Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Introduction of the PECCS MAAP5 Model developed for Preliminary PSA in the Innovative Passive Reactor

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1. Introduction

The preliminary scoping probabilistic safety assessment (PSA) of the innovative passive reactor is being performed. The Passive Emergency Core Cooling System (PECCS) is one of the engineered safety features in the innovative passive reactor [1]. To perform thermal hydraulic analysis of the preliminary scoping PSA for the conceptual design of the innovative passive reactor, the MAAP5 model for the PECCS has been developed [2]. This paper presents development and verification of the PECCS MAAP5 model.

2. Methods and Results

2.1 Design Feature of the PECCS

The PECCS is designed to perform following functions:

- Passive Safety injection function for makeup and boration using Hybrid Safety Injection Tank (H-SIT), Safety Injection Tank (SIT) and In-containment Refueling Water Storage Tank (IRWST)
- Passive Core cooling function in accidents (i.e., decay heat removal)
- Reactor Coolant System (RCS) depressurization using Automatic Depressurization Valves (ADVs)

The PECCS is comprised of four systems as below.

- Automatic Depressurization System using ADVs
- Hybrid Safety Injection Tank
- Safety Injection Tank
- Gravity Injection System using IRWST

2.1.1 Automatic Depressurization System

The Automatic Depressurization System (ADS) consists of four stages (from stage #1 to stage #4).

The Automatic Depressurization Valves (ADVs) of ADS stages #1, #2 and #3 are installed on the Pressurizer and cooling water in RCS is discharged into the IRWST when the ADVs (ADS stages #1, #2, #3) are opened by the actuation signal.

- The actuation signal of ADV #1 is generated from set point of the H-SIT water level.
- The actuation signals of ADVs #2 and #3 are generated after opening ADV #1.

The Automatic Depressurization Valves of stage #4 are installed on the RCS hot leg and cooling water in RCS is discharged into containment atmosphere when the ADVs of ADS stage #4 are opened by the actuation signal.

- The actuation signal of ADV #4 is generated depending on H-SIT water level and low RCS pressure.

2.1.2 Hybrid Safety Injection Tank

The hybrid safety injection tank is capable of injecting borated water at high pressure. Borated water in H-SIT is injected into the reactor vessel through DVI (Direct Vessel Injection) nozzles only while the pressure of RCS is lower than set pressure in H-SIT. Thus, to operate the H-SIT, the H-SIT actuation valves are opened as following:

- The H-SIT actuation valves installed in the Pressure Balancing Lines (PBLs) are opened by the actuation signals which are generated depending on the RCS pressure or hot leg temperature.

2.1.3 Safety Injection Tank

The safety injection tank is capable of injecting borated water at medium pressure. The operation and design of the SIT are the same as existing KSNP (Korea Standard Nuclear Power Plant). To operate the SIT, the ADVs of stages #1, #2 and #3 are generally opened by the actuation signals.

2.1.4 Gravity Injection system

The gravity injection system is capable of injecting borated water at low pressure using IRWST. When the RCS pressure is dropped to atmospheric pressure and the IRWST isolation valves are opened, borated water in the IRWST is injected into the reactor vessel through the DVI nozzles by gravity.

- To depressurize the RCS pressure to atmospheric pressure for gravity injection using the IRWST, the ADVs #4 installed on the RCS hot leg must be opened.
- IRWST isolation valves are opened by the open signal of ADV #4.

2.2 Results of the Running PECCS MAAP5 Model

For review of the developed PECCS MAAP5 model, sensitivity analysis was performed for SBO initiator to assess the performance of the PECCS in the aspect of core cooling. The initial conditions for the MAAP5 analysis of SBO initiator are as follows:

- Loss of off-site power at time 0.
- 2 H-SIT are available.
- 2 SIT are available.
- ADS #1 ~ ADS #4 stages are available (using Battery Power).
- Gravity injection from IRWST is available.
- Gravity injection from containment is available.
- Passive Containment Cooling System (PCCS[1]) available.

2.2.1 Review of the PECCS operation in the MAAP5

As shown in table 1, the developed PECCS MAAP5 model has been verified to work from the PECCS design perspective (refer to section 2.1). Fig.1 and 2 show the results of the PECCS operation in the MAAP5 model.

Table. 1 Results of the PECCS operation for the MAAP5 analysis of SBO initiator

Time (sec)	Description	Note
5735	H-SIT injection (Het leg Temperature)	Fig. 2
12847	ADV #1 open (H-SIT water level)	Fig. 1
12917	ADV #2 open (ADV #1 open time)	Fig. 1
13037	ADV #3 open (ADV #1 open time)	Fig. 1
13322	SIT injection (Low RCS Pressure)	Fig. 2
13323	ADV #4 open (H-SIT water level +Low RCS Pressure)	Fig. 1
13825	IRWST injection (Low RCS Pressure)	Fig. 2

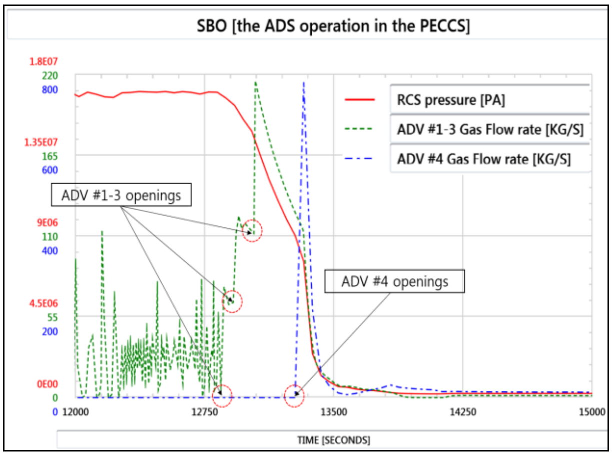

Fig. 1. Results of the ADV operation for the PECCS MAAP5 analysis

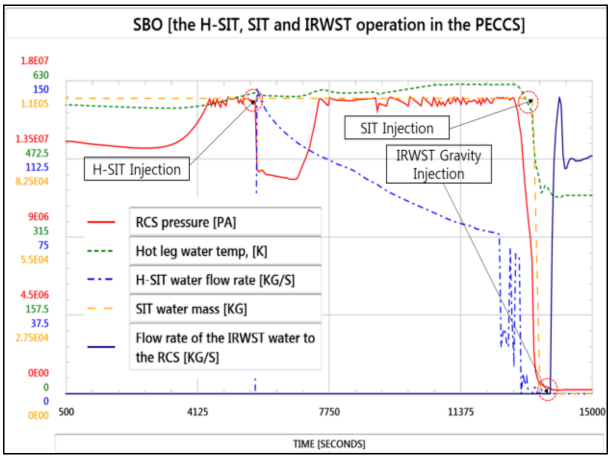

Fig. 2. Results of the H-SIT, SIT and IRWST operation for the PECCS MAAP5 analysis

2.2.2 Results of core cooling for the PECCS MAAP5 analysis

Fig 3 shows the PECCS MAAP5 model's results of the core temperature (K), the core exit temperature (K), the mass of H2 generated in core (kg) and the reactor vessel's water level (m). The MAAP5 analysis results are shown that the PECCS in the innovative passive reactor has sufficient ability for core cooling [3].

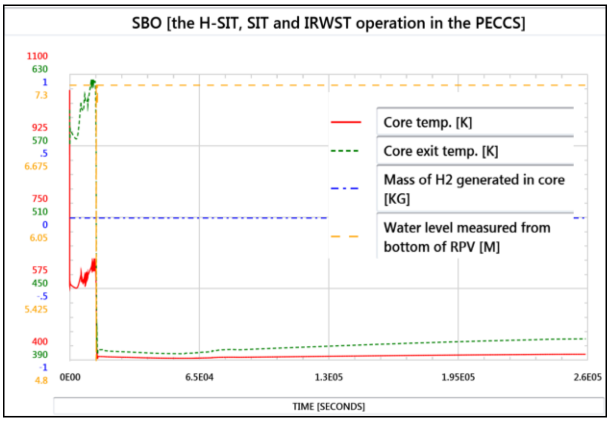

Fig. 3. Results of the core state for the PECCS MAAP5 analysis

1) The passive containment cooling system is one of the engineered safety features in the innovative passive reactor and the PCCS system can remove decay heat from the containment and prevent containment failure.

3. Conclusions

The PECCS has been adopted as emergency core cooling system in the innovative passive reactor. For the thermal hydraulic analysis of this system, the PECCS MAAP5 model has been developed. This model is being used in the preliminary scoping probabilistic safety assessment (PSA). In this paper, the analysis results using the PECCS MAAP5 model have been verified from the perspective of the PECCS design that the PECCS has sufficient core cooling capability.

REFERENCES

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[2] 'MAAP 5.05 beta version Code', EPRI, 2019.
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