Technical Considerations for the Systems Analysis in SMART PSA

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1. Introduction

SMART (System-Integrated Modular Advanced Reactor) is under developing by Korea Atomic Energy Research Institute (KAERI) for power generation and seawater desalination. It employs advanced design concepts, therefore it is essential to develop the new Probabilistic Safety Assessment (PSA) validation guidance or add and remove some items in the current PSA review guidance considering the unique characteristics of SMART. In this paper major technical considerations for SMART PSA review are suggested as well as a brief discussion of the essential results from the worldwide documentations that can be used in reviewing PSA.

2. Review Results and Considerations

2.1 ASME PRA Standard

ASME PRA Standard provides the overall requirements that can be applied in the current Light Water Reactor (LWR) [1]. The high level requirements for systems analysis that are described in ASME PRA Standard are shown in Table I. Most requirements can be applicable to SMART PSA but it is necessary to devote great care to deal with the mission time. According to the system description of SMART, it is expected that the mission time of a Passive Residual Heat Removal System (PRHRS) will have 36 hours. Therefore its impact should be checked during the review process.

Table I: High Level Requirements for Systems Analysis

Designator	Requirement
HLR-SY-A	The systems analysis shall provide a reasonably complete treatment of the causes of system failure and unavailability modes represented in the initiating events analysis and sequence definition.
HLR-SY-B	The systems analysis shall provide a reasonably complete treatment of common cause failure and intersystem and intra-system dependencies.
HLR-SY-C	Documentation of the systems analysis shall be consistent with the applicable supporting requirements.

2.2 Nureg-1860

The high level attributes for the systems analysis that are described in the Nureg-1860 are shown in Table Ⅱ [2].

Table Ⅱ: Systems Analysis Attributes

Item	Attribute
SY-1	Develop models for systems identified in the accident sequence analysis that include both active and passive component failures, human errors, equipment unavailability due to test and maintenance, and external conditions for which the system will not successfully mitigate an accident.
SY-2	Develop the system models using success criteria that are supported with engineering analysis.
SY-3	Include common cause failures, inter-system and intra-system dependencies (e.g., support systems, harsh environments, and conditions that can cause a system to isolate or trip), alternative alignments, and dependencies on the POS in the system model development.
SY-4	Develop system models for those systems needed to support the systems contained in the accident sequence analyses.
SY-5	Develop system models, as required, to determine how initiating events can occur.

Additionally, it is required that the system analysis for PSAs of new reactors will have to address unique features including simplified and passive systems, digital I&C systems and smart equipment in Nureg-1860. Among this kind of features, passive and digital I&C systems except for smart equipment will be adopted in SMART design. Items for two types of systems in Nureg-1860 are as follows;

- Innovative ways to structure the search for unexpected conditions that can challenge design assumptions and passive system performance will need to be developed and applied to advanced reactor.
- It should be checked that passive system behavior is correctly modeled.
- The technical considerations and guidance for modeling digital I&C systems in PSA needs to be

developed since the systems may have different operational and reliability characteristics than the analog systems used in current LWR.

2.3 IAEA Safety Series

IAEA Safety Series No.25 has similar guidance as the others, but especially the treatment of the passive safety system is described in more detail [3].

According to this document, the followings are mentioned to treat the passive safety system in PSA;

- In principle, treatment of the passive safety system in PSA is the same as that of the passive systems, such as accumulators, and of inherent passive safety features, such as natural circulation of reactor coolant when the pumps are not available. However, the reviewers should pay attention that they must, as with active systems, have been shown to be effective by thermohydraulic analysis and by extensive tests.
- This deterministic demonstration of effectiveness needs to cover the full range of accident conditions for which they are claimed.
- The successful performance of passive systems should be demonstrated within a set of boundary conditions which can only be ensured by the correct system set-up, including the correct configuration of the relevant valves.
- The reviewers need to check that full account is taken of the potential for human error in leaving the system in the proper condition, as well as of all necessary valves which are required to act and any active initiation signals.
- Given the correct boundary conditions, and a satisfactory demonstration of effectiveness, it may be assumed that the system will work.

3. Conclusions

The results from some documentation survey associated with PSA are discussed and technical considerations for SMART PSA are made in this paper. Technical considerations focusing on the unique characteristics of SMART are as follows.

- Mission Time
- Passive Safety Systems
- Digital I&C Systems

It is noted that, among them, adoption of passive safety system will be increased due to their potential impact on safety of future reactor. Therefore it is necessary to discuss how to confirm its reliability and deal with it in PSA. In addition, it needs to develop new PSA validation guidance for SMART including above three considerations derived from this paper.

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