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Passive Safety System of the Block-type SMR BANDI-200

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1. Introduction

KEPCO-E&C has been developing a series of block type small modular reactor (SMR), named BANDI. BANDI-60 is a 60 MWe version and designed to be mounted on the floating nuclear power plants [1]. BANDI-200 is a 200MWe version aiming for land based power plants. In this paper, the key passive safety systems and their design concepts of BANDI-200 are introduced.

2. Design Features

2.1 Basic Design Features

BANDI-200 is a block-type pressurized-water-cooled small modular reactor with thermal power of 600 MW. The reactor coolant system consists of one reactor block and one steam generator (SG) block. The reactor block and the SG block are directly nozzle-to-nozzle connected as shown in Fig. 1. This system arrangement eliminates large break LOCA from the design basis accident while providing easier access for operational surveillance and maintenance than the integral type.

The in-vessel control element drive mechanism (IV-CEDM) is installed in the head region of the reactor block. Inside the SG block, there is a pressurizer in the head and a reactor coolant pump in the lower plenum. Heat transfer tubes in the steam generator are helical type and produces superheated steam. Reactor coolant flows inside the tubes and secondary feed water flows outside. The pressurizer pressure is controlled by electrical heaters and spray.

The reactor coolant system and makeup water tanks of the passive safety systems are enclosed in the steel containment vessel (CV). Compared to BANDI-60, the containment diameter is reduced more than a meter while the reactor power of BANDI-200 is increased three times. Then, the CV pressure peak will increase during an accident.

Major technical parameters of BANDI-200 are summarized in Table 1. Key advanced design features of BANDI-200 enhancing safety and operability include:

- Block-type reactor coolant system arrangement
- Extended refueling cycle of 2~2.5 years
- Soluble boron-free (SBF) operation
- In-vessel CEDM
- In-core instrumentations mounted on the reactor vessel head (Top-mounted ICI)
- Passive safety injection system (PSIS), Passive residual heat removal system (PRHRS) and Passive containment cooling system (PCCS)
- Canned-motor RCPs
- Integrated pressurizer with steam generator, etc.

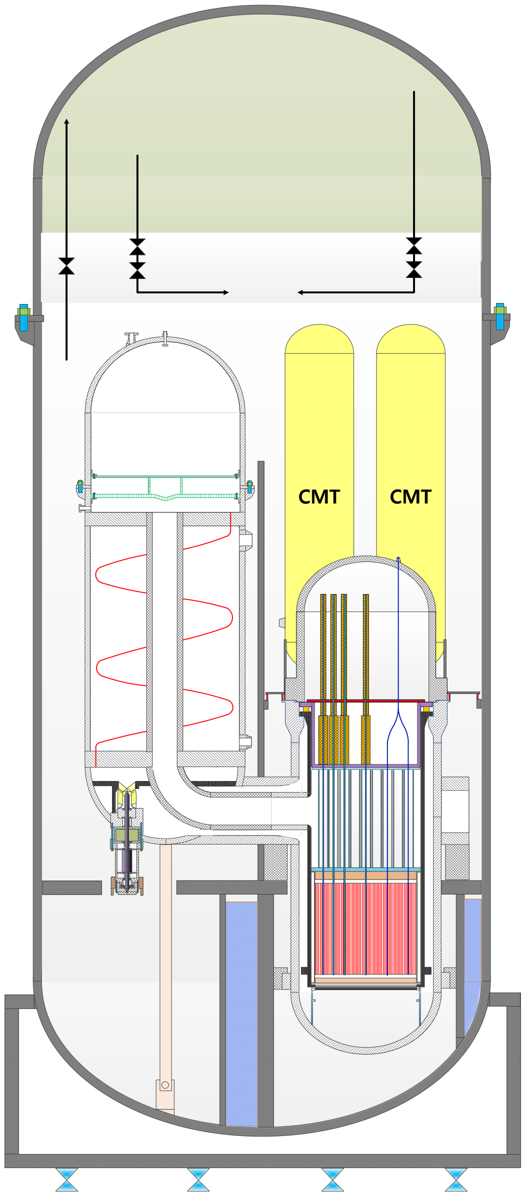

Fig. 1 RCS and PECCS Configuration of BANDI-200

Table 1. Major Design Features and Parameters of BANDI-200

Parameter	Value
Reactor Type	PWR
Coolant/moderator	Water
Thermal/electrical capacity, (MWt/MWe)	600/200
Primary circulation	Forced circulation
System pressure (MPa)	15
Core inlet/exit temperatures (℃)	290/325
Fuel type/assembly array	UO2 pellet/ 17x17 square
Number of fuel assemblies	89
Fuel enrichment (%)	< 5
Steam generator type	Helical coil /Superheated
Main reactivity control mechanism	In-Vessel CEDM
Approach to engineered safety systems	Passive
Design life (years)	60
RPV height/diameter(m)	11/3.3
CV height/diameter(m)	25/10
Distinguishing features	Block-type RCS design In-vessel CEDM, Top-mounted ICI, Boron-free operation Integrated pressurizer Canned motor RCP Passive safety systems

2.2. Safety Features

BANDI-200 is equipped with fully passive safety features. The major passive safety systems consist of the PSIS, PCCS, and PRHRS which rely only on natural forces and stored energy like battery to ensure safety in any postulated accidents without power from outside [2]. Basic concept of the passive systems of BANDI-200 is similar to that of BANDI-60 [1], except a change in the arrangement and configuration of the emergency core cooling tank (ECCT). It is moved and integrated to the head of the steel containment vessel to minimize the containment vessel size in diameter.

The PSIS makes up RCS inventory by gravity for any loss of coolant events. The core makeup tanks (CMT) are pressurized to the RCS pressure by the pressure balance line (PBL) connected to the SG inlet. Pressure of the ECCT is balanced to the containment atmosphere by pressure balance line. Isolation valves between the CMT and direct vessel injection (DVI) nozzle remain closed during normal operation. These valves are opened when, in a LOCA, the RCS depressurizes, the pressurizer level decreases, or the containment pressure increases beyond set points. When the CMT level further decreases, coolant stored in the ECCT in the upper dome of the containment vessel is sprayed to the containment atmosphere by gravity and reduces containment peak pressure below the design pressure of the containment vessel. Exit nozzle elevation from the ECCT is adjusted to maximize the utilization of stored water. In the early phase of the ECCT spray, the whole piping is fully utilized, but in the long term cooling period, just a few part of them is used. [4][5][6]

The PRHRS removes decay heat and RCS sensible heat when the normal cooling of RCS through SGs and condenser is not available after reactor trip. Steam from the SG condenses in the PRHRS heat exchanger, which is located inside the Emergency Cooldown Tank (ECT) located outside the containment and in contact with the metal wall of the containment, and the condensate returns by gravity to the SG via the feedwater nozzle. It cools down the RCS to the safe shutdown condition and maintains it for an extended time without refilling the ECT. When the ECT water temperature is too high or the ECT level is too low during a long term cooling, water from outside is supplied into the ECT to maintain ultimate heat sink.

Heat from the containment is continuously removed to the water stored in the ECT through metal wall during a postulated accident to reduce pressure and temperature of containment.

3. Conclusion and Future works

KEPCO E&C has been developing a block type SMR, BANDI, not only for floating power plants, but also for land-based multi-purposed applications. Its design is mainly based on proven technologies and our experience of over 45 years in the conventional nuclear power plant engineering services in Korea and overseas. To enhance the safety and performance, several advanced design features are adopted such as soluble boron-free operation, in-vessel CEDM, innovative steam generator with integrated pressurizer and top-mounted ICI.

In the present paper, the basic design concept and safety features of the BANDI-200, a bigger version for land-based applications, was briefly introduced. The safety and performance analyses are going to be carried out to see the feasibility of the design concept and to optimize the main components and systems.

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