A sensitivity study on the initial RCS conditions in the major non-LOCA accidents

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1. Introduction

KINS (Korea Institute of Nuclear Safety) has been developing a Non-LOCA regulatory audit methodology, which consisted of advantages from both the conservative method and BEPU approach. BEPU methodology can be one of the best realistic simulations however, it costs much to analyze the range and form of uncertainty parameters. Non-LOCA transients have consisted of a lot of events and simple phenomena during a short transient time in contrast to LOCA. Thus, totally applying to many uncertainty parameters for Non-LOCAs is not efficient in terms of costs and efforts.

Conservative methodology also has several advantages such as sufficient safety margin or low costs. As the way to ensure safety margin among the several advantages, the use of conservative initial RCS operating conditions derived from the sensitivity study is one of the best ways to ensure enough safety margin in the field of safety assessment.

Even though OPR1000 and APR 1400 under operating in south Korea were designed to be similar types, it was not easy to clearly find out their consistent tendency on the effect to acceptance criteria when RCS major parameter changed.

Thus, this study is aimed to give valuable insight on the impact of acceptance criteria under varying initial RCS conditions using the sensitivity study.

2. Test matrix of a sensitivity study

Sensitivity parameters are selected as pressurizer pressure, cold leg temperature, and core inlet flow rate and applied to non-LOCA accidents such as main steam line break (MSLB), main feed line break (MFLB), locked rotor (LR), steam generator tube rupture (SGTR) of APR1400.

Sensitivity ranges were based on limiting condition for operation (LCO) of technical specifications. All of the results calculated by MARS-KS system code focused on acceptance criteria such as RCS pressure, secondary system pressure, and departure from nucleate boiling ratio (DNBR) in representative transients of Non-LOCAs. Trends for major non-LOCA incidents have also been developed to provide an impact on acceptance criteria when RCS initial conditions vary in the LCO range. Table 1 shows the range of sensitivity based on LCO, each of which is applied to major transients. 72 cases of steady-state calculations, including base cases, were performed to meet steady-state conditions for each major transient.

After performing steady-state calculations, the same transient scenario was applied to 72 normal conditions respectively to obtain 216 results in all three acceptable criteria: departure from nucleate boiling ratio, maximum RCS pressure, and maximum SG pressure.

Table 1. Sensitivity range on the RCS conditions

Accident	Parameter	Range	Criteria
MSLB, MFLB, LR, SGTR	PZR Pr.(Bar)	152 ~ 158	Min. DNBR, Max. RCS Pr., Max. SG Pr.
	RCS Temp.(°C)	289.1 ~ 293.6	
	RCS Flow(kg/s)	21,000~ 24,200	

3. Trends on the initial RCS conditions

System behaviors of major transients, which are MSLB, MFLB, LR, SGTR, were analyzed using MARS-KS code to develop the trend map on the RCS initial conditions. Because there was a great deal of analysis results on the transients, this paper described focusing on the results showing the trend clearly with respect to the minimum DNBR, maximum RCS, and SG pressure.

SGTR accident represented the impact of variance on the RCS initial conditions in terms of minimum DNBR. The trend of minimum DNBR was observed to be lower at the condition not only the higher cold-leg temperature was but also the lower PZR pressure and RCS flow rate were. Figure 1 illustrated the DNBR trend in the RCS operating parameters.

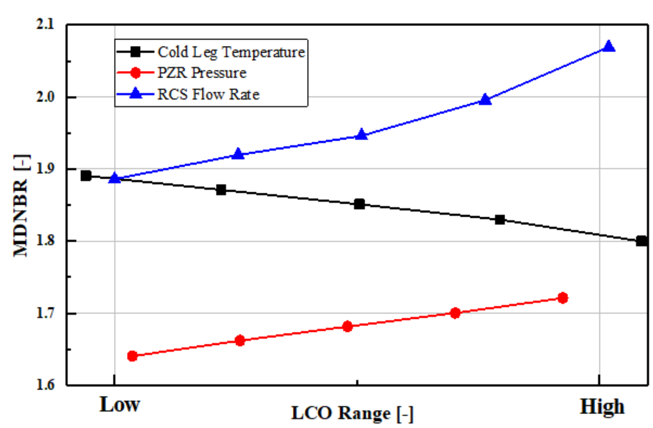

Fig. 1 DNBR trend at the SGTR

In terms of the maximum RCS pressure, the seized RCP rotor had a significant effect on the PZR initial pressure. Other operating parameters did not have the effect of increasing the RCS pressure in the LCO range. Figure 2 shows the RCS pressure trend for the seized RCP rotor.

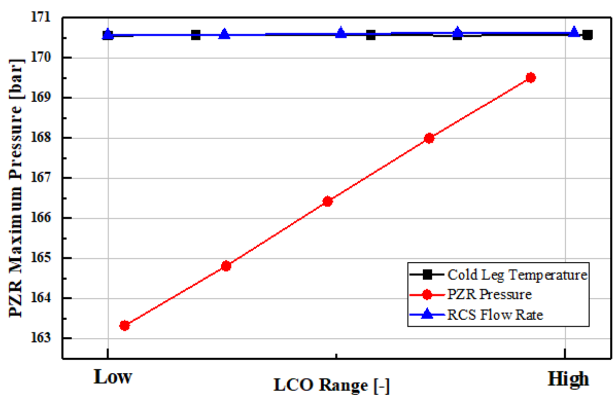

Fig.2 RCS pressure trend at the seized RCP rotor

Additionally, the trend of secondary pressure at the MFLB dramatically varied as gradually increasing PZR initial pressure, and the other parameters somewhat affected that of MFLB. Figure 3 represented the variance of the secondary system pressure at MFLB.

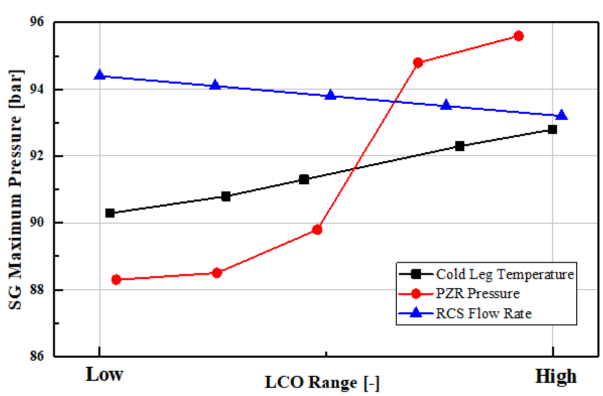

Fig. 3 SG pressure trend at the MFLB

4. Development of trend map

Although sensitivity studies have been conducted using system code so far, the impact trend has not been consistent due to many design changes and unknown parameters affecting safety outcomes, even though power plants of type, for example, APR1400 and OPR1000, have analyzed the same initial state. Thus, the development of a tendency map to easily understand the degree of conservatism in each major transient can be very useful for regulatory staff or designers.

Figures 4, 5, and 6 represented some of the trend maps on the minimum DNBR, maximum RCS, and SG pressure during all transients being studied in this research.

In Figure 4, it was observed that in the case of a locked rotor accident, there was little effect on DNBR despite the change in the flow rate of the core inlet coolant. The locked rotor is expected to have the largest asymmetry for core inlet flow rate than other accidents analyzed, but the system code is very limited to this analysis. Therefore, it is believed that the use of sub-channel code in detail is necessary to analyze the tendency of minimum DNBR to the change in core inlet flow rate of the locked rotor.

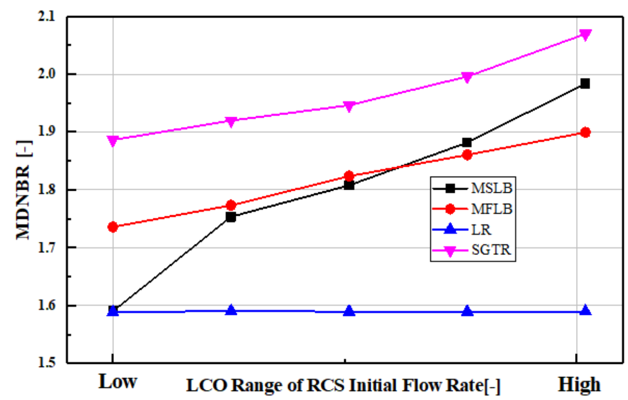

Fig. 4 Trend map on the DNBR in all transient

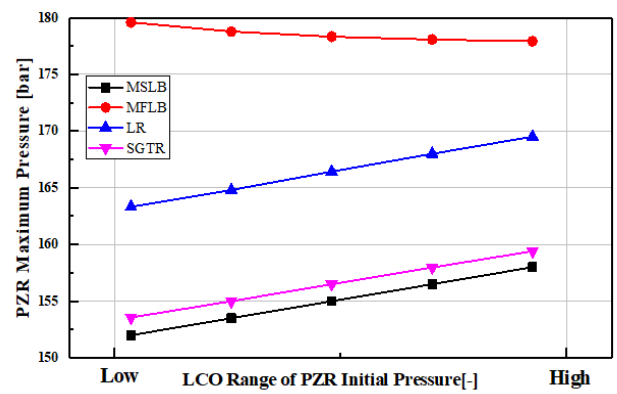

Fig. 5 Trend map on the RCS pressure in all transient

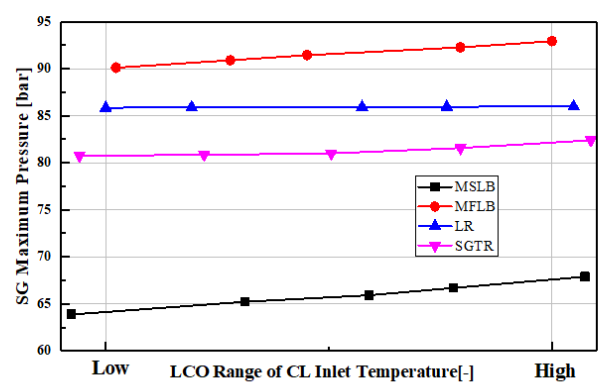

Fig. 6 Trend map on the SG pressure in all transient

5. Conclusions

This study was conducted using MARS-KS to investigate how changes in RCS initial conditions in major non-LOCAs affect regulatory acceptance criteria. Using the results of each accident, a trend map was developed to easily understand the effects of the three acceptance criteria. However, it was found that the use of sub-channel code was also necessary to investigate changes in core flow rates. The study is expected to be completed after analyzing variable sensitivity to secondary system variables and fuel performance.

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