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Preliminary Study on the Technical Acceptability of PRA for Future Plants

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1. Introduction

As the applications of PRA (Probabilistic Risk Assessment) supporting risk-informed decisions for commercial nuclear power plants (NPPs) have increased, related standards and guidance on the technical acceptability of PRA have been developed step by step.

Recently, USNRC proposed guidance on the technical acceptability of PRA for future plants which is applicable to all types of reactor designs, including gas-cooled, liquid metal, and heavy and light-water-moderated reactors. In this proposal, it emphasizes that PRA will evidently play more significant role in the licensing of future plants than current NPPs have ever been in the past.

In accordance with this current trend, this study has analyzed and compared major features of the technical elements and the high level requirements on the technical acceptability of PRA between current NPPs and future plants considering previously published standards and guidance.

With comparison results, we proposed the draft guidance on the technical acceptability of PRA for future.

2. Comparative analysis on the technical acceptability of PRA between current NPPs and future plants

In this section, comparative analysis results on the technical acceptability of PRA between current NPPs and future plants are summarized. Those include major differences of standards and guidance on the technical acceptability of PRA for each plant.

2.1 Comparison of standards and guidance of the technical acceptability of PRA

Table 1 shows the comparison in classification of requirements and scope of applications between the NUREG-1860 and the existing PRA standards and guidance.

Table 1 Comparison of standards and guidance on the technical acceptability of PRA

Requirements/ Standards/Guidance	Classification of requirements	Scope of applications
ASME RA-S(2002) [1]	• High level requirement • Supporting requirement - Capability category I, II, III	• Internal event(including internal flooding) • At power • Level 1 PRA and limited Level 2 PRA(LERF)
NEI 00-02(2002) [2]	• Specific attributes per each grade - Grade 1, 2, 3, 4	• Internal event(including internal flooding) • At power • Level 1 PRA and Level 2 PRA (LERF)
ANSI/ANS 58.21 (2007) [3]	• High level requirement • Supporting requirement - Capability category I, II, III	• External event(other external events, seismic, high winds, external flooding) • Nominal full power(applicable to external events during low-power/shutdown operation) • Level 1 PRA and limited Level 2 PRA(LERF)
ANSI/ANS 58.23 (2007) [4]	• High level requirement • Supporting requirement - Capability category I, II, III	• Fire event • Nominal full power • Level 1 PRA and Level 2 PRA (LERF)
NUREG 1860 (2007) [5]	• High level requirement	• Internal(including flooding, fire) & external events(including seismic, other events) • All operating modes • Level 1, Level 2 & Level 3 PRA (full scope)
Regulatory Guide 1.200/NUREG-0800 19.1(2007) [6]	• Endorsed ASME RA-S-2002 and NEI 00-02	• Internal events(including flooding, fire) & external hazards • All operating modes • Full scope Level 1 & Level 2
ANS-58.22(200x)	Low power and shutdown PRA methodology (under development)	
ANS-58.24(20xx)	Severe accident progression and radiological release : Level 2 PRA (under development)	
ANS-58.25(20xx)	Standard for radiological accident offsite consequence analysis : Level 3 PRA (under development)	

2.2 Major differences of standards and guidance of the technical acceptability of PRA

NUREG-1860 provides several augmented technical element with respect to the existing PRA standards and guidance. Comparing to other standards and guidance which provides the technical element for a limited or full scope Level 1 and Level 2 PRA to the maximum extent, NUREG-1860 proposes that a site-specific consequence assessment, i.e., a level 3 PRA. In addition, NUREG-1860 addresses the high level requirements related to source of radioactive material and its exposure in some technical element of accident sequence development such as hazardous source identification, initiating event analysis and accident sequence analysis. This means that the scope of PRA for future plants is broader than that applied currently for LWR risk analysis.

NUREG-1860 provides more detailed high level requirements for seismic PRA than those of Reg. Guide 1.200. To the contrary, NUREG-1860 does not contain the high level requirements for high winds PRA with respect to ANSI/ANS 58.21.

3. Draft guidance on the technical acceptability of PRA for future plants

In this section, draft guidance on the technical acceptability of PRA for future plants is proposed and peer review results of the draft guidance were contained.

3.1 Development of draft guidance

The development of the draft guidance for the technical acceptability of PRA for future plants is mainly based on NUREG-1860 in combination with comparison results of each document and peer review results.

The PRA used in licensing future plants would be required to be full scope, including both internal and external events and addressing the plant during all operating modes. The proposed guidance of the technical acceptability of PRA for future plants is divided into high level attributes for life cycle phases of the plant and functional attributes for the PRA. Firstly, high level PRA attributes for each phase are summarized as shown in table 2.

Table 2 High level PRA attributes for each phase

Each phase	High level PRA attributes
Design	• Generation of a complete set of accident sequences • Development of a rigorous accounting of uncertainties • Evaluation of the PRA results against the QHOs (Quantitative Health Objectives) • Evaluation of the PRA results against the F-C curve • PRA supported assessment of security • Identification and characterization of the LBEs (licensing basis events) • Identification and characterization of the special treatment structures, systems and components (SSCs) • Support the development of the environmental impact statement(EIS) and the severe accident mitigation design alternative(SAMDA) analysis
Construction	• Maintain PRA • Perform risk-informed inspections
Startup	• Maintain PRA • Support the determination of staffing requirements • Support the development of the technical specifications • Support the development of inspection, testing and preventative maintenance • Support the development of procedures and training • Support the development of emergency preparedness (EP)
Operation	• Maintain PRA • Assess and manage operational risk • Assess and manage plant changes • Monitor SSC performance • Maintain a risk-informed training program

Secondly, functional attributes of the PRA for future plants are described in this draft guidance, as follows:

• Technical elements
• Consensus standards
• Analytical methods
• Independent peer review
• Configuration control
• Quality assurance criteria
• Assumptions and inputs
• Analytical tools
• Documentation

Technical elements of the draft guidance are built on existing PRA technical characteristics and attributes delineated in Reg. Guide 1.200 and the high level requirements currently identified in the existing PRA standards with some appropriate modifications. These technical elements of PRA are divided into three levels of analysis as shown Table 3.

Table 3 Technical elements of PRA

Level of analysis	Type of events	Technical elements	
		• Plant operating state and hazardous source identification	
Accident sequence development	Internal events	• Initiating event analysis • Accident sequence analysis • Human reliability analysis • Accident sequence quantification	• Success criteria analysis • System analysis • Parameter estimation
	Internal Flood event	• Flood source identification • Flood sequence quantification	• Flood scenario evaluation
	Internal Fire event	• Fire area screening • Fire damage analysis	• Fire initiation analysis • Fire response analysis & quantification
	External seismic event	• Seismic hazard analysis • Seismic systems & quantification	• Seismic fragility analysis
	Other external events	• External event screening & bounding analysis • External event fragility analysis	• External event hazard analysis • External event systems & quantification
Release analysis		• Accident propagation analysis	• Source term analysis
Consequence Assessment		• Consequence analysis	• Health and economic risk estimation

3.2 Peer review results of the draft guidance

The draft guidance was reviewed by several experts engaged in industries, universities, and research institutes. Various comments from those experts were reflected in the draft guidance. Especially, some critical comments needing to achieve completeness of this guidance were derived, as follows:

• Relationship with the similar guidance previously applied to PWR to be clearly settled
• QHOs, F-C curve and LBEs to be defined
• Failure mechanism of passive systems to be technically addressed, and so on.

4. Conclusions

This study has performed comparison of the technical elements and the high level requirements on the technical acceptability of the PRA. With comparison results, it has proposed the draft guidance on the technical acceptability of PRA for future plants based on NUREG-1860. However, this draft guidance needs to be updated considering new publications or revisions of related standards and guidance as well as unresolved items commented by experts.

The finalized guidance will be able to provide a basis for confirming technical acceptability of PRA for future plants licensing. Accordingly, we expect that this guidance can play a key role in constructing the risk-informed and performance-based regulatory framework for future plants licensing.

REFERENCES

[1] Standard for probabilistic risk assessment for nuclear power plant applications, ASME RA-S, 2002
[2] PRA Peer Review Process Guidance, NEI 00-02, 2002
[3] External events PRA methodology, ANSI/ANS-58.21, 2003
[4] Fire PRA methodology, ANSI/ANS-58.23, 2007
[5] Feasibility study for a risk-informed and Performance-based regulatory structure for future plant licensing, NUREG-1860, 2007
[6] An approach for determining the technical adequacy of probabilistic risk assessment results for risk-informed activities, Reg. Guide 1.200, 2007