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Sensitivity of Safety Analysis for ASI Operating Range Change

Il Tak Woo*, Chang Hyun Jee, Yoon Sik Kwon, Young Han Song, Kyung Sik Choi, Jae Yong Chang
KEPCO Nuclear Fuel, Safety Analysis Dept., 242 Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Korea
**Corresponding author: itwoo@knfc.co.kr*

1. Introduction

The LCO(Limiting Conditions for Operation) of ASI(Axial Shape Index) range for CE type plant in Korea is the same value above certain power level. If the load-follow operation is applied, the ASI becomes larger due to the power change and the Xenon oscillation after the middle cycle, which may exceed the LCO of ASI range. The exceeding ASI may lead to power decreasing, which may reduce the utilization rate of the plant. In order to effectively control the Xenon oscillation due to the power change, it is necessary to expand the LCO of ASI range at the low power to improve the ease of load-follow operation. And it is necessary to reduce the ASI range at the high power to secure safety analysis margin. In this paper, sensitivity study results for safety analysis margins were described assuming various ASI ranges to determine the optimal LCO of ASI range.

2. Methods and Results

The optimal LCO of ASI range was determined by the sensitivity study of safety analysis according to various ASI operating range. The ASI operating range used for the sensitivity study was ±0.2 ASI and ±0.3 ASI for the full power and ±0.5 ASI for the low power. The ±0.3 ASI at the full power was used for the existing CE type plant in Korea. The changing LCO of ASI range ensures the safety analysis margin by reducing the ASI operating range at the full power condition and provides the ease of load-follow operation by extending the ASI operating range at the low power condition. The sensitivity analysis was performed with some accident analysis related to ASI operating range as follows; the single reactor coolant pump rotor seizure(Locked Rotor, LR), the control element assembly ejection(CEAE) and the single control element assembly withdrawal (SCEAW). Also, the peak pressure of primary system(Reactor Coolant System, RCS) and secondary system(Steam Generator, S/G) was performed for loss of reactor coolant flow(LOF) accident.

2.1 Single Reactor Coolant Pump Rotor Seizure(LR)

The sensitivity study for LR was performed by evaluating the MDNBR(Minimum DNBR) with the corresponding ROPM(Required Overpower Margin) at each ASI operating range. The safety analysis was performed by ±0.2 ASI and ±0.3 ASI at the full power condition. Fig. 1 shows the axial power distribution for the ASI used in the safety analysis.

As a result of sensitivity study, the result of MDNBR are shown as Table I. The MDNBR of ±0.3 ASI was less than that of ±0.2 ASI.

Table I: Results of sensitivity for LR

ASI	MDNBR
0.3 ASI [Ref. case]	Ref.
0.2 ASI	↑ 0.03

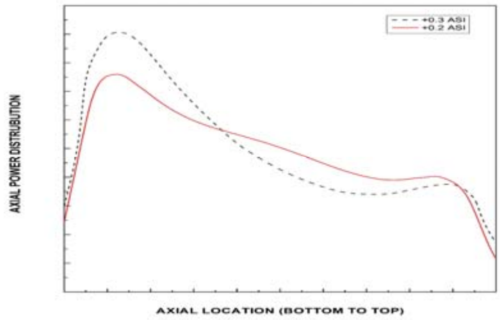

Fig. 1. Axial power distribution for LR

2.2 Control Element Assembly Ejection(CEAE)

The sensitivity study for CEAE was performed by evaluating the enthalpy and fuel failure at each ASI operating range. The safety analysis was performed by ±0.2 and ±0.3 ASI for the full power condition and ±0.3 and ±0.5 ASI for the low power condition.

As a result of sensitivity study, the fuel centerline temperature and maximum enthalpy increased due to increased Fz according to the extended ASI operating range as shown Table II. However, those result met acceptance criteria[1]. The fuel failure of ±0.3 ASI was larger than that of ±0.2 ASI at the full power condition with same the ROPM. However, the fuel failure of the ±0.3 ASI was greater than that of ±0.5 ASI at the low power condition. The ±0.5 ASI had a larger ejected rod worth than ±0.3 ASI, but the change in the pre and post condition of axial power distribution was smaller than ±0.3 ASI. Therefore, the result of fuel failure was improved by expanding ASI operating range.

Table II: Results of sensitivity for CEAE

Power	ASI	Fuel Centerline Temp. , ˚F	Enthalpy, cal/g	Fuel Failure, %
Full	±0.3*	Ref	Ref.	Ref.
	±0.2	↓ 55	↓ 1.4	↓ 0.8
Low	±0.3*	Ref	Ref.	Ref.
	±0.5	↑ 210	↑ 17	↓ 1.4

* Reference case

2.3 Single Control Element Assembly Withdrawal (SCEAW)

The sensitivity study for SCEAW was performed by evaluating the ROPM for each power condition. The safety analysis was performed by ±0.2, ±0.3 and ±0.5 ASI at each power condition. The ROPM of SCEAW was determined to meet the acceptance criteria of AOO(Anticipated Operational Occurrence)[2].

As a result of sensitivity study, the ROPM increased as the extending ASI operating range for all power condition as shown Table III. It was because the axial power distribution assumed in safety analysis was more conservative according to extended ASI operating range. The ROPM was increased due to the extended ASI operating range but the increased ROPMs were within the conventional values. Therefore, it was considered that the increase of ROPM due to the extended ASI operating range will be acceptable in the detailed safety analysis.

Table III: Results of sensitivity for SCEAW

Power	ASI	ROPM, %
Full	±0.3 [Ref. case]	Ref.
	±0.2	↓ 1.5
Low (1)	±0.3 [Ref. case]	Ref.
	±0.2	↓ 1.0
	±0.5	↑ 1.0
Low (2)	±0.3 [Ref. case]	Ref.
	±0.5	↑ 1.5

2.4 Loss of Reactor Coolant Flow(LOF)

The sensitivity study for LOF was performed by evaluating the peak pressure for the full power condition. The safety analysis was performed by ±0.2, ±0.3 and ±0.5 ASI. Fig. 2 shows the scram curve for the ASI operating range used in the safety analysis. As the ASI operating range extends, the insertion of the scram reactivity by control rod drop was delayed.

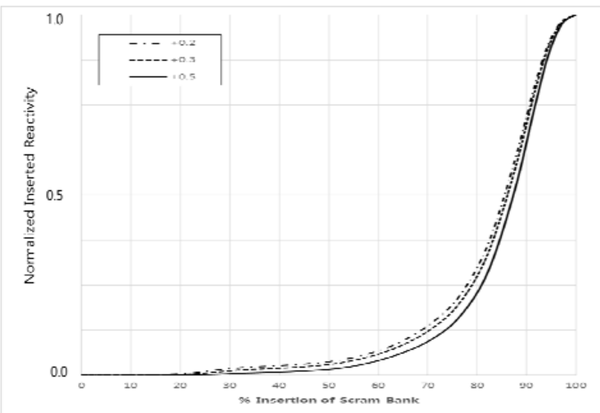

Fig.2. Scram curve according to ASI used in the peak pressure evaluation

As a result of sensitivity, the primary system(RCS) peak pressure increased as the extending ASI operating range. However, the secondary system(S/G) peak pressure did not changed as shown Table IV. And those results met acceptance criteria[2]. The reduction of core power was delayed more conservatively as the scram curve according to the extending ASI operating range. This change in scram curve did not affected the peak pressure of secondary system.

Table IV: Results of sensitivity for LOF

ASI operating range	Peak pressure, psia	
	RCS	S/G
±0.3 [Ref. case]	Ref.	Ref.
±0.2	↓ 8	same
±0.5	↑ 14	same

3. Conclusions

As a results of sensitivity study, the ROPM decreased due to reduction of ASI operating range at the full power condition. At the low power condition, the ROPM increased with ASI operating range expansion, but it was within the normal ROPM value. For the peak pressure according to ASI operating range, the peak pressure of RCS increased with extending ASI operating range, but it was assessed to meet the acceptance criteria[2]. The peak pressure of secondary system was found to have no significant effect on the ASI operating range. In conclusion, the extended ASI operating range worsened some safety analysis results, but the results were met the acceptance criteria. The extended ASI operating range is expected that the efficiency of plant operation for the load-follow.

In the future, detailed safety analysis will be performed by applying ASI operating range for the load-follow operation.

REFERENCES

[1] NRC Regulatory Guide 1.77, “Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors”, May 1974.

[2] NRC Regulatory Guide 1.70, Revision 3, “Standard Format and Content of Safety Analysis Reports for Nuclear power Plants”, November 1978.