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Improvement of the PSA model using a best-estimate thermal-hydraulic analysis of LOCA scenarios

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1. Introduction

In the probabilistic safety analysis (PSA) of Korean Standard Nuclear Power Plant (KSNP), loss-of-coolant accidents (LOCA) are classified into three scenarios by the break size, such as large-, middle-, and small-break LOCA. The specific break sizes were adopted to identify the boundaries of the three groups in the previous PSA model [1] and the success criteria has been conservatively applied to each state of safety system in the event tree.

This study was performed to propose both new success criterion and heading of the event tree by using best-estimate analysis of each LOCA scenario, aiming at the improvement of the PSA models. The MARS code was used for the thermal-hydraulic analysis of LOCA and the Ulchin units 3&4 were selected as a reference plant in this study.

2. Calculation Procedure and Results

For the PSA model improvement, the following conditions were analyzed:

1) The integrity of nuclear fuel during the large-break LOCA with or without high-pressure safety injection (HPSI) system.
2) The integrity of nuclear fuel during the middle-break LOCA with or without low-pressure safety injection (LPSI) system.
3) The integrity of nuclear fuel during the small-break LOCA without the HPSI system and with rapid primary depressurization.

Based on the results, the transition break sizes can be changed.

2.1 Calculation of LOCA with various conditions

The conditions of the safety system, including LPSI, HPSI and auxiliary feedwater (AFW), are divided into nine cases during the LOCA and they are listed in Table 1. The safety injection tanks (SIT) were assumed to be always available. Break sizes ranging from 1 inch to 32 inch were considered.

With the given initial and boundary conditions [2], the LOCA calculations for 154 cases were carried out by the ASME PRA standard [3]. If the peak cladding temperature (PCT) exceeded 1,500 K, the calculation was terminated because it does not meet the LOCA acceptance criterion in 10CFR 50.46.

Table 1 Conditions of the safety systems for the LOCA analysis

	HPSI	LPSI	AFW
Case A1	0%	100%	100%
Case B1	50%	100%	100%
Case C1	100%	100%	100%
Case A2	0%	100%	0%
Case B2	50%	100%	0%
Case C2	100%	100%	0%
Case A3	0%	0%	0%
Case B3	50%	0%	0%
Case C3	100%	0%	0%

Fig. 1 shows results of the MARS calculations for the cases A1, B1, and C1 in Table 1, presenting the PCTs of each calculation. When the break size is greater than 3.2 inch, the integrity of nuclear fuel would be assured without the HPSI. On the contrary, when the break size is less than 3.2 inch, the nuclear fuel would be damaged if the HPSI is not available.

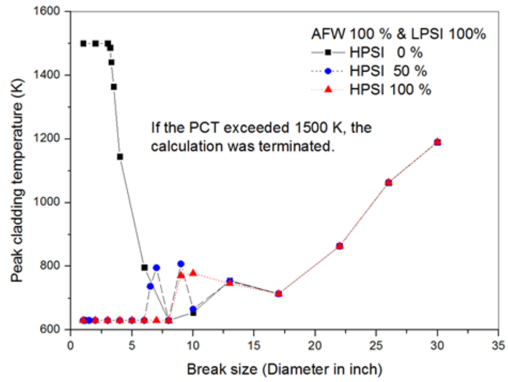

Fig. 1. The effects of the HPSI and the break size on the PCS when the AFW and the LPSI are available.

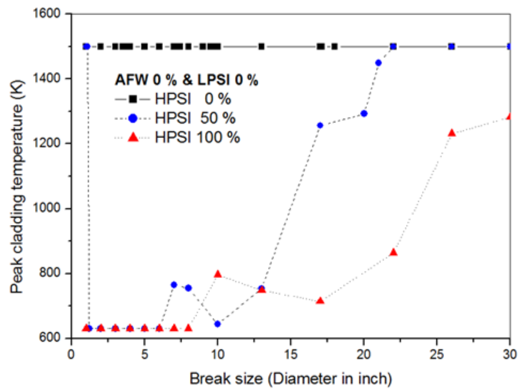

Fig. 2. The effects of the HPSI and the break size on the PCS when the AFW and the LPSI are not available.

Fig. 2 shows results of the PCTs of each calculation for the cases A3, B3, and C3. If the HPSI is not available, the nuclear fuel would be damaged for the all break sizes. The integrity of nuclear fuel would be assured under the middle-break size without the HPSI.

For the PSA model improvement, the results of the MARS calculation were reflected to improve the event trees [4].

2.2 Event Tree Modifications

2.2.1 Large-Break LOCA

The large break is defined as any break in the cold leg greater than 6-inch in diameter. If an LBLOCA occurs, the RCS reactor coolant is discharged into the containment in a few seconds and then the RCS is rapidly depressurized. As a result, the HPSI, SIT, and LPSI actuate, injecting the cooling water into the RCS to maintain the integrity of nuclear fuel.

Fig. 3 shows the old and new event tree for LBLOCA. In the old event tree, the availability of HPSI was not taken into account. The MARS calculations showed that, even without the LPSI, the PCT remains below 1,500 K If 100% of the HPSI is available. Thus, in the new one, the HPSI is added as a new heading of the event tree and it is proposed as a success criteria.

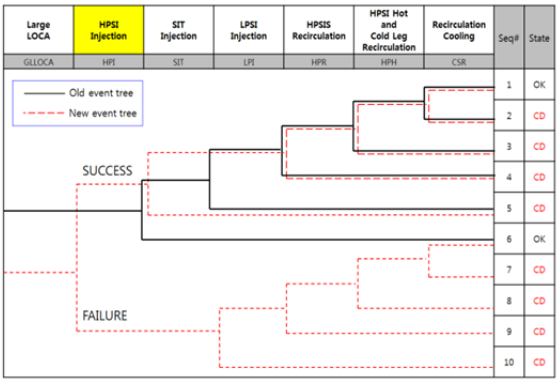

Fig. 3. The old and new event tree for LB LOCA

2.2.2 Middle-Break LOCA

The middle break is a break ranging from 2-inch to 6-inch in diameter. In the early phase of the accident, the primary pressure is higher than the shutoff head of LPSI pump. The coolant cannot be injected into the RCS. For this reason, the LPSI is not considered in the old event tree. However, for the breaks greater than 3.2 inches, the integrity of nuclear fuel would be assured because the SIT and the LPSI are available. The calculation results were reflected to the event tree in the Fig. 4.

2.2.3 Small-Break LOCA

The small break is a break ranging from 3/8-inch to 2-inch in diameter. In the case of an SBLOCA, the RCS is slowly depressurized. The reactor is usually tripped by the low RCS pressure signal. However, since the RCS remains long at a relatively high pressure, the SIT and LPSI may not inject the water into the RCS. The transient is rather mild and complicated in comparison with those of middle-break LOCAs. This, in turn, implies the possibility of operator action to mitigate the transients. If the operator depressurizes the RCS rapidly, e.g., by using the atmospheric dump valves in the steam line, the SIT and LPSI can cool down the reactor core. Thus, it is necessary to analyze the effects of operator actions and to implement the results into a new event tree [5]. This is being conducted.

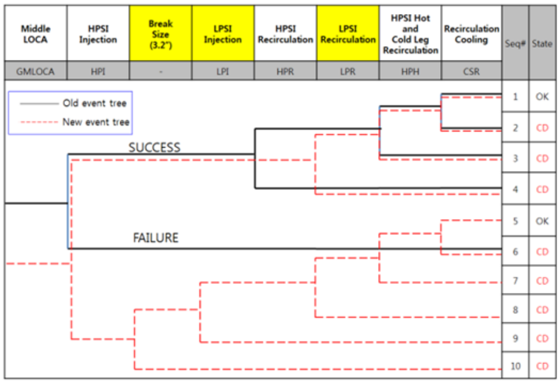

Fig. 4. The old and new event tree for MB LOCA

3. Conclusions

This study was performed to improve the PSA model of three LOCA scenarios by using best-estimate thermal-hydraulic analysis. The LOCA calculations with various configurations of the safety systems and break sizes were performed. Using the results, we proposed both new success criterion and heading of the small- and middle-break LOCA scenario. The small-break LOCA will be analyzed later in terms of operator actions to depressurize the RCS. The results of this analysis may contribute to improve the PSA model of LOCA.

REFERENCES

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