Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

Study on Deterministic Regulatory Framework for the Development of Safety Analysis System of Sodium Fast Reactors

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1. Introduction

Since late 1980s, power reactor innovative small module (PRISM) liquid-metal reactor has been developed in U.S., and Korea Advanced Liquid Metal Reactor (KALIMER) in Korea as a Sodium Fast Reactor (SFR). Recently, further elaborating is encouraged on the research and development program for Generation IV reactors, and in collaboration with other interested countries through the Generation IV International Forum (GIF). Korea also takes part in that program and plans to construct a demonstration reactor of SFR.

In light of the development of SFRs in the midst of the licensing and safety basis primarily tailored to Light Water Reactors (LWRs), there is an urgent need to establish a new licensing and safety analysis framework that is reliably applicable to SFR. The insights from the Probabilistic Safety Assessment (PSA) tend to be increasingly used to improve the deterministic approaches. And, in the early 2000s U.S. NRC has developed Technology-Neutral Framework (TNF). TNF also has been criticized because the reliability of PSA in its design step is suspected and the conventional deterministic approach has played a successful role for the safety of LWR [1].

The objective of this study is to derive technical insight from critical review of past safety analysis approach for a regulatory framework for safety analysis of SFR in the position of deterministic approach with partially adopting the strong points of risk-informed approach for TNF approach in future.

2. Design Features of SFR: KALIMER-600

Fig.1 shows the layout of KALIMER-600 system [2]. Overall system is composed of primary heat transport system (PHTS), intermediate heat transport system (IHTC), residual heat removal system (RHRS), steam generator system (SGS), and so on. Noticeable design features of KALIMER-600 can be listed as followings

- Pool Type
- 20% enriched metal fuel
- 2 Loop IHTS
- Triple decay heat removal systems
    - PDRC (Passive decay heat removal circuit , Passive)
    - IRACS (Intermediate Reactor Auxiliary Cooling System , Active)
    - FW/SG (Feedwater/Steam Generator)

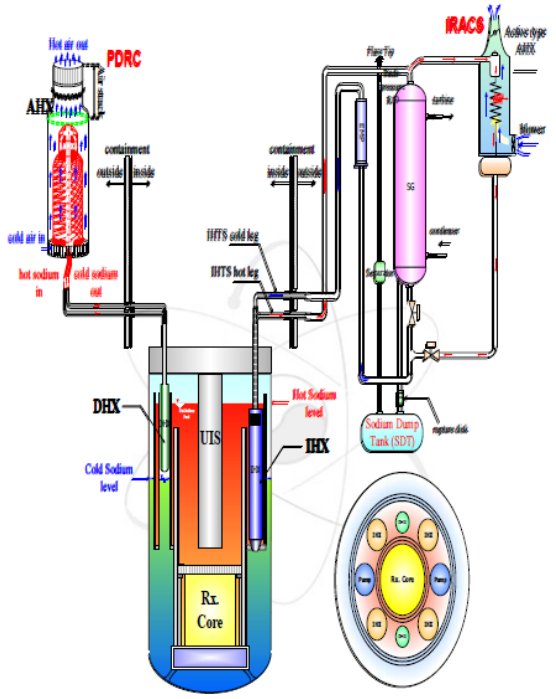

Fig. 1 Layout of KALIMER-600 system

3. Review of Deterministic Regulatory Framework for Safety Analysis

One plausible logic tree to identify the attributes of licensing structure to assure safety of reactor is shown in Fig.2 [3]. The top goal of 'Safety Assurance of Advanced Reactors' can be satisfied if the three goals are achieved. For safe design, the following three subgoals should be satisfied: 'Proper Selection and Categorization of Events', 'Proper Establishment of Acceptance Criteria', and 'Proper Classification of Equipment'. Among these three, the first two are important. And it is indicated in Fig. 2 that the two principles of defense in depth (DID) and safety margin, among others, will keep playing an utmost important role even in assuring safety of advanced reactors.

Conventional deterministic approach for the subgoals above has evolved during several decades: ANSI N18.2, regulatory guide 1.73, ANSI/ANS-51.1, regulatory guide 1.206, standard review plan (SRP) chapter 15, and so on. From the earlier standards, there have been the concepts of barrier integrity criteria in connection

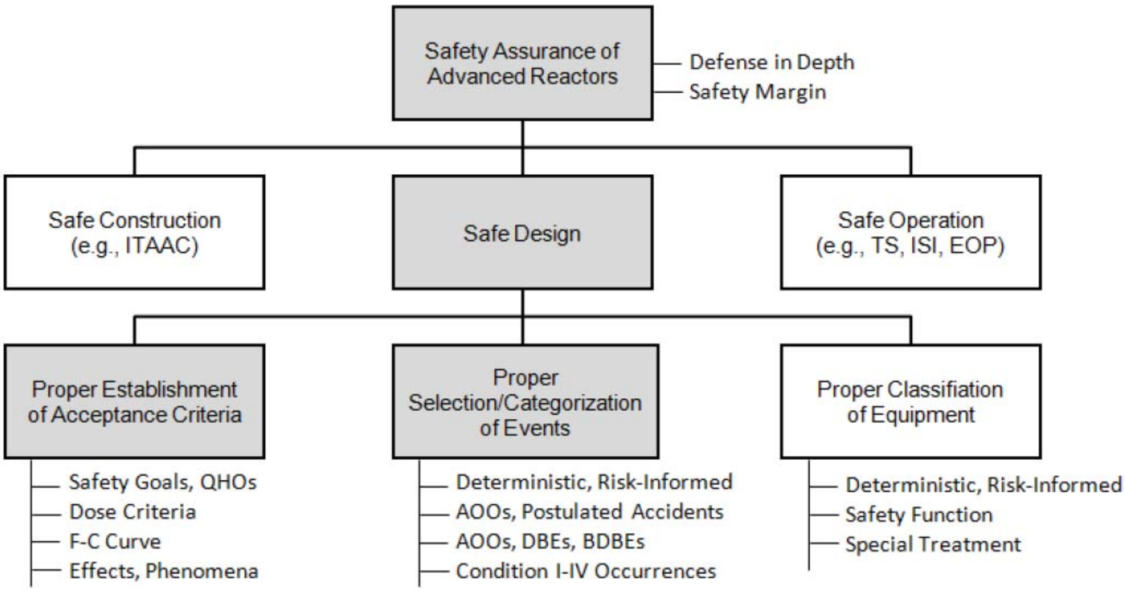

Fig. 2. Logic tree for safety assurance

with the condition occurrences, plant safety analysis for the condition occurrences, design criteria for the reactor core and various systems, and so on. In particular, intensive review on the comparison of event categories leads to the insight for the deterministic approaches;

- Selection of initiating events was considered more important than the event sequences: PSA can complement the selection of initiating events
- Categorizations of initial events in conventional methods seem essentially same each another.
- Another classification of initial events is based on the type of transients. Such classification eases selecting bounding event.
- Concept of quantitative frequency of occurrence was used and the initiating events are reassigned to lower frequency categories after combining with single failures and coincident occurrences.
- DID principle for physical barriers was applied in establishing acceptance criteria.

4. Conclusions and Conceptual Suggestion

Regulatory framework for the safety analysis of SFR is now under development, and critical review of conventional LWR approaches was conducted. Detailed level of development of safety analysis system will be filled up according to the progress of our research. And our research will address the development of PIRT and review of related experiments and assessments for the sake of completeness of its applicability.

From the review of deterministic safety analysis methods we can get some insights for SFR safety analysis considering its unique design features. Classification of initial events according to the transient type is totally based on its design features. Multiple categories for initial events according to frequency of occurrence are desired. Initial events outside the categories may be corresponding to the beyond design basis event (BDBE) and some may lead to severe accidents. Boundaries of each category are expected to be similar to those of conventional LWRs. Such an approach will give the convenience and familiar way in setting up the acceptance criteria.

Acceptance criteria should be setup in the fundamental concept of DID: offsite consequence limit and barrier integrity limit should be imposed. One candidate of barrier integrity limit may be temperature limit. Single failure and concurrent occurrence should be considered in the actual safety analysis. Conservative setting for the initial operation values is also an effective method for the compensation of uncertainties.

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