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Preliminary Development of Regulatory PSA Models for SFR

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1. Introduction

The deterministic safety analysis method has been used in the design and licensing review of NPPs (Nuclear Power Plant) for the last thirty years. However, the PRA (Probabilistic Risk Assessment) could contribute to the risk identification of important configuration and thus to enhancing the safety of NPP.[2] Well developed PRA methodology exists for LWR (Light Water Reactor) and PHWR (Pressurized Heavy Water Reactor). Since KAERI is developing a prototype SFR targeting to apply for a license by 2017, KINS needs to have a PRA models to assess the safety of this prototype reactor. The purpose of this study is to develop the regulatory PSA models for the independent verification of the SFR safety. Since the design of the prototype SFR is not mature yet, we have tried to develop the preliminary models based on the design data of KAERI's previous SFR design.

2. Development concept of regulatory PSA models for SFR

In this study, the regulatory PSA models of SFR were developed based on the following concepts [1]

○ Evaluate the overall safety level of NPP through CDF (Core Damage Frequency) caused by all kinds of internal initiating events.

○ Confirmation of the response ability to each initiating event through relative comparison and review of CCDP (Conditional Core Damage Probability) to initiating event.

○ Evaluate the vulnerability to specific operator error and common cause failure which have a serious impact on safety through performance of a sensitivity analysis.

○ Evaluate whether the plant has sufficient defense-in-depth and safety margins. Evaluate also whether the SCC (Structures, Systems, and Components) is designed to keep independence, diversity and redundancy

3. Selection of preliminary initiating events for SFR Level 1 PRA

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 [3] 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.

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

1. Initiating events that are used in the PRA of operating LWR (with the exception of initiating events by the failure of auxiliary system) [2]
2. Initiating events that are considered in PRA for PRISM [5] and ASTRID [6]
3. Initiating events that are considered in PRA model for KALIMER-600 of KAERI [1],[4]

As the result, ten initiating events are selected as preliminary regulatory model. Table 1 shows the comparison of these initiating events with that of KAERI model. For example, when reactor shutdown and reactivity feedback fails, the heat removal using the main feedwater is considered in KAERI model, but the in our regulatory model it is deleted because the basis for this could not be clearly identified.

Table 1. Comparison of initiating events between regulatory model and KAERI model

	The preliminary initiating events of regulatory verification model	The initiating events of KAERI model [1]
1	General Transients	General Transients
		Loss of Primary Loop Flow
2	Loss of Offsite Power	Loss of Normal Electrical Power
3	Station Blackout	
4	Loss of Flow	Loss of Intermediate Loop Flow
		Loss of Secondary Loop Flow
5	Vessel Leak	Vessel Leak

6	Reactivity Insertion (Control Rod Withdrawal, Speed Increase of Primary Pump or Intermediate Pump, Gas Passing through the Core)	Reactivity Insertion
7	Sodium Water Interaction in SG	Sodium Water Interaction in SG
8	Loss of All RHR	PDRC Unavailable
9	Local Core Coolant Blockage (> 6 sub-channels)	None
10	Main Steam Line Break	Main Steam Line Break

4. Development of preliminary event for SFR Level 1 PRA

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 [1] and the key assumptions to be used for it are as follows:

1. In general, to maintain the stable hot shutdown state is defined as success criteria in terms of core damage in PRA for LWR. However, in this regulatory PRA models, maintaining the stable hot standby state is defined as a success criteria.
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.
3. In case of a reactivity accident, the reactivity feedback is not considered conservatively.

Fig. 1 and 2 show a part of the ten event trees that were developed.

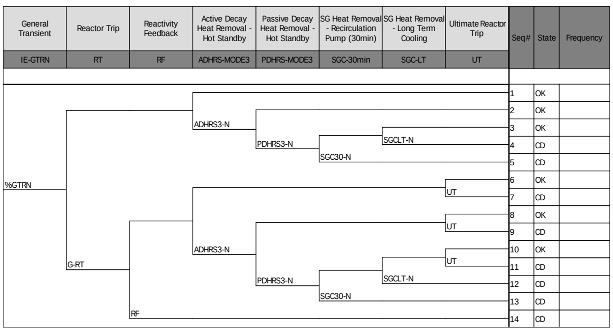

Fig. 1. Event Tree of General Transient (Ex)

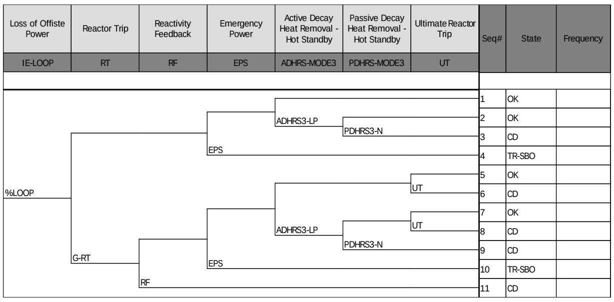

Fig. 2. Event Tree of Loss of Offsite Power (Ex)

5. Conclusions

In this study, the preliminary initiating events of level 1 internal event for SFR were selected through reviews of existing PRA (LWR, PRISM, ASTRID and KALIMER-600) models. Then, the event tree for each selected initiating event was developed.

The regulatory PRA models of SFR developed are preliminary in a sense, because the prototype SFR design is not mature and provided yet. Still it might be utilized for the forthcoming licensing review in assessing the risk of safety issues and the configuration control of the design.

REFERENCES

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