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A Preliminary Study for the Analysis of PSA Success Criteria for Kori Units 3&4

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1. Introduction

This paper identifies the event sequences that require thermal-hydraulic analyses for the success criteria of probabilistic safety analysis (PSA). The selection of the sequences is performed based on the review of the NEI Peer Review Process Guidance [1] and ASME PRA Standard [2].

Success criteria are the important element of PSA quality. Success criteria decide the success or failure of the key function in the PSA event tree. It is defined as a minimum set of components/trains of system required to mitigate an accident. Thermal-hydraulic codes are generally used to derive time-related criteria in the PSA, such as operator action time used in human reliability analysis (HRA), event timing, and time to recover the component or the power.

This paper suggests the use of the MARS code for the T-H analysis to obtain the success criteria and sequence timing, and operator action time. In the Kori Units 3&4 PSA report [3], the T-H analyses for those criteria were performed by the MAAP code. However, since the MAAP code was developed for severe accident analysis, it has limitations when applied to the success criteria in the PSA. The NEI peer review has also recommended that the MAAP code should be used within its known limitations [4]. The MARS code is more suitable to perform a plant specific analysis because it describes the behavior of RCS fluid more realistically than the MAAP code.

2. Review on the Success Criteria

This paper analyzes the event trees of initiating events in the Kori Units 3&4 PSA report. Important accident sequences and their success criteria of the top events in the small LOCA event tree are identified. Then, the success criteria of the high pressure safety injection system are identified among the systems which are involved in the PSA event tree. Last, this paper provides a brief rationale for the use of the MARS code to replace the MAAP code.

2.1 Success criteria with initiating event

The thermal-hydraulic analyses of the initiating event used to define the success criteria include small LOCA, medium LOCA, large LOCA, LOFW, SBO, LOCCW, and SGTR. Small LOCA is considered in this paper for further study. The break size of small LOCA ranges from 3/8 inch to 2 inches in the Kori Units 3&4 PSA. The break size of a 1 inch diameter is considered as the representative accident in the Kori Units 3&4 PSA. When the small LOCA occurs, the reactor is tripped and then a safety injection (SI) signal is generated by low PZR pressure. And then the SI signal starts the high pressure safety injection (HPSI) pump and low pressure safety injection (LPSI) pump sequentially. The main feedwater pump is stopped by a SI signal and a motor-driven auxiliary feedwater pump (MD-AFWP) starts. At the beginning of the event, the HPSI pump plays an important role in mitigating the accident. Figure 1 shows the event tree of small LOCA and the selected cases.

Fig. 1. Event tree of small LOCA

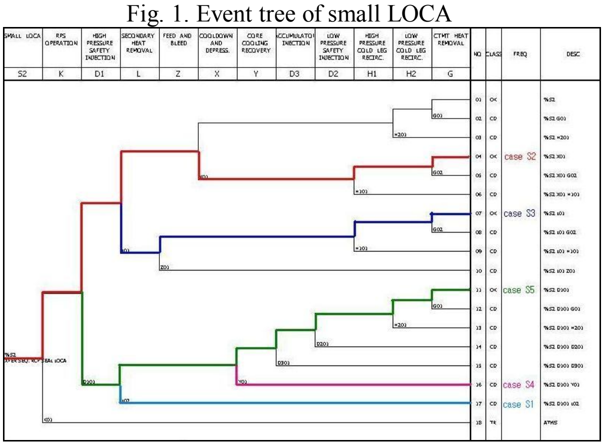

Table I: Thermal-hydraulic results of small LOCA

Event\time(min)	S1	S2	S3	S4	S5
Event begins	0.0	0.0	0.0	0.0	0.0
Reactor trip by low PZR press.	3.3	3.3	3.3	0.7	0.7
SIAS on	3.7	3.7	3.7	1.0	1.0
HPSI starts	-	3.7	3.7	-	-
SG dries out	60.1	-	-	-	-
SIT injects	-	-	-	-	60.7
LPSI starts	-	-	-	-	67.8
Core uncover	84.0	-	-	47.2	47.2
Feed and Bleed	-	-	60.0	-	-
Core outlet gas temp> 700°F	85.1	-	-	50.7	50.7
Core outlet gas temp> 1200°F	95.0	-	-	57.2	57.2 CCR
Peak cladding temp> 1800°F	103.3	-	-	62.2	-
End time	500.0	1000.0	1000.0	500.0	1000.0

This work analyzes the success criteria, operator action time, and system response time for five representative cases in the small LOCA. Case S1 is the basecase that shows how the behavior of primary and secondary side progresses when the recovery action is not performed since the reactor trip. Case S2 and Case S3 are selected by whether the secondary heat removal (SHR) by the MD-AFWP is performed or not, after the HPSI pump starts. Case S4 and Case S5 are chosen according to success or failure of the action of the core cooling recovery (CCR) when the HPSI pumps fail to start and SHR is done successfully. It is considered that the selected cases are adequately representative in the event tree of small LOCA for the existing analyses. Operator action time and response time of the system such as safety injection time are shown in Table I.

2.2 Success criteria of system

Eight systems are related with the heading of event tree directly in the Kori Units 3&4 PSA. They are high pressure injection system, low pressure injection system, safety injection tank system, pressurizer pressure relief valve system, containment heat removal system (containment spray system, containment fan cooler system), auxiliary feedwater system, main feedwater system, and main steam supply system.

This work chose the high pressure injection system for further analysis, since the system is the first actuated system after the trip in preventing core damage and so it is critical in the PSA. The headings of the event tree related to the high pressure injection system include:

- D1 (High Pressure Injection)
- Z (Feed and Bleed)
- H1 (High Pressure Cold Leg Recirculation)
- H4 (High Hot Leg Recirculation)
- U (Long Term Cooling)

Tables II and III show the initiating events and the success criteria related with the high pressure injection system. The initiating events can use different success criteria for the same system. The success criteria of the feed and bleed are equal to all the initiating events except for the time to start the action.

Table II: Success criteria of heading D1 (HPSI)

Initiating Event	Success Criteria
Small LOCA, SGTR, MSLB	Inject borated water from RWST to at least 1 of 3 cold legs using 1 of 3 HPSI pumps
Medium LOCA	Inject borated water from RWST to at least 1 of 2 intact cold legs using 1 of 3 HPSI pumps

Table III: Success criteria of heading Z (Feed & Bleed)

Initiating Event	Success Criteria
Small LOCA, LOFW, LOCV, MSLB	Inject borated water from RWST to at least 1 of 3 cold legs using 1 of 3 HPSI pumps and bleed RCS inventory using 2 of 3 PZR PORV within 50min after event
TLOFW, LOOP, SBO	Inject borated water from RWST to at least 1 of 3 cold legs using 1 of 3 HPSI pumps and bleed RCS inventory using 2 of 3 PZR PORV within 35min after event

In the case of feed and bleed (F&B), the bleed action should be taken within 5 min after the dry-out of SG from the beginning of the accident to prevent core damage [5]. Therefore, the time to the dry-out of the SG is equivalent to the operator action time which is 60 min in the small LOCA and 55 min in the loss of feedwater flow (LOFW). The time to start F&B after the beginning of the small LOCA is conservatively selected as 50 min. The existing PSA uses the MAAP code to calculate this time.

2.3 Rationale using the MARS code

As an ongoing work, analysis of the success criteria for the five sequences addressed above is being performed by using the MARS code. The MAAP code that has been used for the existing PSA was developed for severe accident analysis. Due to the very fast speed of calculation, ease of use, and relation of level 2 PSA analysis, the MAAP code has been used very widely for thermal-hydraulic analysis of the PSA in US nuclear power plants. The MARS code is superior in simulating realistically the thermal-hydraulic behavior of a nuclear steam supply system (NSSS). However, it consumes more time in the calculation than the MAAP code. According to the peer review results by NEI guidance and ASME PRA Standard, accidents such as a blowdown of large LOCA and ATWS should be calculated by one of best-estimate codes. The first analysis is being performed for the small LOCA by using the MARS code and will be followed by other initiating events such as medium LOCA and large LOCA.

3. Conclusions

The event trees on small LOCA and the success criteria of the system related to accident mitigation were analyzed based on the review of NEI guidance and ASME PRA Standard. The KHNP is conducting the calculation of the success criteria of accidents and systems using the MARS code as future work.

The MARS code analysis is expected to provide more precise results than MAAP analysis results. The realistic TH analysis results will contribute to the improvement of PSA quality.

REFERENCES

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