A Sensitivity Study on High Pressure External Injection Pump used in ELAP Coping Strategy for APR1400

Sang Jin Kim*, Jae Woo Cho, Chan Eok Park, Gyu Cheon Lee
Safety Analysis Group, KEPCO-E&C, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Rep. of KOREA
**Corresponding author:sangjin@kepco-enc.com*

1. Introduction

Recently, a strategy called MACST (Multi-barrier Accident Coping Strategy) was established for the Korean domestic NPPs (Nuclear Power Plants) to cope with the multiple failure accidents. A high pressure external injection pump was adopted as one of the equipment for the MACST.

Main purpose of the external injection pump is to feed coolant water to the RCS (Reactor Coolant System) inventory in case of the loss of coolant accidents coincident with ELAP (Extended Loss of All AC Power).

If ELAP occurs, the only available electric power source is the safety class battery system. So that RCP (Reactor Coolant Pump) seal leakages occur due to loss of charging flow. Therefore, operators must recover the alternating current electric system using the mobile generators and make up RCS inventory using the ACP (Auxiliary Charging Pump) or the high pressure external injection pump.

In this paper, a sensitivity study to determine requirements of design specifications of the external injection pump such as an actual pump head, a range of flow rate and a range of injection time was performed using RELAP5 that is a best-estimate computer code for simulating safety related accidents in nuclear power plant.

2. Event Description

During ELAP in APR1400, both reactor trip and turbine trip occur within 5 seconds right after the event. Most of requiring electrical sources such as the main feedwater pumps, the pressurizer heater, the pressurizer spray, the turbine bypass valves, the charging pump and the letdown isolation valve are also not available. Furthermore, the RCP seal leakages occur because of loss of charging pump.

After the reactor and turbine trip, the water levels of steam generators decrease due to boil-off during the natural circulation cooling of RCS. If the steam generator levels become lower than the AFWPs (Auxiliary Feedwater Pumps) actuation setpoint, the AFWPs are operated automatically.

Meanwhile, it is required for operators to try to connect the 1 MW and 3.2 MW mobile electric generators in order to recover the alternating electric current system.

If the 1 MW mobile generator is connected on the electric power system in APR1400, operators try to control ADVs for depressurizing and cooling RCS and to operate the ACP. Nevertheless if the operation of ACP is failed, a high pressure external injection pump should be available used as alternative means.

If the pressure and the temperature of RCS reach the entry condition of the SCS (Shutdown Cooling System), operators have to maintain the hot shutdown condition until recovering the electric power system.

And if 3.2 MW mobile electric generator is connected, operators can cool the RCS to the safe cold shutdown condition.

3. Analysis Methodology

Table 1 shows the initial conditions of RELAP5 code for the simulation of APR1400 ELAP event.

Table 1 Initial Conditions in ELAP

Parameter	Design Value	RELAP5
Core Power, MWt	3983	3983
Pressurizer pressure, MPa(a)	15.51	15.52
RCS average temperature, K	580.35	580.29
Secondary pressure, MPa(a)	6.89	7.04
Pressurizer level, %	50.0	49.9
Steam Generator level, % WR	77.0	76.81
Mass Flow of RCS, kg/s	10,495	10,501

For the sensitivity analysis, it is assumed that the range of injection time is between 2 and 8 hours following the event because the average connection time of 1 MW mobile electric generator is 2 hours according to the results of ST (Stress Tests) [1-4] and the battery capacity after load shedding is at least 8 hours [5].

It is also assumed that the range of injection flow rates varies from 16 to 48 GPM because the design flow rate of the ACP is 44 GPM.

Table 2 shows the sensitivity ranges of the analysis conditions.

Table 2 Sensitivity ranges of the analysis conditions

Injection Time (hours)	Injection Flow rate (gallons per minute)
2	16
	24
	32
	40
	48
8	16
	24
	32
	40
	48

4. Analysis Results

Figures 1 shows the pressurizer pressure behavior during ELAP. The pressure decreases from 1,421 psia to 232 psia during 2 to 8 hours following the event.

Consequently, the proposed pump head of the external injection pump should be at least greater than 1500 psia considering an additional margin.

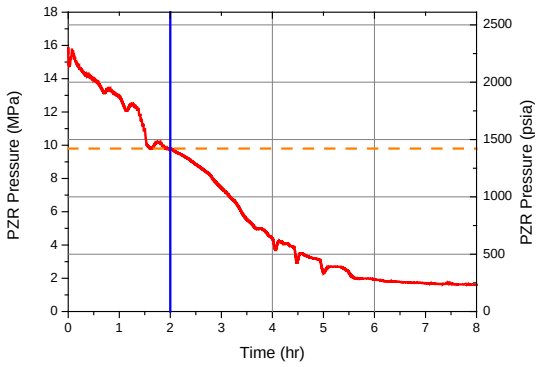

Fig. 1. Pressurizer Pressure

Figures 2 and 3 show the pressurizer level behaviors in response to the various injection times of 2 hours and 8 hours, respectively.

As shown in figure 2, the RCS inventory cannot be recovered with the injection flow of 16 GPM, while the pressurizer level with the injection flow of 48 GPM reaches 100%. Therefore, it can be concluded that the effective range of injection flow is from 24 to 48 gallons per minute.

In the same way, it is evaluated, as shown in figure 3, that the efficient range of injection flow is from 32 to 48 GPM.

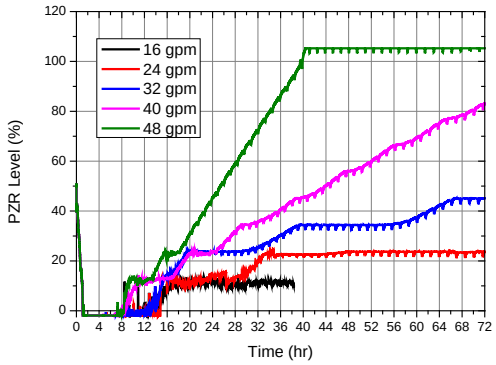

Fig. 2. PZR Level response to the injection flow rates (2 hours)

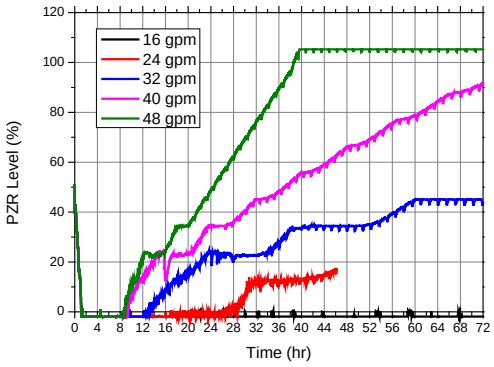

Fig. 3. PZR Level response to the injection flow rates (8 hours)

5. Conclusions

This sensitivity studies were performed using RELAP5 code to evaluate the effectiveness of the external charging pump specifications as coping strategy during ELAP in APR1400. It can be concluded the adequate pump head is 1500 psig (1514.7 psia) and the adequate range of injection flow rate is from 32 to 48 gallons per minute.

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