Preliminary Study of Operation Strategy of Charging Pumps under the event of Loss of Ultimate Heatsink for Shin Kori Unit 1

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1. Introduction

After the Fukushima nuclear power plant accident, the Korea government and the nuclear industry have been developing the accident management plan for various Beyond Design Basis Accident (BDBA). Loss of Ultimate Heat Sink (LUHS) is one of the accidents to be considered in the accident management plan, which is defined as the complete loss of the Essential Service Water (ESW) System. [1] The loss of ESW leads to the loss of Component Cooling Water (CCW), therefore, all components and systems which are cooled by CCW are unavailable in the event of LUHS.

In this scenario, the injection of borated water into Reactor Coolant System (RCS) by actuating Charging Pumps (CPs) is a critical function for maintaining RCS inventory and providing Reactor Coolant Pump (RCP) seal injection. However, the loss of CCW system accompanies the isolation of RCS letdown line and there are concerns about the possibility of RCS overpressure by uncontrolled operations of CPs in some situations.

A preliminary study has been performed about the operational strategy with CPs in the LUHS events of OPR1000 (Shin Kori Unit 1), to avoid the possibility of the RCS overpressure due to uncontrolled operation of CPs.

2. Method and Results

2.1. RELAP code modeling

The RCS response of Shin Kori Unit 1 (SKN-1) has been calculated using RELAP5/MOD3.3 [2] code. Fig. 1 shows the nodalization diagram of SKN-1 thermal-hydraulic system. In order to simulate the Nuclear Steam Supply System (NSSS) of SKN-1, the main systems in the plant were modeled with 264 control volume and 311 junctions.

2.2. LUHS Assessment Scenarios

Table 1 shows a major sequence of the plant response under the LUHS event up to the connecting time of a mobile equipment stored at or near the plant site for supplying additional resources until the restoration of the function of ESW.

Table 1. Major sequence of LUHS event

Time	Event	Set value
0 sec	Initiating event	
0 sec	Circulating Water (CW) system trip	
	Condenser trip	
	Turbine trip	
	Component Cooling Water (CCW) system trip	
	Letdown HX isolation	
5 sec	Rx trip	PZR Pressure : 16.43 MPa
6 sec	Main Steam Safety Valves (MSSVs) open	SG pressure: 8.682 MPa
7 sec	Pressurizer Safety Valve (PSV) open	PZR Pressure : 17.06 MPa
10 min	Start of AFWPs operation	SG level: 24.5 %(WR)
30 min	RCP manual trip	
	Pressurizer heater turnoff	
	Reactor Coolant Gas Vent (RCGV) system (PZR, RVUH vent) operation	
	Atmospheric Dump Valves (ADVs) open	RCS Cooling: 50 °F/hr
8 hr	Connecting a mobile equipment	

2.3. Analysis results

The two transient cases were considered in this study. Case 1 assumes that both CPs are operating for the entire event. In Case 2, one pump is stopped 30 minutes after initiating event and the other operates for the rest of the LUHS event.

Fig. 2 shows the pressurizer pressure for both cases. In the beginning of the event, the pressures of both cases rapidly increase due to the heat unbalance of between the primary side and secondary side in the Steam Generator (SG). The reactor trip signal is generated by the high pressurizer pressure signal. The pressure sharply decreases after the reactor trip due to shrinking of the reactor coolant. Up to 30 min, the pressure increases due to the injection flow from CPs without letdown of RCS inventory. Thereafter, the RCS

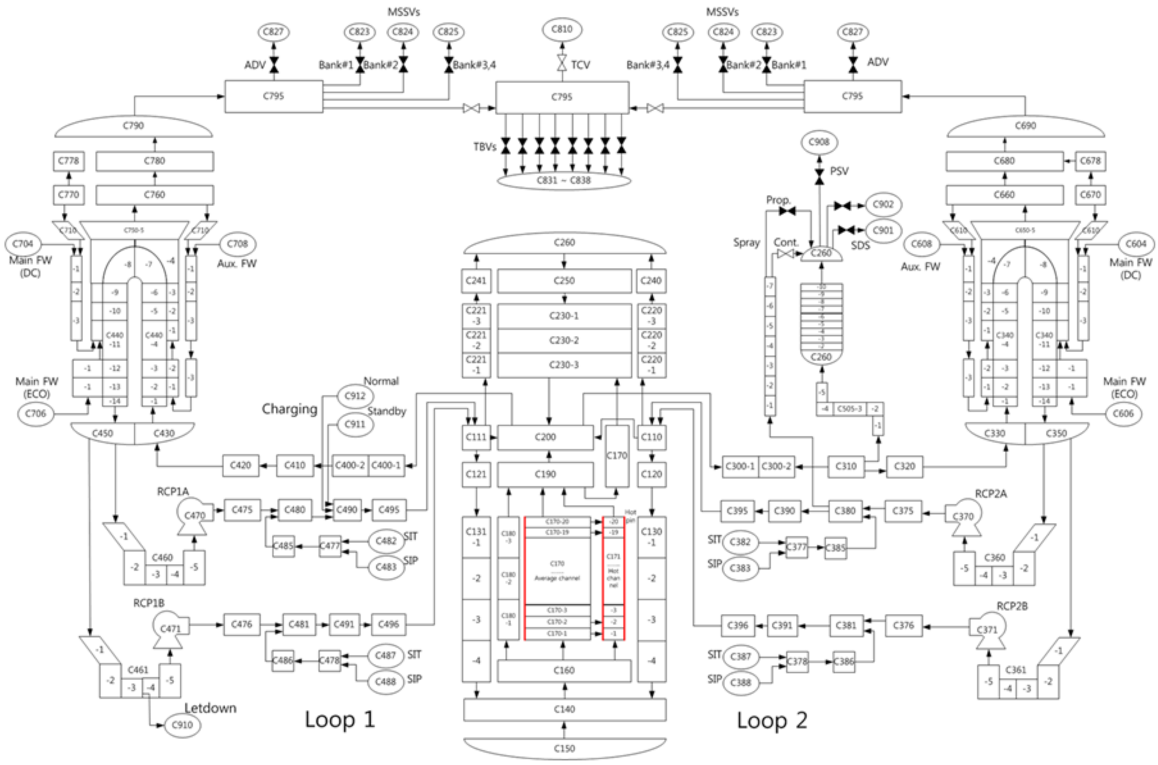

Fig.1 Nodalization diagram of RELAP for SKN-1

pressure decreases due to RCS depressurization and cooldown through the ADVs opened manually. In the case 1, the RCS pressure abruptly increases to the set point pressure of the PSVs and the coolant is released through the PSVs after the about 4.5 hours. In the other hands, the RCS pressure of the case 2 continuously decreases.

Fig. 3 shows the RCS flowrate. The results of both cases shows similar trends until 4.5 hours after initiating the event. The RCS flowrate is maintained at the beginning of the event and then rapidly decreases after the RCP manual trip.

The hot-leg temperatures are shown in Fig. 4. The hot-leg temperature is maintained until the RCPs are tripped manually. With the ADVs control, the secondary side can continuously remove the heat of the primary side. The cooling rate of the primary side depends on the secondary side conditions.

In the case 1, the pressurizer level reaches the top of pressurizer as shown in Fig.5, the coolant is continuously released through Reactor Coolant Gas Vent (RCGV) System until steam in the pressurizer is exhausted as shown in Fig.6. In the case 2, the pressurizer level is decreased during the pressurizer vent operation and increased using the Reactor Vessel Upper Head (RVUH) vent. At all event, the pressurizer level is maintained within 70% before the connecting the mobile equipment.

Therefore, operating strategy of case 2 is desirable for maintaining the RCS inventory and avoiding overpressure of RCS in the LUHS event.

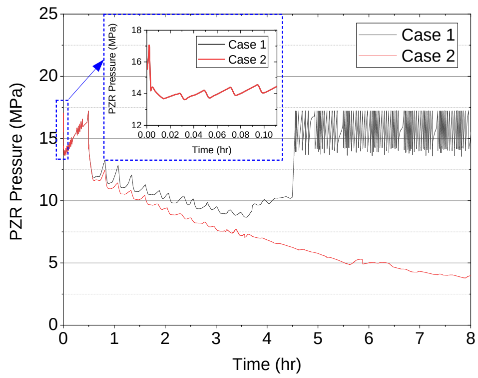

Fig. 2 Pressurizer Pressure

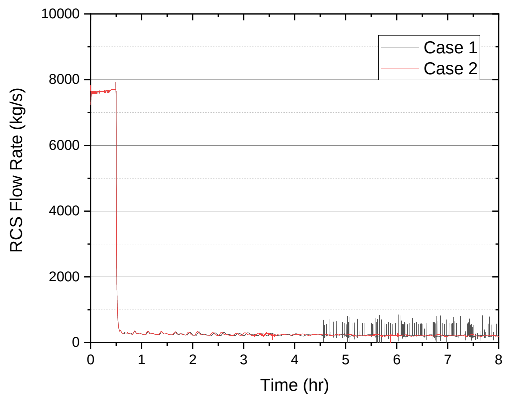

Fig. 3 RCS Flowrate

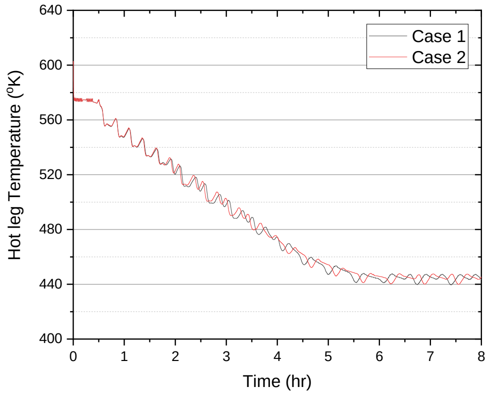

Fig. 4 Hot leg Temperature

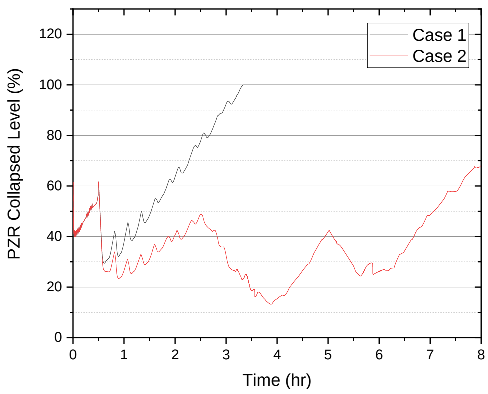

Fig. 5 Pressurizer collapsed level

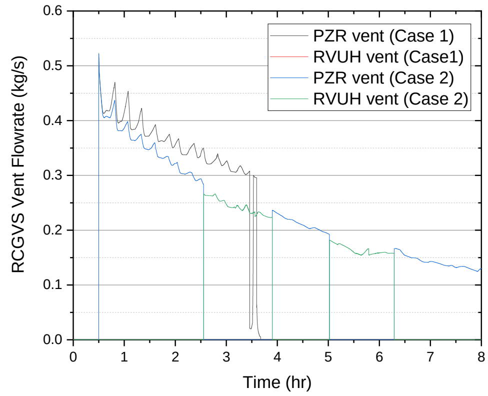

Fig. 6 Steam mass flow rate through RCGV ventilation

3. Conclusions

A preliminary study has been performed about the operational strategy with CPs in the LUHS events of OPR1000 (Shin Kori Unit 1). In case of operation of two CPs, the pressurizer level reaches the top of the pressurizer and RCS pressure abruptly increased, as a result, the coolant is released through PSV. In contrast, the pressurizer level could be maintained within 70% and the RCS cooled down steadily through the natural circulation in case of operation of one CP. Through the present study, it can be concluded that the operation of one CP is desirable to prevent the overpressure and inventory loss through safety valve and should be adopted as a major strategy for RCS inventory control in the event of LUHS.

REFERENCES

[1] Nuclear Safety and Security Commission, Stress Test Implementation Guide, October, 2016.
[2] “RELAP5/MOD3.3” Code Manual”, NUREG/CR-5535, Revision1, December, 2001.