Current Regulatory Approaches for External Hazard Assessment of SMRs: Focusing on NuScale's External Hazard Screening

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Keywords : SMR, external hazard, screening criteria, probabilistic safety assessment

1. Introduction

Nuclear power plants have to ensure safety against natural hazards such as earthquakes, heavy rainfall, and typhoons throughout their entire lifecycle, including construction, operation, and decommissioning. With the effects of climate change, the frequency and severity of such hazards are increasing. This trend raises stronger demands for enhanced safety measures against events that may exceed existing design standards. For small modular reactors (SMRs), higher safety goals are typically set compared to conventional nuclear power plants, which necessitates a more comprehensive assessment of external hazard impacts in line with these elevated safety objectives. Accordingly, international efforts are underway to optimally assess external hazards in the development of SMR. This study reviews the regulations under development concerning external hazards and SMRs, and also introduces the case of NuScale's external hazard screening.

2. Regulatory Frameworks in Preparation

International organizations related to nuclear energy have been actively promoting various activities focusing on SMRs and external hazard considerations. IAEA (International Atomic Energy Agency) is preparing several publications addressing SMRs and external hazards. First, the Specific Safety Guide on "Safety Evaluation of Nuclear Installations for External Events Excluding Earthquakes" (DS552) is being developed, as existing IAEA safety reports provide limited guidance on non-seismic external hazards. This guide will offer detailed recommendations for conducting safety evaluations of both new and existing nuclear installations against such hazards. Second, the revision of SSG-18, "Meteorological, Hydrological and Other Natural Hazards in Site Evaluation for Nuclear Installations" (DS541), originally published in 2011, is underway. The revision aims to incorporate the growing importance of climate change and beyond design basis external events (BDBEE), address graded approaches specific to nuclear installations, and reflect updated knowledge on climate change. Third, a Safety Report on "Application of a Graded Approach for Site Evaluation for Advanced Nuclear Power Plants (Including SMRs)" is being prepared, recognizing that site evaluation for SMRs should not follow the same time and cost structure as large nuclear power plants, and therefore requires a suitable graded approach.

In addition, IAEA hosted the "Technical Meeting on the Optimization of Protection of SMRs in Relation to External Events," where participating organizations from around the world shared updates on SMR development and approaches to external hazard considerations. In parallel, the U.S. NRC (Nuclear Regulatory Commission) is also developing 10 CFR Part 53 to be applied to advanced reactors.

3. NuScale's External Hazard Screening

NuScale US460 is a light-water SMR designed as an integral pressurized water reactor (PWR) with a rated output of 77 MWe per module. In May 2025, it received Standard Design Approval (SDA) from the U.S. NRC. *Chapter 19 of the NuScale US460 SDA Application addresses Probabilistic Risk Assessment (PRA) and Severe Accident Evaluation* [1], including the external hazard screening criteria and results, as well as the safety assessment of hazards that were not screened out.

External hazards relevant to NuScale are identified in accordance with the requirements of ASME/ANS RA-Sa-2009 [2]. Once identified, each hazard is evaluated through a progressive screening process consistent with ASME/ANS RA-Sa-2009, incorporating the review guidance of DC/COL-ISG-028 [3].

As shown in Table 1, the screening criteria are classified into preliminary and bounding categories. NuScale's preliminary screening criterion 1 adopts the content of ASME's qualitative screening criterion 2 with the supplement from DC/COL-ISG-028. Preliminary screening criterion 2 is not included in the original ASME criteria but was newly introduced in DC/COL-ISG-028. Preliminary screening criteria 3 and 4 are directly adopted since their content is identical in both ASME and DC/COL-ISG-028. Most of NuScale's bounding screening criteria are adopted from DC/COL-ISG-028. Criteria a, b, and c include more quantitative indicators, specifying that the initiating event frequency should be less than 10^{-6}, 10^{-7}, and 10^{-8}, respectively, in contrast to ASME's initiating event frequency threshold of 10^{-5}. The reason for applying lower initiating event frequencies is that SMRs are designed to achieve enhanced safety, or equivalently, a lower core damage

Table I: Screening Criteria of NuScale US460

number	Preliminary Screening Criterion
1	The hazard has a significantly lower mean frequency of occurrence than another hazard, taking into account the uncertainties in the estimates of both frequencies, and the hazard could not result in worse consequences than the consequences from the other hazard. The phrase "significantly lower" implies that the screened hazard has a mean frequency of occurrence that is at least two orders of magnitude less than (1%) the mean frequency of occurrence of the other event.
2	The hazard does not result in a plant trip (manual or automatic) or a controlled manual shutdown and does not impact a structure, system, or component that is required for accident mitigation from at-power transients or accidents. If credit is taken for operator actions to correct the condition to avoid a plant trip or controlled shutdown, then ensure the credited operator actions and associated equipment have an exceedingly low probability of failure (i.e., collectively less than or equal to 10^{-5}) following the applicable supporting requirements.
3	The impacts of the hazard cannot occur close enough to the plant to affect it.
4	The hazard is included in the definition of another event.
Letter	Bounding Screening Criterion
a	The mean frequency of the initiating event is less than 10^{-6} per reactor year and core damage could not occur unless at least two trains of mitigating systems are failed independent of the event.
b	The mean frequency of the initiating event is less than 10^{-7} per reactor year and the initiating event does not involve or create an ISLOCA, containment bypass, containment failure, or direct core damage (e.g., RPV rupture).
c	The mean frequency of the initiating event is less than 10^{-8} per reactor year.
d	The external hazard affects, directly and indirectly, only components in a single system, AND it can be shown that the product of the frequency of the external hazard and the probability of SSC failure given the hazard is at least two orders of magnitude lower than the product of the non-hazard (i.e., internal events) frequency for the corresponding initiating event in the PRA, and the random (non-external hazard) failure probability of the same SSC that are assumed failed by the external hazard. If the external hazard impacts multiple systems, directly or indirectly, do not screen on this basis.

Table II:. PRA results of NuScale US460

Hazard	CDF (mean value)
Internal Floods	1.6E-09
External Floods	9.5E-09
High Winds (Tornado)	2.6E-09
High Winds (Hurricane)	1.9E-08

frequency (CDF), compared to conventional nuclear power plants.

Screening was performed for a total of 44 hazards, and the results are presented in Fig. 1. Most hazards were screened out by the preliminary screening criteria, while those not eliminated were subjected to probabilistic risk assessment. PRA was conducted for internal flooding, external flooding, and high winds induced by hurricanes and tornadoes. As shown in Table 2, the calculated CDF (mean) values are ranging from 10^{-8} to 10^{-9}. For the seismic assessment, a Seismic Margin Assessment (SMA) was performed instead of a PRA, and the HCLPF was calculated to be 0.92 g.

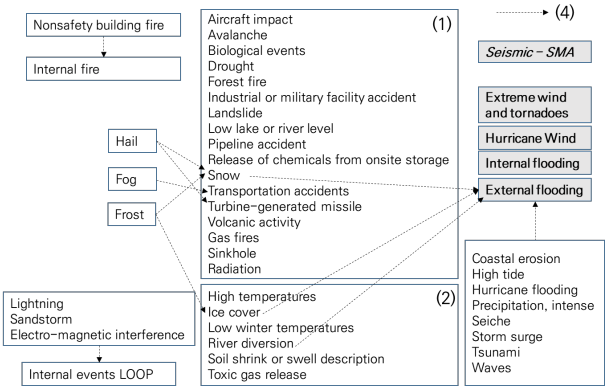

Fig. 1. NuScale External Hazard Screening Results. The number in parentheses indicates that the hazard was screened out according to the corresponding preliminary screening criterion. The dotted arrows indicate the inclusion relationships corresponding to preliminary screening criterion 4. The hazards within the shaded boxes were not screened out, and thus PRA and SMA were performed.

4. Conclusions

This study reviews regulations under development for external hazards in SMRs and introduces NuScale's case. As global competition for SMR technology and licensing intensifies, the IAEA is preparing safety requirements that reflect SMR-specific features. NuScale applies more conservative screening criteria to achieve its lower CDF target. For the development of SMRs in Korea, it is essential to establish external hazard assessment criteria that reflect the impacts of climate change, ensure consistency with international regulatory frameworks, and prepare for licensing.

ACKNOWLEDGEMENT

This work was supported by the Nuclear Safety Research Program through the Regulatory Research Management Agency for SMRs(RMAS) and the Nuclear Safety and Security Commission(NSSC) of the Republic of Korea.(No. RS-2025-02313808)

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