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Review of SFR Design Safety using Preliminary Regulatory PSA Model

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1. Introduction

SFR (sodium-cooled fast reactor) which is Gen-IV nuclear energy system, is designed to accord with the concept of stability, sustainability and proliferation resistance. KALIMER-600, which is under development in Korea, includes passive safety systems (e.g. passive reactor shutdown, passive residual heat removal, and etc.) as well as active safety systems.

Risk analysis from a regulatory perspective is needed to support the regulatory body in its safety and licensing review for SFR (KALIMER-600). Safety issues should be identified in the early design phase in order to prevent the unexpected cost increase and delay of the SFR licensing schedule that may be caused otherwise. The major objective of this research is to develop a risk model for regulatory verification of the SFR design, and thereby, make sure that the SFR design is adequate from a risk perspective. In this paper, the development result of preliminary regulatory PSA model of SFR is discussed[1].

2. Identifying Initiating Events

In the PRA analysis, the first step is a proper grouping of the similar initiating events through type analysis. The initiating events that can cause reactor shutdown have the potential to induce core damage when it was accompanied by a failure of safety systems.

In case of SFR, the initiating events that are considered in the operating LWR (Light Water Reactor), such as General Transient and Loss off Off-site Power and so on, also have a potential to happen. Furthermore, it must be considered the initiating events caused by the inherent characteristics of SFR, such as Vessel Leak and sodium water interaction in SG and so on.

Because the SFR design is an early stage and supporting systems (e.g, electrical system and component cooling water system) are not designed yet, supporting system initiating events (e.g. in case of light water reactor, Loss of electric 4.16 kV bus, Loss of 125V electric DC bus, Loss of CCW) are not considered in this regulatory PSA model.

In this study, the initiating events are identified referencing the current LWR PRA, PRISM and ASTRID design, and also the KALIMER-600 design.

○ General Transients
○ Loss of Offsite Power
○ Station Blackout
○ Loss of Flow
○ Vessel Leak
○ Reactivity Insertion
○ Sodium Water Interaction in SG
○ Loss of All RHR
○ Local Core Coolant Blockage (> 6 sub-channels)
○ Main Steam Line Break

3. Development of Event Trees

In this study, based on the selected preliminary initiating events for SFR, the event trees for ten initiating events are developed. These event trees have been developed referencing the event trees of KALIMER/DEMO 600 [2] and the key assumptions to be used for it are as follows:

(1) Following an event sequence of KALIMER-600 safety analysis[3], heat removal heading with residual heat removal system is classified with ADHRS (Active Decay Heat Removal System) and PDHRS (Passive Decay Heat Removal System)

(2) In regulatory PRA model, the heat removal is performed using an auxiliary feedwater tank during only 30 minutes. And then, after 30 minutes, a stable core cooling is possible only if follow-up actions for long-term cooling such as a suppliance of auxiliary feedwater tank are performed..

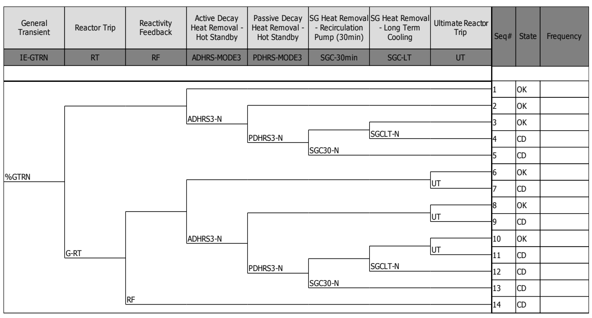

Figure 1. General Transient Event Tree

4. Preliminary Quantification Results

At this stage, fault trees of regulatory PSA model have been developed with minor modification of KAERI fault trees [3]. Fault trees of supporting systems (e.g, electrical power system and cooling water system, etc) had not been developed because they are not designed yet. According to the report on the KAERI PSA model, the failure rate of PDRC/ADRC dampers is the most significant contributor on CDF. In the regulatory PSA model, the following three cases related the PDRC/ADRC dampers were reviewed.

[Case 1] It is assumed that the model types of PDRC and ADRC dampers are same. Same CCF factors with those of KAERI PSA are used for PDRC and ADRC dampers.

[Case 2] It is assumed that the model types of PDRC and ADRC dampers are same. CCF factors of the value presented in NUREG/CR-5497 (2010) are used for PDRC and ADRC dampers.

[Case 3] It is assumed that the model types of PDRC and ADRC dampers are different, and there is no CCF mechanism between them. CCF factors of the value presented in NUREG/CR-5497 (2010) are used for PDRC and ADRC dampers.

Table 1. Assumptions of PDRC/ADRC Damper Failure Probability and CCF

Case	PDRC/ADRC Damper Assumption		
	Fail to Open Prob. of Damper	Damper CCF factor (alpha)	Damper CCCG
Case 1	1e-5 (PDRC/ADRC Damper)	KAERI Data	4 (PDRC/ADRC Damper)
Case 2	1e-5 (PDRC /ADRC Damper)	NUREG/CR-5497 (2010)	4 (PDRC/ADRC Damper)
Case 3	1e-5 (PDRC Damper) 1e-3 (ADRC Damper)	NUREG/CR-5497 (2010)	2 (PDRC Damper) 2(ADRC Damper)

Table 2 shows the preliminary CDF quantification result (8.10E-08 ~ 2.50E-07). The results show that the value of CDF can be changed significantly depending on the assumption of CCCG and CCF factor of dampers. In Case 1, the most important initiating event was Loss of Flow (Intermediate Flow, Secondary Flow) similar to that of KAERI PSA model. It is because the assumption of CCCG and CCF factor of dampers in Case 1 was similar to that of KAERI PSA model. In Case 2, the most important initiating event was Loss of All RHR (47% of total CDF). In Case 3, the most important initiating event was Loss of All RHR (74% of total CDF).

In case of Loss of All RHR initiating event, the only remaining mitigation system is SG heat removal system. Therefore, the CDF contribution of SG heat removal system can be significant in Case 2 and 3.

Table 2. Preliminary CDF Results of SFR Regulatory PSA Model

Case	CDF (/yr)	Important Initiating Event (CDF Contribution)
Case 1	2.50E-07	Loss of Flow (53%)
Case 2	1.29E-07	Loss of All RHR (47%)
Case 3	8.10E-08	Loss of All RHR (74%)

5. Conclusion

In this paper, development and quantification result of preliminary regulatory PSA model of SFR is discussed.

It was confirmed that the importance PDRC and ADRC dampers is significant as stated in the result of KAERI PSA model. However, the importance can be changed significantly depending on assumption of CCCG and CCF factor of PDRC and ADRC dampers.

ACKNOWLEDGMENT

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REFERENCES

[1] Korea Institute of Nuclear Safety, Development of Regulatory PSA Models of SFR (1st year), KINS/HR-1264

[2] Korea Atomic Energy Research Institute, Conceptual Design Report of SFR Demonstration Reactor of 600MWe Capacity, KAERI/TR-4598/2012

[3] Korea Atomic Energy Research Institute, Probabilistic Safety Assessment for KALIMER-600 Conceptual Design II, KAERI/TR-4700/2012

[4] P.Gauthe et al., Use of simplified PSA studies in support of the ASTRID design process, ICAPP 2012

[5] General Electirc, PRISM PSID Volume IV (Ch 15-17)

[6] CCF Parameter Estimations 2010, NUREG/CR-5497 /2010