Insights on PRA Review Practices: Necessity for Model Shaking

Inn Seock Kim*, Misuk Jang, Seoung Rae Kim
Nuclear Engineering Service & Solution Company (NESS), Daejeon Business Agency #705,
96 Gajeongbuk-ro,Yuseong-gu, Daejeon 34111, Republic of Korea
**Corresponding author: isk@issatechinc.com*

1. Introduction

Probabilistic risk assessment (PRA) is increasingly used as a technique to help ensure design and operational safety of nuclear power plants (NPPs) in the nuclear industry. Hence, there is considerable interest in the PRA quality, and as a result, a peer review of the PRA model is typically performed to ensure its technical adequacy as part of the PRA development process or for any other reason (e.g., regulatory requirement). This paper provides insights on the PRA review practices, especially with regard to how the peer review process could be further enhanced to gain more confidence on the PRA model as a tool for risk-informed applications.

2. Methods and Results

A peer review of the PRA model is carried out by experienced PRA practitioners in general following a number of high-level and supporting requirements as set forth in the ASME/ANS RA-Sa-2009 PRA Standard [1] or other guidelines, such as Regulatory Guide 1.200 [2], NEI-00-02 [3], and NEI-05-04 [4]. The PRA requirements are adequately established in these documents for various types of PRA (e.g., internal events, external events including earthquake and fire, full power operation, low power and shutdown operation) through a consensus process. A major guideline to ensure PRA quality, i.e., ASME/ANS RA-Sa-2009, is built around the seven PRA elements:

1. Initiating Event Analysis
2. Accident Sequence Analysis
3. Success Criteria Analysis
4. Systems Analysis
5. Human Reliability Analysis
6. Data analysis
7. Quantification

The primary focus of the peer review process being performed using the aforementioned guidelines is on ensuring that the PRA model will result in a reasonable estimate of the risk associated with the plant design or operation. As such, whether each PRA element has been properly implemented is checked in great detail by the peer reviewers, including uncertainties associated with initiating event frequencies, equipment failure data, human error probabilities, core damage frequencies, etc.

Perhaps one of the most important steps in the peer review process is to evaluate the reasonableness of the accident scenarios and sequences from the physical or plant design/operation points of view along with the quantification results; for example, core damage or radiological release scenarios with associated minimal cutsets (MCSs). Each MCS typically consists of an initiating event, hardware (including digital components) failures, human error events, equipment unavailability events due to test or maintenance, and/or recovery failures (e.g., failure to recover loss of offsite power or repair a failed pump within a certain time), among others.

In the ASME/ANS RA-Sa-2009 PRA Standard, the way of how the quantification results should be reviewed is defined in terms of the High Level Requirement HLR-QU-D and associated Supporting Requirements (i.e., QU-D1 through QU-D7).

> <u>HLR-QU-D</u>: The quantification results shall be reviewed, and significant contributors to CDF (and LERF), such as initiating events, accident sequences, and basic events (equipment Unavailabilities and human failure events), shall be identified. The results shall be traceable to the inputs and assumptions made in the PRA.

In particular, QU-D1 requires reviewing of a sample of significant accident sequences and cutsets to determine the logic of the cutset or sequence is correct, while a similar requirement is defined in terms of QU-D5 so that a sampling of nonsignificant accident cutsets or sequences will be reviewed to determine they are reasonable and have physical meaning.

Note that the review is only tailored to the accident sequences and cutsets that were obtained by quantifying the PRA model for the ‘normal’ plant configurations that will be encountered during the plant lifetime. In other words, the existing peer review guidelines do not require a review of the ‘conditional’ accident sequences and cutsets, e.g., resulting from outage of several components in accordance with the limiting conditions for operation of the Technical Specifications, preventive maintenance schedule, or occurrence of a certain initiating event.

For PRA applications such as risk-informed Technical Specifications, maintenance rule implementation, accident sequence precursor analysis, online risk monitor or plant configuration control, it is extremely important to make sure that the logic of such conditional accident sequences and cutsets is correct and have adequate physical meaning within the uncertainty range of the analysis. Therefore, a guideline for checking the conditional accident sequences and cutsets need to be developed and added to the existing peer review documents. The conditional accident sequences and cutsets can be obtained by 'shaking' the PRA model, for instance: 1) assume that a certain initiating event occurred; 2) assume that certain specific systems or components are unavailable (due to failure or test/maintenance).

3. Conclusions

The current PRA peer review process primarily centers around ascertaining the quality of the PRA model as a tool for 'measuring the risk associated with normal plant configurations'. For the PRA model to be used as a valuable vehicle for risk-informed applications, it is essential that the PRA model must yield correct and physically meaningful accident sequences and minimal cutsets for specific plant configurations or conditions relating to the applications. Hence, the existing peer review guidelines need to be updated to reflect these insights so that risk-informed applications could be more actively pursued with confidence.

REFERENCES

[1] ASME/ANS RA-Sa-2009, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, American Society of Mechanical Engineers, New York, NY, 2009.

[2] USNRC, An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, Regulatory Guide 1.200, Rev. 2, March 2009.

[3] NEI, Probabilistic Risk Assessment (PRA) Peer Review Process Guidance, NEI 00-02, Rev. 1, May 2006.

[4] NEI, Process for Performing Internal Events PRA Peer Reviews Using the ASME/ANS PRA Standard, NEI-05-04, Rev. 2, November 2008.