Current Status and Strategy for the Development of the Korean PSA Standard

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Abstract: In Korea, after the Fukushima accident, the PSA became a legal requirement in many areas in Korea. The PSA became one of the elements to be assessed in the Periodic Safety Review (PSR) in 2014. The safety goal was also introduced in 2016. In addition, the Korean regulatory body asked the Korean utility to perform the PSAs of all NPPs again to support the development of the Accident Management Plan (AMP). After the legalization of the PSA, the quality of the PSA becomes an important issue in the Korean PSA community. The Korean regulatory body asks the quality of the PSA model meets the Capability Category II of ASME/ANS PRA standards in general. However, there are many cases where some requirements of ASME/ANS PRA standards and/or some PSA practices of the USA could not be applied to Korean PSA models. It is due to the differences in regulatory environments and technical basis between Korea and the USA. To cope with this situation, the Korean PSA community is trying to develop the Korea-specific PSA standards. The Korean industry side performs a project to develop a strategy and roadmap for the development of new Korean PSA standards. This paper summarizes the current status and the strategy for the development of the Korean PSA standards.

1. INTRODUCTION

The Probabilistic Safety Assessments (PSA) for Korean nuclear power plants (NPPs) started as one of the post-TMI action items in 1988. Each NPP of Korea has a plant-specific PSA model to assess the risk of the NPP. However, before the Fukushima accident, the PSA was not a legal requirement, and it was regarded as one of the utility's voluntary works to enhance the safety of NPPs.

However, after the Fukushima accident, the PSA became a legal requirement in many areas in Korea. The PSA became one of the elements to be assessed in the Periodic Safety Review (PSR) in 2014. The safety goal was also introduced in 2016. In addition, the Korean regulatory body asked the Korean utility to perform the PSAs of all NPPs again to support the development of the Accident Management Plan (AMP). The Level 3 PSA becomes one of the legal requirements for the licensing of new NPPs.

To fulfill the objectives of the PSA, it is essential to keep the appropriate quality of PSA models. The PSA standard is one of the critical elements to ensure the quality of PSA models. In the early 2010s, the Korean industry tried to develop the Korean PSA standard, KEPIC (Korea Electric Power Industry Code) NPA [1], based on the ASME PRA standard (2009) [2] of the USA. However, the Korean regulatory body did not endorse the KEPIC NPA since it had some problems such as the unclear expressions of the requirements, etc. Therefore, the KEPIC NPA was not used in real works to assess the quality of Korean PSA models, and it has not been updated after that. Instead, ASME/ANS PRA standards were used for the real works. Even though the use of ASME/ANS PRA standards resulted in various technical issues difficult to be resolved, it was not a serious problem since the PSA was not a legal requirement at that time. However, after the legalization of the PSA, the quality of PSA models becomes an important issue in the Korean PSA community.

The Korean regulatory body asks the utility to meet the "internationally accepted PSA standard" to ensure the appropriate quality of Korean PSA models. Since there are no Korean PSA standards endorsed by the Korean regulatory body, the utility still uses ASME/ANS PRA standards to assess the

quality of Korean PSA models as before the legalization of the PSA. However, as mentioned before, there are many cases in which some requirements of ASME/ANS PRA standards and/or some PSA practices of the USA could not be applied to Korean PSA models. Nowadays, such problems became important since these are official regulatory issues to be resolved. It seems such problems are caused by the differences in technical basis and regulatory environments between Korea and the USA.

For instance, ASME/ANS PRA standards are developed for the operating Light Water Reactors (LWRs). However, many Korean PSAs are performed during the construction period of NPPs in which some data required for the PSA are unavailable. In this case, there is no way to meet some requirements of ASME/ANS PRA standards. In addition, in Korea, there are PSAs for CANDU NPPs (Wolsong 2/3/4) designs of which are quite different from those of LWRs [3].

To cope with this situation, the Korean PSA community is trying to develop new Korean PSA standards. The Korean Nuclear Society organized a special committee to resolve these issues and the Korean industry side also performed a project to develop the strategy and the roadmap for the development of new Korean PSA standards [4]. This paper summarizes the current status and the strategy for the development of new Korean PSA standards. In Section 2, the issues that arise when ASME/ANS PRA standards are applied to Korean PSA models are summarized. In Section 3, we describe the strategies for the development of Korean PSA Standards. The conclusion is provided in Section 4.

2. ISSUES REGARDING PSA STANDARDS IN KOREA

When applying ASME/ANS PRA standards to PSA models of Korean NPPs, some requirements were inapplicable and/or could not be met. Such problems occurred due to the differences in (1) the technical basis/PSA practices and (2) the regulatory environments. Sometimes the problems are caused by the combinations of those two aspects. In this section, we describe those issues in detail.

3.1. Issues Related to the Technical Basis/PSA Practices

From the technical basis point of view, many issues are related to the availability of the reliability data. That is, in many cases, there are not enough reliability data in Korea. For instance, common cause failure (CCF) data is very rate in Korea. When we use the generic CCF data, it is difficult to meet the requirement of ASME/ANS PRA standards regarding the CCF.

In Korea, many PSAs are performed during the construction period of NPPs. Some requirements of ASME/ANS PRA standards require to use plant-specific data (e.g. procedures, operating experience, maintenance data, etc.) that are unavailable during the construction period of an NPP. Therefore, there are many cases in that we do not have data to meet some requirements of the ASME/ANS PRA standards in the PSA for new NPPs.

Some issues are related to external events. For the seismic PSA, the code case of the ASME/ANS PRA standard (2013) [5] is used in the USA that requires a site-specific hazard analysis. However, in Korea, the site-specific hazard analysis is ongoing, and the plant-specific ground motion response spectrum is unavailable. So, it is impossible to meet the requirements of the ASME/ANS PRA standard (2013) related to the site-specific hazard analysis.

Some issues related to the fire PSA are caused by the differences of PSA practice. ASME/ANS PRA standards use the Core Damage Frequency (CDF) and the Large Early Release Frequency (LERF) as the screening criteria in the fire PSA. However, in Korea, only the CDF is used as the screening criteria and the Level 2 PSA is only performed for the fire protection area after the screening process. So Korea's fire PSA practices are to be changed to meet the requirements of ASME/ANS PRA standards regarding fire PSA.

Korea has four CANDU NPPs. Recently, the PSAs of CANDU NPPs were reviewed based on ASME/ANS PRA standards. Some requirements cannot be met due to the different design concepts of CANDU NPPs from those of LWRs. For instance, the definition of core damage of ASME/ANS PRA standards cannot be applied to CANDU PSA models.

3.2. Issues Related to the Regulatory Environments

The objectives of Korean PSAs are quite different from those of PSAs of the USA. In Korea, the PSA is necessary for many areas such as the followings:

(1) The licensing of a new NPP
(2) The PSR of NPPs for every 10 years
(3) PSA updates for the AMP
(4) PSA for some risk-informed applications (RIA)
(5) PSA for the life extensions of old NPPs

In Korea, the PSA is to be performed twice for a new NPP, i.e. for the Construction Permit and the Operating License, respectively. In addition, the scope of the PSA for the licensing of a new NPP is extended to the Level 3 PSA. It is expected to be a big challenge since there is no official Level 3 PSA up to now and there are no Level 3 PSA codes used for the licensing works in the world.

From the regulatory requirements point of view, there are issues related to the safety goal. The safety goal of Korea introduced in 2016 is based on the 0.1% rule of the USA. However, the Korean regulatory body introduced an additional safety goal regarding Cesium-137 (Cs-137). This goal is related to the frequency of accidents that result in the release of Cs-137 of more than 100TBq. Such accident frequencies should be less than 1.0E-6/year. Therefore, in Korea, we have to estimate not only the LERF but also the Large Late Release Frequency (LLRF). That is, we need to perform the full scope of Level 2 PSA to check whether the Cs-137 related safety goal is satisfied or not

In Korea, the RIAs are allowed for some limited cases only such as RI-ILRT (Risk-informed Integrated Leakage Rate Test), RI-ISI (Risk-informed In-serve Inspection), etc. Many risk-related regulations of the USA are not implemented in Korea such as the Maintenance Rule (MR), the On-line Maintenance (OLM), and the ROP (Reactor Oversight Process). However, the Korean regulatory body requires a peer review of the PSA to ensure the quality of PSA models. The Korean regulatory body regards the Capability Category II of ASME/ANS PRA standards as the basic level of the PSA quality regardless of the objectives of the PSA. It could cause unnecessary burdens to the utility in some cases.

There are other problems related to peer review. In Korea, there is only one utility, Korea Hydro & Nuclear Power Co., Ltd. (KHNP), operating NPPs. And the number of Korean PSA experts is limited. That is, in Korea, there are not enough PSA experts who are independent of the PSA of KHNP. So, it is not easy to consist of an independent peer review team.

3. STRATEGY FOR THE DEVELOPMENT OF THE KOREAN PSA STANDARDS

The scope and content of the ASME/ANS PRA standards are very vast and extensive. In addition, new PRA standards are under development for new issues such as the multi-unit PRA and the SMR (Small and Modular Reactor). In addition, we have to resolve the issues described in Section 2 for the development of the Korean PSA standard. Considering the difference in the technical basis and the number of PSA experts in Korea, it is almost impossible for Korea to develop Korean PSA standards corresponding to ASME/ANS PRA standards of the USA in a short period. Therefore, we choose two approaches as the basic strategies for the development of Korean PSA standards:

(1) Use ASME/ANS PRA standards of the USA as the technical basis for the development of Korean PSA standards,

(2) Develop the Korean-specific requirements considering Korean situations and incorporate these requirements into the Korean PSA standards to be developed.

In Section 3, we describe the strategies to resolve the issues mentioned in Section 2.

☐ Data related issues

One of the biggest problems in applying ASME/ANS PRA standards to Korean PSA models is related to the reliability data. As mentioned earlier, CCF data is very rare in Korea. Therefore, the generic CCF data is used in most cases. In such cases, it is difficult to meet the requirements of the ASME/ANS PRA PSA standard (DA-D7) related to CCF. Similar situations occur frequently in the PSA for new NPPs under construction. Therefore, when it is difficult to meet the requirements with only plant-specific data of Korea, we plan to develop additional requirements allowing alternate ways such as Bayesian update using generic data (NUREG data, etc.) and available plant-specific data.

☐ Seismic PSA related issues

The code case of the ASME/ANS PRA Standard (2013) [5] for the seismic PRA is endorsed by the NRC. This code case requires that the frequency of seismic ground motion is to be derived based on the Probabilistic Seismic Hazard Analysis (PSAHA). However, in Korea, the work to derive the ground motion response spectrum (GMRS) for a specific site is ongoing. Therefore, it is difficult to meet the related requirements of the code case. Therefore, even though we plan to use the code case as the basis for the Korean seismic PSA standards, we also plan to allow the use of the ASME/ANS PRA Standard (2009) regarding the GMRS temporarily until the site-specific GMRS problem is resolved in Korea.

☐ Fire PSA related issues

There are two issues related to the fire PSA. The first one is related to the methods of the fire PSA, and the second one is related to the PSA practice of Korea.

Currently, the Korean regulatory body recommends the utility use the fire PSA method of NUREG/CR-6850 [7]. Therefore, we plan to develop the Korean fire PSA standards considering the NUREG/CR-6850 method. However, it is not easy for the Korean utility to fully introduce the NUREG/CR-6850 method due to the lack of technical basis for the fire analysis and Multiple Spurious Operations (MSO), etc. In addition, Korean NPPs are relatively new ones that satisfy new regulations of the USA for fire protection (10CFR50.48 (a) and (b)). Therefore, we plan to develop prerequisites for the use of the requirements of fire PSA standards related to the NUREG/CR-6850 method. That is, we plan to develop prerequisites that confine the application of requirements related to the NUREG/CR-6850 method only for the fire PSA performed for the resolution of specific fire protection issues.

As we mentioned, the LERF is not used as the screening criteria in the Korean fire PSA. However, considering the importance of the LERF, the practice of the Korean fire PSA should be changed. Therefore, we plan to introduce the requirements on the LERF in the Korean fire PSA standards.

☐ Other External Hazard related issues

For other external events, the Korean PSA standard should be developed in consideration of the natural environments of Korea. There were discussions about other external events in Korea based on the operating experiences such as the inflow of aquatic organisms such as jellyfish, and forest fires. In addition, concern about typhoons has arisen recently. Such external events would be addressed to identify candidates to be included in the PSA standards related to the external events.

☐ CANDU PSA related issues

The peer review of the CANDU PSA was performed in Korea based on ASME/ANS PRA standards. As expected, there are some requirements of the standards that cannot be applied to the CANDU PSA. However, it seems it is not necessary to develop the CANDU PSA standard separately. We plan to

develop some CANDU-specific requirements instead of the requirements of the ASME/ANS PRA standards that cannot be applied to the CANDU PSA, e.g. the definition of the core damage, etc.

☐ Level 3 PSA related issues

Currently, the NRC does not have legal requirements on the Level 3 PSA and the Level 3 PRA standards are not endorsed by the NRC. However, in Korea, we need the official Level 3 PSA standards for the PSA of new NPPs. It seems the Level 3 PSA code will be an important issue in developing the Korean Level 3 PSA standards since there is no Level 3 PSA codes used for the real licensing works up to now. The most famous Level 3 PSA code, MACCS [7], has never been used for the PSA related to the licensing of NPPs. At present, KAERI (Korea Atomic Energy Research Institute) is developing a Level 3 PSA code called RCAP [8]. We plan to endorse the use of the RCAP code in the Level 3 PRA standards considering the validation and verification of the code. At present, the RACAP is under development and it is not endorsed by the Korean regulatory body. However, a considerable amount of time will be required for the development of the Level 3 PSA standards in Korea in the future. During this period, we expect that the Korean PSA community would finish the validation and verification of the RCAP code.

☐ Safety Goal related issues

To handle the safety goal related to the Cs-137, it seems we need to develop the full scope of Level 2 PSA standards including the Cs-137 related requirements.

☐ RIA related issues

The level of the PSA quality is to be related to the objectives of the PSA. In the USA, there is a Regulatory Guide related to this aspect [9]. In general, it is known that the Capability Category II is required for risk-informed applications. Currently, even though the RIA is not active in Korea, the Korean regulatory body generally requires the Category II level of PSA quality.

To resolve this issue, we plan to specify the relationship between the requirements of the standards and the specific RIA. For instance, it can be stated as a footnote like 'The requirement XX is not necessary for the PSA for the construction permit.'

☐ Peer Review related issues

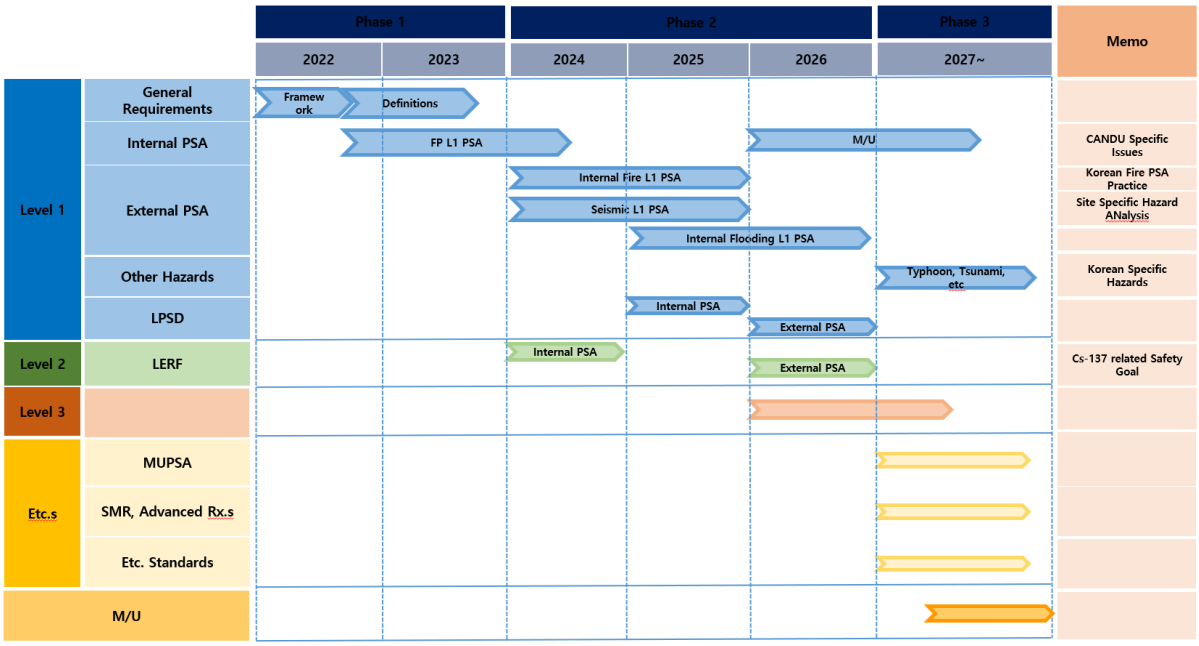
The peer review in the USA is a process for verifying the quality of a specific PSA model based on PSA standards. For the peer review, the independence of experts participating in the peer review is important. However, in Korea, only the KHNP is operating NPPs. In addition, there is a limited number of PSA experts in Korea. Therefore, it is not easy to organize a peer review team with experts completely independent of the PSA being reviewed.

In the USA, issues related to peer review are not included in PSA standards. It is defined in the separate NEI Peer Review Guidance [10]. However, in Korea, there is no institute similar to the NEI. Therefore, it is necessary to include the contents related to the peer review as a part of PSA standards. Also, requirements regarding the independence of experts participating in peer review should be re-established in consideration of the Korean PSA environments.

☐ Road Map for the Development of Korean PSA Standards

The roadmap for the development of Korean PSA standards is shown in Fig.1. It is a tentative roadmap. The schedule will be adjusted according to the changes in the environment regarding the PSA standards in the future.

Figure 1: Roadmap for the Korean PSA Standards



5. CONCLUSION

After the legalization of the PSA, the quality of PSA models becomes an important issue in the Korean PSA community. Up to now, the utility uses ASME/ANS PRA standards to assess the quality of Korean PSA models since there are no Korean PSA standards endorsed by the Korean regulatory body.

However, there are many cases where some requirements of ASME/ANS PRA standards and/or some PSA practices of the USA could not be applied to Korean PSA models. It seems such problems occurred due to the differences in (1) the technical basis/PSA practices and (2) the regulatory environments. To cope with this situation, the Korean PSA community is trying to develop new Korean PSA standards. Considering the differences in the technical basis and the regulatory environments between Korea and the USA, we propose two approaches as the basic strategies for the development of Korean PSA standards as followings:

(1) Use ASME/ANS PRA standards of the USA as the technical basis for the development of Korean PSA standards,
(2) Develop the Korean-specific requirements considering Korean situations and incorporate these requirements into the Korean PSA standards to be developed.

We identify the issues that arise when we apply ASME/ANS PRA standards to Korean PSA models and derive strategies to develop the Korean PSA standards by resolving those issues.

In addition, it seems there are several issues to be resolved. The first one is how to get the endorsement of the regulatory body for the Korean PSA standards to be developed. The second one is the maintenance and update of the PSA standards. We plan to organize the system for the cooperation between the developers of PSA standards and the Korean regulatory body. We plan to build the process for the maintenance and update considering the corresponding process of other Korean standards.

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References

[1] KEPIC, NPA: Probabilistic Safety Assessment, (2010)
[2] ASME/ANS RA-Sa-2009, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications - Addenda to ASME/ANS RA-S-2008," ASME, (2009)
[3] KEPRI, Level 2 Probabilistic Safety Assessment for PHWR, TR.93NJ10.97.67, (1997)
[4] KEPIC, Strategy for the Development of the Korean PSA Standards, (2021)
[5] ASME, ASME/ANS RA-S CASE 1, Case for ASME/ANS RA-Sb–2013, (2013)
[6] NRC, EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Final Report, (NUREG/CR-6850, EPRI 1011989)
[7] NRC, Code Manual for MACCS2, NUREG/CR-6613, 1998
[8] KAERI, Summary of Workshop on Task and Prospect of Level 3 PSA R&D, KAERI/GP-528/2018, (2018)
[9] NRC, Acceptability of Probabilistic Risk Assessment Results for Risk-Informed Activities, Regulatory Guide 1.200, Revision 3, (2020)
[10] NEI, Process for Performing Internal Events PRA Peer Reviews Using the ASME/ANS PRA Standard, NEI 05-04, Revision 2, (2008)