Development of A New Framework for the Integrated Risk Assessment of All Modes/All Hazards

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1. Introduction

Nowadays, the PSA (Probabilistic Safety Assessment) is widely recognized as an essential tool to enhance both the safety and economy of nuclear facilities. The use of the PSA has been expanded from the just safety assessment to the daily operational support [1]. Furthermore, recently, the PSA plays the critical role in optimizing the design of new NPPs (Nuclear Power Plants) [2].

Even though, the traditional PSA has worked very well during the last several decades in many areas, it still has many limitations.

As the application scope of the PSA has been expanded continuously, the requirements on the PSA has become stricter than those of the past, e.g. the requirements on the PSA quality [3] and the extended scope of analysis [4], etc. It is clear that such stringent requirements are related to the limitations of the current PSA.

In this paper, we have reviewed the limitations of the current PSA, and proposed a new framework to handle one of the new requirements i.e. the extended scope of the PSA.

2. The Limitations of the PSA

There are various limitations in the current PSA, some of them are intrinsic and others are extrinsic.

Uncertainty is a typical long and ever-lasting intrinsic issue in the PSA. It is well known that there are three types of uncertainties: parametric, modeling and completeness [5]. In addition, we still lack of the knowledge in some areas, e.g. the exact assessment of the common cause failure (CCF), the human reliability, the seismic hazard and/or the severe accident phenomena, etc. Some new issues are emerging such as the assessment of the DI&C (Digital Instrument and Control) reliability and various performance measures, etc. There are some extrinsic limitations such as the documentation issue, and the requirements on the extended scope of the PSA, etc.

All of the limitations can be categorized into three groups: ones related to (1) uncertainty, (2) consistency, and (3) efficiency.

KAERI is performing various researches regarding the CCF, human performance, DI&C, the seismic hazards, etc. to overcome those limitations [6]. We have to overcome such challenges in order to properly expand the risk-informed approach.

In this paper, however, we will confine the issue related to the consistency and efficiency of the current PSA. We propose a new framework to enhance the consistency and efficiency of the PSA related to the extended scope of the PSA.

3. The Integrated Risk Assessment Framework

3.1 Extended Scope of the PSA for the Risk-informed Applications

Even though, we have used the results of Level 1 and limited Level 2 internal PSA for most risk-informed applications, in principle, the PSA for the risk-informed application should cover the risks from all mode and all hazards [4]. In addition, the NRC (Nuclear Regulatory Commission) requires that the SAR (Safety Assessment Report) for the D.C. (Design Certification) of new NPPs should include the PSA for all modes and all hazards that are listed in Table 1 [7].

Table 1. Models and Hazards to be Analyzed in PSA

Mode	Level / Hazards	Level 1	Level 2	Level 3
Full Power	Internal	CDF	LRF	Fatality
	External (Flooding/Fire/External)	CDF	LRF	Fatality
Low Power/Shutdown	Internal	CDF Fuel Damage	LRF	Fatality
	External (Flooding/Fire/External)	CDF Fuel Damage	LRF	Fatality

* CDF: Core Damage Frequency/** LRF: Large Release Frequency

Such extended scope of the PSA requires a lot of resources since the scope of modeling has increased by an incredible amount. In addition, the traditional way of performing the PSA may have problems in its consistency and efficiency. Since the external PSA model is developed manually from the internal PSA model, resulting in some cases, to a possible inconsistency between models. Since we handle so many models, it is difficult to change the models in the case that some changes may occur in the internal PSA model.

So KAERI is developing a more systematic and efficient framework for the risk assessment of all modes and all hazards. In order to build such framework, we need the new algorithm to enhance the efficiency of the modeling and quantification process and new PSA tools for implementing a new algorithm. These will be explained in the following sections.

3.2 New Algorithm for the Integrated Risk Assessment

For the integrated risk assessment, we have to develop new algorithms such as for (1) the integration of Level 1/2 PSA models [6], (2) the integration of full power and low-power/shutdown PSA models [8], (3) the integration of internal and external PSA models [9].

The Level 1 and 2 PSA models are integrated through the PDS (Plant Damage State) event tree [6] where the fault tree models for Level 2 PSA uses those of the Level 1 PSA. The fault tree models for the low-power/shutdown PSA can be automatically generated from the full power PSA model by incorporating the condition gate [8]. KAERI is also developing a new modeling algorithm in order to build an external PSA model for a simultaneous single quantification and to avoid the latent contradictory or misleading results [9]. For the details of each methodology, please refer to the references [6, 8, 9].

2.3 New PSA Tools for the Integrated Risk Assessment

KAERI is developing new PSA software for the integrated risk assessment. The new PSA software generates the PSA model for each scope of a PSA automatically from the Level-1 internal PSA model by incorporating the specific information for each scope of the PSA. We are building new PSA software to follow the work flow for each scope of PSA:

1. Define a PSA scope such as an internal model and/or an external model.
2. Manage the typical model such as the event trees and fault trees, and specific information for each PSA scope.
3. Integrate the PSA model where one big fault tree is built from these models.
4. Generate minimal cut sets for one big fault tree using the FTREX.

This work-flow for the integrated fire PSA is described in the Figure 1. The PSA modeling and quantification becomes simpler using the new PSA software.

3. Conclusions

The integrated risk assessment framework is being developed by KAERI. We expect that the developed framework will enhance not only the efficiency of assessment but also the consistency of PSA by generating the non-internal PSA models from the internal one automatically.

. It will enable us to cope with the emerging needs that require the extended analysis scope and applications.

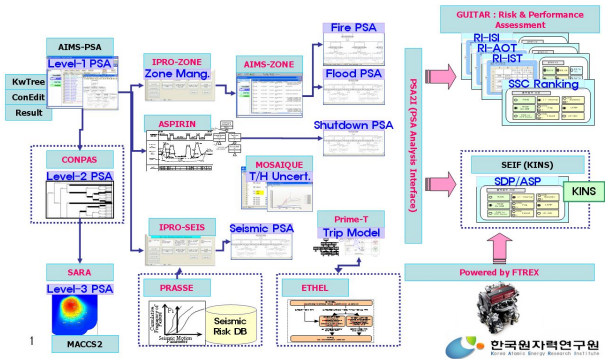

Figure 1. Overall Structure of New PSA Tool for the Integrated Risk Assessment

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