to jointly advance marine nuclear power plant technology development. DMSE is in the process of being acquired by South Korea's shipbuilding giant, Hyundai Heavy Industries Holdings (HHIH), which expects to complete the acquisition in the first half of 2021. By the time actual construction starts, the first Kepco E&C FNPP likely will be built in an HHIH shipyard.

Kepco E&C FNPP has not announced a development / construction schedule for the first BANDI-60S FNPP.

A concept for a BANDI-60S FNPP. Source: Kepco E&C

5. For more information

- I. H. Kim, et al., "Development of BANDI-60S for a Floating Nuclear Power Plant," Transactions of the Korean Nuclear Society Autumn Meeting Goyang, Korea, October 24-25, 2019: https://www.kns.org/files/pre_paper/42/19A-242-김일환.pdf
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- “Korea takes another step toward floating nuclear power plants,” Global Construction Review, 8 October 2020: https://www.globalconstructionreview.com/news/korea-takes-another-step-toward-floating-nuclear-p/
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