

# Analysis of LOCV and MMPSMF on i-SMR for Setup of High Pressurizer Level Trip Setpoint

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## 1. Introduction

The protection of reactor coolant system (RCS) of pressurized water reactor (PWR) is achieved by releasing steam through a pressurizer safety valve (PSV) during an over-pressurization event such as loss of condenser vacuum (LOCV) [1]. However, in spite of over-pressurization event, pressurizer (PZR) level can increase without pressurization of RCS. As a result, discharge of liquid through PSV can occur and damage to the integrity of components in reactor building. In addition, pressurizer level control system malfunction (PLCSMF), which is recently required to be investigated by nuclear regulatory body [2], results in a rise of pressurizer level. Therefore, the assessment for high pressurizer level trip (HPLT) setpoint is necessary to prevent full pressurizer level. Likewise, the investigation for HPLT setpoint of innovative SMR, which is a small modular PWR being developed in Korea, should be performed. Meanwhile, the modular makeup and purification system malfunction (MMPSMF) of i-SMR is corresponded to the pressurizer level control system malfunction (PLCSMF) of general PWR.

In this study, the analysis focuses on the reachability of pressurizer full-level in LOCV and MMPSMF on i-SMR to evaluate appropriate high pressurizer level trip setpoint. The thermal-hydraulic behavior were calculated by Safety and Performance Analysis Code for nuclear power plants (SPACE) [3]. The maximum pressurizer levels were analyzed with the numerous combinations of initial conditions.

## 2. Methodology

### 2.1 Descriptions for the LOCV of i-SMR

The LOCV is categorized in decrease in heat removal by the secondary system [4]. When LOCV is initiated, a turbine trip occurs. Eventually, the turbine stop valves and turbine bypass valves are closed to protect the turbine and related system. The reduction of heat removal results in increase of RCS pressure, RCS temperature, and RCS water volume. Subsequently, primary and secondary pressure could reach setpoints of high pressurizer pressure trip (HPPT), high pressurizer

level trip (HPLT), or the high steam pressure trip (HSPT).

### 2.2 Descriptions for the MMPSMF of i-SMR

The MMPSMF is categorized in increase in RCS inventory [4]. The maximum charging pump flow and the minimum letdown flow are generated by the low pressurizer level. As a result, the inventory of RCS increases and results in the increase of RCS pressure and RCS water volume. Finally, the HPPT and HPLT could occur. If the pressurizer spray is activated, the pressurizer level can reach to full-level.

### 2.3 Initial conditions

Table 1 shows the range of initial conditions which can be assumed Limiting Condition for Operation (LCO). The combinations of all these initial condition are 486 cases. The sensitivity analysis of trip setpoints by initial condition was performed. The HPPT setpoints range was assumed to be between the PSV opening time setpoint and the maximum pressurizer pressure in LCO range. The HPLTs are assumed as 80%, 90% and 110%. In case of 110% HPLT, only HPPT effect can be investigated. The effect of pressurizer spray on and off are also investigated.

Table 1. Initial Conditions and Trip Setpoints

Parameter	Min.	Nom.	Max.
Core $T_{in}$ , °C	318.9	322.9	324.9
PZR P, MPa	14.3	15.0	15.4
PZR Level, %	56.0	70.0	75.5
HPPT SPT, MPa	15.6	16.1	16.6
HPLT SPT, %	80.0	90.0	110.0
PZR Spray	On / Off		

## 3. Results

### 3.1 LOCV

Figure 1 illustrates the maximum pressurizer level of LOCVs with 80%, 90%, and 110% of HPLT setpoints. In LOCVs, no difference of maximum pressurizer level by HPLT setpoint is observed. Furthermore, none of LOCVs reached to pressurizer full-level. Moreover, the analysis of LOCVs on i-SMR shows that HPLT was not generated in all cases because HPPT already occurred before HPLT. Therefore, LOCV is not significant event to investigate the appropriate HPLT setpoint of i-SMR.

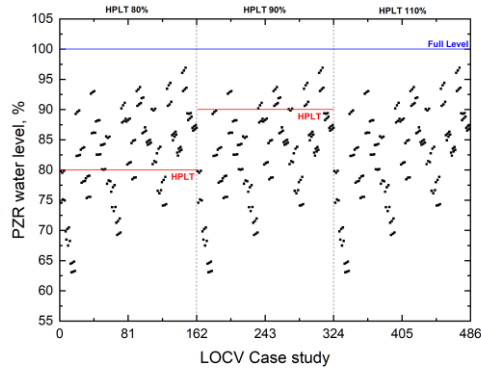


Fig. 1. Maximum pressurizer levels reached in LOCVs

### 3.2 MMPSMF

As shown in Figure 2, some MMPSMFs on i-SMR reached to pressurizer full-level in case of 110% of HPLT setpoint. However, no maximum pressurizer full-level is reached to 100% in cases with 80% and 90% of HPLT setpoint. Therefore, HPLT setpoint needs to set to 90% or less. In addition, MMPSMF can be considered as significant event for pressurizer full-level.

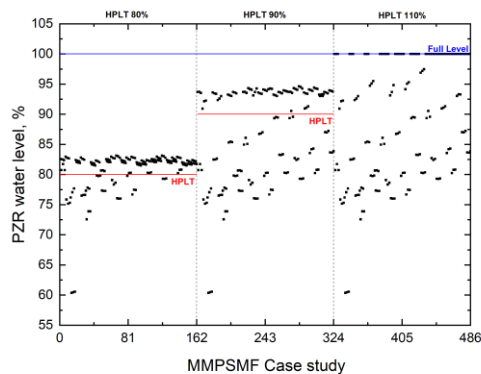


Fig. 2. Maximum pressurizer levels reached in MMPSMFs

Figure 3 shows the effect of each initial condition in MMPSMFs with pressurizer spray off. The case with minimum pressurizer level of initial condition reached to the highest maximum pressurizer level. Moreover, the lower the initial pressurizer pressure was assumed, the higher maximum pressurizer level was observed. On the other hand, the higher the HPPT setpoint was applied, the higher maximum pressurizer level was observed. If the difference between initial pressurizer pressure and

HPPT setpoint, the time for RCS pressure reaching to HPPT setpoint is delayed. Meanwhile, the RCS temperature didn't show a significant tendency of the maximum pressurizer level.

Figure 4 shows the effect of each initial condition in MMPSMFs with pressurizer spray on. The tendencies of maximum pressurizer level in case of different pressurizer pressure and HPPT are similar to the results of MMPSMF with pressurizer spray on. No clear effect on initial pressurizer level and RCS temperature is observed due to the activation of pressurizer spray.

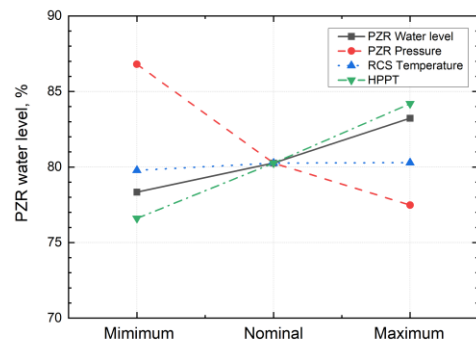


Fig. 3. Effect of each initial condition in MMPSMFs with pressurizer spray off

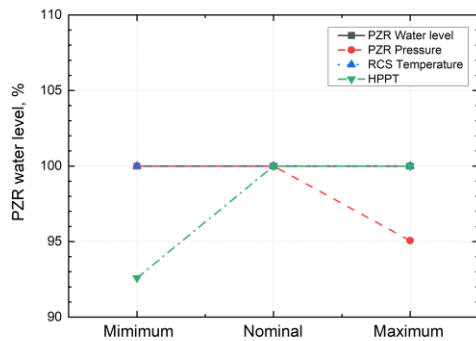


Fig. 4. Effect of each initial condition in MMPSMFs with pressurizer spray on

## 4. Conclusions

In this study, the analysis for HPLT setpoint of i-SMR was performed on the pressurizer full-level in LOCVs and MMPSMFs with numerous initial conditions. LOCV was not significant event to set HPLT setpoint of i-SMR because all cases didn't reach to pressurizer full-level. Of the 486 MMPSMFs, 54 cases with pressurizer spray on and 110% of HPLT setpoint were observed to reach to pressurizer full-level. It was investigated that the HPLT setpoint of i-SMR needs to be set to 90% or less. In the future works, the additional study for HPLT setpoint with other initial conditions is necessary because i-SMR is being developed.

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