# The Optimum Operation Strategy of Hybrid SIT with PAFS following a Station Blackout Accident

Sun Heo*, Hui-Un Ha
*Korea Hydro & Nuclear Power Co., 70, Yuseong-daero 1312beon-gil, Yuseong-gu, Daejeon, Korea*
**Corresponding author: hs@khnp.co.kr*

## 1. Introduction

Korea Hydro & Nuclear Power Co. (KHNP) has developed APR+ (Advanced Power Reactor Plus) which is a Gen III+ nuclear power plant of 1500 MWe.

Passive Auxiliary Feedwater System (PAFS) of APR+ had been developed to provide the ultimate heat sink for steam generator and reactor core cooling when a AC power is available or not[1,2]. A coolant storage tank of PAFS can provide coolant for reactor cooling more than 8 hours and a dedicated battery system of PAFS can provide electricity for I&C more than 72 hours. PAFS is 2-train system, that is, PAFS has two water tanks, two battery systems and two heat exchangers. PAFS provides feedwater to steam generator more than 8 hours, even if single train was unavailable, AC power was not provided and water tank is not refilled.

Following Fukushima Daiichi Accident, we have made many improvements and challenging research to prevent and mitigate accidents which can be caused by earthquake, tsunami or station blackout. It includes the Hybrid SIT to deliver cooling water into core even if RCS pressure is high[3,4].

To prevent a waste of SIT water and maintain core cooling more long time, an optimum operation strategy of Hybrid SIT has been developed. It considers the operation of PAFS and the optimum coolability of SIT water.

## 2. Hybrid SIT concept

During a loss of AC power, coolant injection by active pump, such as, safety injection pump, shutdown cooling pump, etc., is not possible. Safety Injection Tank (SIT) has coolant and connected to Reactor Coolant System (RCS) but it cannot delivers coolant into RCS because the pressure of RCS is higher than that of SIT during SBO accident.

Hybrid SIT concepts are developed to provide cooling water to reactor core on condition of station blackout (SBO) accident. Fig. 1 shows the conceptual diagram of Hybrid SIT. A normal SIT is connected to Direct Vessel Injection (DVI) nozzle through check valve. The SIT is pressurized to about 4 MPa by nitrogen gas and it can inject coolant to reactor if only if the pressure of RCS is lower than that of SIT. Hybrid SIT has not only injection line to DVI nozzle nut also a pressure balancing line, which connects between the nitrogen space of SIT and steam space of pressurizer. Following the opening of pressure balancing valve, the pressure of the SIT is equalized with that of pressurizer and RCS. After the equalization of pressure, the coolant in SIT can flow into the reactor according to the head different between SIT and RCS. The pressure balancing line of SIT makes it possible to deliver coolant into RCS where the pressure is higher than that of normal SIT.

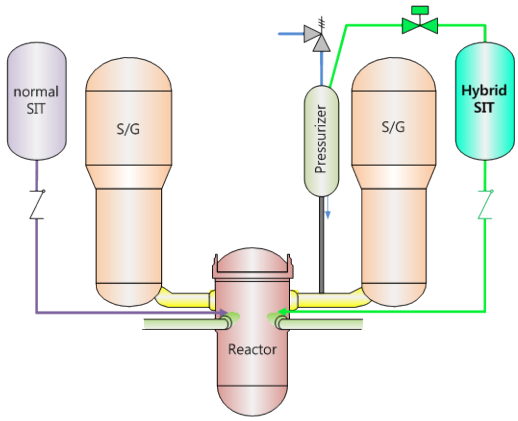

Fig. 1. Hybrid SIT conceptual diagram

## 2. RELAP5 Analysis of Hybrid SIT with PAFS

Following the SBO, PAFS and Hybrid SIT can provide cooling water into steam generator and reactor, respectively. To optimize the operation strategy of Hybrid SIT and increase the period of core cooling, we must consider the operation of PAFS and the RCS condition during and after PAFS operation. In this section we show the effect on core cooling according to the some operation methods of Hybrid SIT. In this analysis, RELAP5/MOD3.3 code is used. We adapt single failure criteria and assume that only one train of PAFS is available. PAFS can be operated more than 8 hours but assumed to be only available during 8 hours because the design parameter of water tank is 8 hours without refilling.

### *2.1 Normal SIT operation*

Fig. 2 shows the RCS pressure where SIT is operated in normal mode, in which the pressure balancing line is not used and SIT injects water only when the RCS pressure is lower than 4 MPa. During SBO and PAFS operation, the RCS pressure is higher than that of SIT and no water is delivered into RCS.

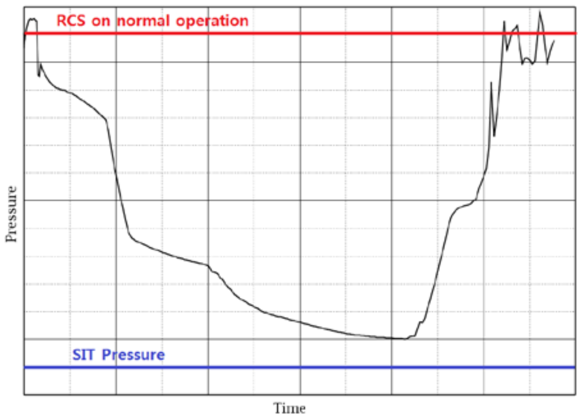


Fig. 2. RCS pressure with normal SIT

*2.2 Hybrid SIT following SBO*

Second operation method is that Hybrid SIT is actuated following SBO occurrence. In this method, we consider an operator action time of thirty minutes. Fig. 3 shows the RCS pressure and POSRV flowrate. Hybrid SIT delivers coolant into reactor very well and it decreases the temperature and pressure of RCS during early period of accident. The low temperature of RCS decreases the cooling performance of the PAFS. The Early injection of Hybrid SIT induces the higher temperature of RCS when the PAFS stops and the faster heatup of core.

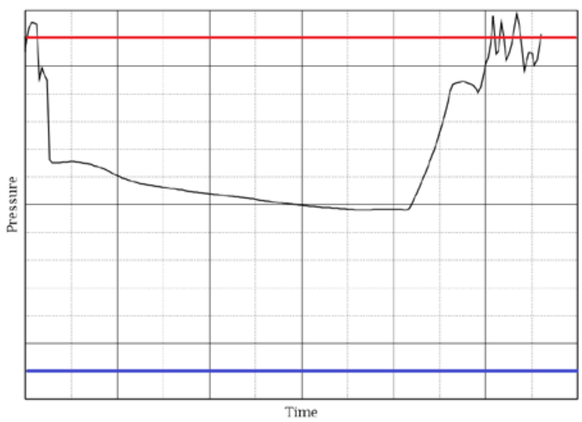


Fig. 3. RCS pressure with Hybrid SIT injection

*2.3 Hybrid SIT injection after POSRV opening*

Several try for Hybrid SIT operation give us the insight that the coolant injected before the swelling of RCS water is released during the first POSRV opening and has very little effect on core cooling. The third operation method is that Hybrid SIT is actuated following POSRV opening.

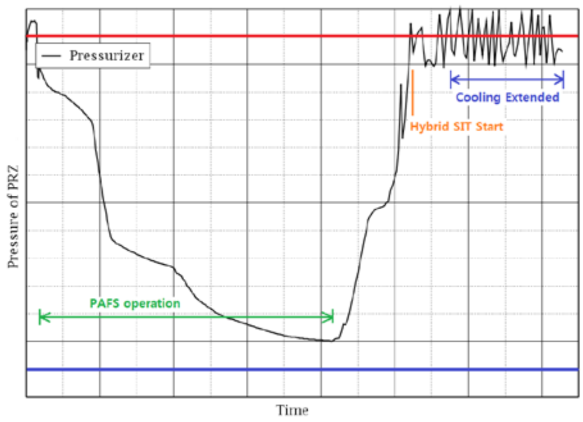


Fig. 4. RCS pressure with a delayed injection of Hybrid SIT

## 7. Conclusions

For the optimum coolability of Hybrid SIT with PAFS, some operation methods were considered. It shows that the coolant injected before the swelling of RCS water is released during the first POSRV opening and has very little effect on core cooling. The core cooling period is longest when the Hybrid SIT is actuated one by one after a exhaustion of PAFS and POSRV opening. It is the best operation strategy of Hybrid SIT with PAFS and Hybrid SIT can extend the core cooling more than 3 hours.

## ACKNOWLEDGMENT

This work was supported by the Nuclear Power Core Technology Development program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) granted financial resource from the Ministry of Trade, Industry and Energy, Republic of Korea (No. 20131510101670)

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