A Review of ASME/ANS PRA Standard 2022 with Focus on Fire PRA Requirements

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***Keywords : probabilistic safety/risk assessment, fire protection, fire risk, PRA standard**

1. Introduction

A Probabilistic Safety/Risk Assessment (PSA/PRA) needs to demonstrate the completeness, correctness, accuracy, and fidelity of its technical content are sufficient for its intended purpose and use. In other words, the sufficiency of the PRA's technical content determines the acceptability of a PRA. PRA acceptability describes the ability of a PRA for its intended purpose and use, which is measured against the scope, level of detail, conformance with PRA technical elements, plant representation, and configuration control of a PRA considering regulatory positions in the relevant regulatory guidance document.

According to U.S. Nuclear Regulatory Commission (NRC)'s Regulatory Guide (RG) 1.200 [1], in the U.S. (a similar framework applies to Korea), achieving PRA acceptability depends on three aspects, which are interdependent. These three aspects are as follows: (1) meeting NRC regulatory positions in the relevant regulatory guidance document; (2) using NRC-endorsed national consensus PRA standards (i.e., a set of minimum requirements that can be met) in the development and maintenance of a PRA; and (3) using a NRC-endorsed peer review process to independently determine whether a PRA meets the requirements provided in the PRA standards. This study focuses on the second element: national consensus PRA standards.

Fig. 1. U.S. NRC's general framework for achieving PRA acceptability (Source: RG 1.200 Rev. 3 [1] Figure 1)

(1) RG 1.200 [1] provides U.S. NRC's regulatory positions and guidance on how to meet them for determining the acceptability of the base PRA used in support of risk-informed regulatory activities. RG 1.200 also endorses the national consensus PRA standards and industry guidance on how to perform a PRA peer review process, with staff exceptions and clarifications.

(2) U.S. national consensus PRA standards have been jointly developed by the American Society of Mechanical Engineers (ASME) and the American Nuclear Society (ANS), and they are referenced or directly used worldwide, including in Korea. In February 2009, ASME and ANS issued the currently endorsed edition of the Level 1/Large Early Release Frequency (LERF) PRA standard, ASME/ANS RA-Sa-2009, Addenda to ASME/ANS RA-S-2008 (Addendum (a)) [2], which provides requirements for a Level 1 or LERF PRA for Light Water Reactor (LWR) type Nuclear Power Plant (NPP) Applications. A revised edition of the Level 1/LERF PRA standard, ASME/ANS RA-Sb-2013, Addenda to ASME/ANS RA-S-2008 (Addendum (b)) [3], was issued in September 2013. In May 2022, ASME and ANS issued a new edition of the Level 1/LERF PRA standard, ASME/ANS RA-S-1.1-2022 [4], which addresses the same scope as the prior editions [2, 3], i.e., a Level 1 PRA (for the evaluation of core damage frequency, CDF) and a limited Level 2 PRA (for the evaluation of LERF) for at-power conditions, internal events, internal floods, internal fires, seismic, high wind, external flood, and other hazard groups.

In addition to the Level 1/LERF PRA standard, ASME and ANS issued a PRA standard for Non-LWRs in 2021, RA-S-1.4-2021, and continue to develop PRA standards for Level 2 (RA-S-1.2-202x), Level 3 (RA-S-1.3-202x), Advanced LWRs (RA-S-1.5-202x), Low Power and Shutdown (LPSD) modes of operation (RA-S-1.6-202x), and multi-unit PRA (RA-S-1.7-202x). For Level 2, Level 3, LPSD, draft standards for trial use have been issued.

(3) Nuclear Energy Institute (NEI) issued NEI 17-07 [5], which provides guidance on how to perform a PRA peer review to meet the PRA peer review requirements in the ASME/ANS Level 1/LERF PRA standard. NEI 17-07 is endorsed by the NRC in RG 1.200, as a consolidated update of NEI 00-02 [6], NEI 05-04 (for internal events PRA peer review) [7], NEI 07-12 (for

fire PRA peer review) [8], NEI 12-13 (for external hazards PRA peer review) [9], and so forth.

This study reviews the new edition of the ASME/ANS Level 1/LERF PRA standard (referred to hereafter as the PRA Standard 2022) [1] in comparison with the prior editions [2, 3], especially focusing on fire PRA requirements.

2. Overview of the Standard

A structure of the PRA standard 2022 [1] is the same as in prior editions [2, 3], and its constituent parts or elements can be listed as follows in descending order of level.

(1) PART (hazard group):
e.g., PART 4 INTERNAL FIRES AT-POWER PRA
(2) Technical Element (TE):
e.g., FSS (Fire Scenario Selection and Analysis)
(3) High Level Requirement (HLR): e.g., FSS-A, B, … H
(4) Supporting Requirement (SR): e.g., FSS-C1, C2, … C7
(5) Capability Category (CC): e.g., FSS-C4 CC-I, CC-II, ~~CC-III~~

This section discusses overall revisions of the PRA standard 2022. Major revisions are summarized as follows.

(A) First of all, the PRA standard 2022 is a new edition of the Level 1/LERF PRA standard, as described in the introduction, and therefore supersedes all prior editions.

(B) The most important revision made in the PRA standard 2022 is the removal of Capability Category III (CC-III) from the standard for all requirements. The rationale for the removal of CC-III is that Capability Category II (CC-II) already encompasses refined analysis and realism implemented for the risk-significant elements. Because the standard is developed to provide the minimum requirements for a technically adequate analysis, there is no need for the standard to include the CC-III requirements.

(C) The third major revision is related to the contents of the standard. The Seismic Margin Assessment has been withdrawn, and therefore, Part 10 is removed from the standard. Significant lessons learned on high wind PRAs and external flood PRAs have been reflected in their corresponding requirements in Part 7 and Part 8. A new section is added in Part 1 (Section 1-7) to provide requirements for assessing the technical adequacy of newly developed methods to be used in the plant PRA.

(D) The forth one involves many changes to enhance consistency and avoid duplication. As a results of these changes, for example, it is now required to revisit requirements associated with screening, uncertainty, human reliability analysis, and documentation that are cross-cutting through different hazards. The screening criteria have been consolidated into a single set of screening criteria in Part 1 (Section 1-1.8). All peer review requirements have been consolidated into one section in Part 1 (Section 1-6). Note that important footnotes at the end of each HLR in the prior edition have been incorporated into the main bodies of the corresponding SRs. Other remaining footnotes are listed in appendices at the end of each part (e.g., Non-Mandatory Appendix (NMA) 4-A in Part 4).

(E) The last one is to provide aid in interpreting the intent of the requirements, especially for users for whom English is not the first language. A new appendix is added at the end of Part 1 (NMA 1-A) to provide the meanings of action verbs used in the standard.

3. Review of Fire PRA Requirements

Part 4 of the PRA standard 2022 [1] provides requirements for a Level 1/LERF PRA of internal fires while at-power. The fire PRA requirements of the PRA standard 2022 are classified into the following 10 TEs (including technical guidance for each TEs):

(a) TE: Internal Fire Plant Boundary Definition and Partitioning (PP)
Guidance: NUREG/CR-6850 Ch. 1
(b) TE: Internal Fire Initiating Events and Equipment Selection (ES)
Guidance: NUREG/CR-6850 Ch. 2 & App. A + α
(c) TE: Internal Fire Cable Selection and Location (CS)
Guidance: NUREG/CR-6850 Ch. 3, 9 & App. B, I + α
(d) TE: Internal Fire Qualitative Screening (QLS)
Guidance: NUREG/CR-6850 Ch. 4
(e) TE: Internal Fire Plant Response Model (PRM)
Guidance: NUREG/CR-6850 Ch. 5 + α
(f) TE: Internal Fire Scenario Selection and Analysis (FSS)
Guidance: NUREG/CR-6850 Ch. 8, 11
& App. E, F, G, H, L, M, N, O, P, Q, R, S, T + α
(g) TE: Internal Fire Ignition Frequency (IGN)
Guidance: NUREG/CR-6850 Ch. 6 & App. C, F + α
(h) TE: Internal Fire Circuit Failure Analysis (CF)
Guidance: NUREG/CR-6850 Ch. 9, 10 & App. I, J, K + α
(i) TE: Internal Fire Human Reliability Analysis (FHR)
Guidance: NUREG/CR-6850 Ch. 12 + α
(j) TE: Internal Fire Risk Quantification (FQ)
Guidance: NUREG/CR-6850 Ch. 7, 14, 15 & App. D, U, V + α

Note that the PRA standard only provides requirements (i.e., the "what-to-do" for qualifying a PRA). Conversely, the PRA guidance provides detailed methods for them (i.e., the "how-to-do" for meeting the requirements). Here, "+α" guidance refers to additional guidance documents other than NUREG/CR-6850 [10, 11]. These include various NUREGs, EPRI TRs and other guidance documents referred to as "Post-6850" guidance.

This section discusses revisions of fire PRA requirements in the PRA standard 2022. Major revisions are summarized as follows.

(TE) Outwardly, three TEs called Quantitative Screening (QNS), Seismic / Fire Interactions (SF), and Uncertainty / Sensitivity Analyses (UNC) have been removed from the TE list. Consequently, the total number of TEs has been reduced from 13 to 10. However, their requirements have been integrated into other related TEs or Parts (hazard groups). The TE QNS and its requirements from the previous edition are

now addressed in the TE FQ (SRs FQ-A1 and FQ-D1). The TE SF and its requirements from the previous edition have been transferred to Part 5 Seismic PRA requirements (SRs SFR-D6, SFR-E4, SPR-A2, SPR-B10, and SPR-C4) and Part 9 Other Hazard PRA requirements (SR XPR-B11). The TE UNC and its core SR (SR UNC-A1) from the previous edition are now included in the TE FQ (SR FQ-F1), or indirectly in all the other TEs and their SRs (see "UNC" summarized below). These types of revisions are denoted as "TE" in the last column of Table I. It should be noted that, in the definitions of all the remaining TEs, it is emphasized that the requirements are solely for "internal fires" (i.e., any fire originating within the global analysis boundary), but not for "external fires". Another important thing to note is that TE "HRA" from the previous edition has been renamed to "FHR", although they have the same meaning, which is "Fire Human Reliability Analysis".

(GC) The most important revision made in the PRA standard 2022 is the generalization and consolidation of requirements across the board. A notable example is the consolidation of nine SRs from CS-A1 to CS-A9 in the previous edition into a single SR in the new edition, SR CS-A1. Many detailed and specific items from the previous nine SRs have been condensed into the single phrase, "by using a structured and systematic process" within SR CS-A1. These types of revisions are denoted as "GC" in the last column of Table I.

(REF) As mentioned in Section 2, fire PRA requirements also extensively reference similar requirements, primarily from internal events PRA, to avoid any inconsistencies or duplication. These requirements include SRs PRM-B4 to PRM-B9, PRM-B12, PRM-B14, PRM-C2, FSS-E1, IGN-A3, IGN-A6, IGN-A9, FHR-A1, FHR-B1, FHR-B2, FHR-C1, FHR-D1, FHR-E1, FQ-A5, FQ-B1, FQ-C1, and FQ-D2. Similarly, screening-related requirements (both qualitative and quantitative) refer to generic screening criteria in Part 1 (Section 1-1.8) for consistency. These requirements encompass SRs ES-A7, ES-B3, QLS-A1, QLS-A2, FQ-A1, and FQ-D1. For example, SRs FQ-A1 and FQ-D1 reference the CDF and LERF screening criteria in SCR-2, as shown in Table II. SCR-2, serving as generic screening criteria, is referenced and commonly used in the standard for quantitative screening individual contributors. These types of revisions are denoted as "REF" in the last column of Table I.

(WD) The clarification regarding the required scope of walkdown activities documented in JCNRM Inquiry 20-2435 for the 2013 edition [12] has been incorporated into certain walkdown-related requirements such as SRs PP-B5, FSS-D9, and FSS-D10. More detailed descriptions of these SRs are provided in the appendix for Notes and Explanatory Material at the end of Part 4 (NMA 4-A). These types of revisions are denoted as "WD" in the last column of Table I.

(UNC) The requirements for identifying or documenting the sources of model uncertainty and assumptions have been added to all TEs except TE CS. The former requirements (for identification) include SRs PP-B7, ES-C2, QLS-A5, PRM-B15, FSS-G8, IGN-A10, CF-A3, FHR-D2, and FQ-F2. The latter requirements (for documentation) include SRs PP-C2, ES-D2, QLS-B2, PRM-C3, FSS-H3, IGN-B2, CF-B2, FHR-E2, and FQ-G2. It is noteworthy that, from a different standpoint, these latter SRs correspond to SR UNC-A2 in the previous edition. These types of revisions are denoted as "UNC" in the last column of Table I.

(DOC) All documentation-related requirements have been revised to specify items required to be documented in a detailed manner. These requirements include SRs PP-C1, ES-D1, CS-C1, QLS-B1, PRM-C1, PRM-C2, FSS-H1, FSS-H2, IGN-B1, CF-B1, FHR-E1, and FQ-G1. These types of revisions are denoted as "DOC" in the last column of Table I.

Table I: Summary of Revisions in Fire PRA Requirements

TE	No. of SRs				Revised Items
PP	10	→	10		GC, WD, UNC, DOC
ES	14	→	13	(-1)	GC, REF, UNC, DOC
CS	16	→	7	(-9)	GC, DOC
QLS	7	→	7		GC, REF, UNC, DOC
PRM	20	→	21	(+1)	GC, REF, UNC, DOC
FSS	44	→	40	(-4)	GC, REF, WD, UNC, DOC
IGN	15	→	12	(-3)	GC, REF, UNC, DOC
~~QNS~~	6	→	0	(-6)	TE
CF	3	→	5	(+2)	GC, UNC, DOC
FHR	12	→	9	(-3)	GC, REF, UNC, DOC
FQ	10	→	15	(+5)	TE, GC, REF, UNC, DOC
~~SF~~	10	→	0	(-10)	TE
~~UNC~~	2	→	0	(-2)	TE
Total	169	→	139	(-30)	

Table II: Generic Screening Criteria SCR-2

- **Index No:** SCR-2
- **Screening Metric:** Relative (individual contributors)
- **Screening Criteria:**

(a) Less than 1 % contribution
to the aggregate probability or frequency of the items
subject to screening as defined in the referencing SR
AND
the total contribution of the screened out items
not exceeding 5% of the group of items
subject to screening as defined in the referencing SR,

OR

(b) contributing <1.0E-8 per reactor-year to CDF
and <1.0E-9 per reactor-year to LERF
AND
the total contribution of the screened out items
not exceeding 5% of the group of items
subject to screening as defined in the referencing SR

4. Conclusions

This study conducted a review of the ASME/ANS Level 1/LERF PRA standard 2022 [1] in comparison with the prior editions [2, 3] with focus on fire PRA requirements. As a new edition that supersedes all prior editions, the PRA standards 2022 is expected to soon be endorsed by the U.S. NRC and widely used in peer reviews. Various types of revisions have been made to fire PRA requirements. From the author's perspective, the main keywords of these revisions are the generalization and consolidation of the requirements. The author believes that these revisions will help users make more efficient use of the PRA standard for application, development, maintenance upgrade, and peer reviews of PRAs.

The PRA standard is one of three major elements in a regulatory framework for achieving PRA acceptability. The use of the PRA standard, particularly in peer reviews, and the interpretation of peer review results strongly rely on regulatory positions regarding PRA acceptability. As described in the introduction, PRA acceptability is determined by the intended purpose and use of the PRA. RG 1.200 highlights that which capability category needs to be met for each technical requirement depends on the specific application. CC-II represents the level of detail acceptable for the majority of applications in general, but for some applications, CC-I may be sufficient for certain requirements. Korean regulatory guidance documents provide regulatory positions on the technical acceptability of Korean NPP PSAs. Unfortunately, however, there remains a lack of detail on the use of the PRA standard and interpretation of peer review results, especially concerning the intended purpose and use of Korean NPP PSAs. Therefore, it is necessary to establish detailed regulatory positions on the technical acceptability of Korean NPP PSAs specific to their intended purpose and use in the near future.

Acknowledgements

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(Ministry of Science and ICT)(RS-2022-00144204).

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