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A Site Selection of Small Modular Reactor: A Review from the Perspective of Multihazard Risk Analysis

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1. Introduction

After the Fukushima earthquake-tsunami accident (Japan, 2011), understanding and quantifying the multihazard of nuclear power plants (NPP) become a significant issue in the nuclear safety community. In this circumstance, there had been several efforts to estimate the risk of NPP against the various type of multihazard [1]. Due to the increasing uncertainty of external hazard risk caused by climate change, global efforts to estimate and mitigate the multihazard risk are continued.

On the other hand, a number of innovative small modular reactor (SMR) technology had been developed to tackle the global need for safer and more economical nuclear energy. Due to its increased flexibility in siting, when compared to the conventional NPPs, various locations (e.g., underground, underwater) are listed for new types of SMR designs. Development of this innovative technology raises the need effect of external hazard risk of SMRs. The Defence-in-Depth (DiD) working group of the IAEA SMR Regulators' Forum, for example, reports that multihazard can lead to the loss of DiD and the risk of external hazards should be accounted for in the safety assessment of SMRs. However, despite its importance, the effect of external multihazard risk on site selection of SMR is relatively little discussed in the literature.

In this paper, we aimed to review state-of-the-art research in multihazard analysis on site selection of various SMRs especially cases that cannot be covered by those of conventional NPPs, and discuss the progress and challenges. Section 2 briefly introduces three SMR site categories. Section 3 provides the state-of-the-art multihazard risk analysis for SMRs site selection. Finally, Section 4 summarizes the review and provides concluding remarks.

2. Site Types

In this section, three general types of sites for NPP are introduced [2, 3]. The site locations can be categorized as follow: (1) existing NPP sites, (2) Brownfield sites, and (3) Greenfield sites.

2.1 Existing NPP Sites

The first site type is a location that approximates current NPP sites or previous NPP sites. These types of sites have great benefits from previous site analysis including various external hazards. In addition to data archives, this type of site is likely to use conventional NPP site selection guidelines, unless the innovative design (e.g., underground) requires a new type of external hazard analysis.

2.2 Brownfield Sites

The second site type is a location where reused by SMR after previously occupied by other industrial and urban activities. The former fossil fuel-fired power plant and metal fabrication facilities can be examples. Same as the existing NPP sites, the brownfield sites are likely to be compatible with the conventional NPP site selection procedure, preferred to greenfield sites, due to less strict regulations on land use. However, collecting site information may challenging due to the effect of previous land use.

2.3 Greenfield Sites

Lastly, greenfield sites are locations where urban and industrial activities had not been made before. For example, agricultural areas, forest areas, and others where didn't previously use can be categorized into greenfield sites. While there is the benefit of no unknown pollution in these sites. Specific hazards (e.g., single- and multihazard undersurface) that those not covered by the conventional IAEA safety standards [4] can be categorized into this greenfield type.

3. Multihazard Risk Quantification

In previous work of authors, state-of-the-art multihazard analyses for the conventional NPPs were reviewed in of hazard, fragility, and risk level [1]. Fig. 1. shows a conceptual illustration of various natural hazards that can affect virtual conventional NPPs or SMRs. Especially, current technology development stages of eight multihazard combinations were investigated: (1) earthquake and tsunami, (2) earthquake and landslide (3) earthquake mainshock and aftershock, (4) earthquake and flashflood, (5) earthquake and snow, (6) earthquake and wind, (7) wind and rain, and (8) wind and snow. While the component hazard capacity and system model vary by the SMR design type, general single and multihazard risk quantification methods developed for the conventional NPPs likely to apply to the SMR design suitable for the existing NPP sites, brownfield sites, and some of the above surface greenfield sites. However, as mentioned in the previous review [1], multihazard risk quantification is relatively less investigated than single hazard risk analysis, and therefore for both conventional NPPs and SMRs further research investigation on multihazard risk quantification is required for various multihazard combinations.

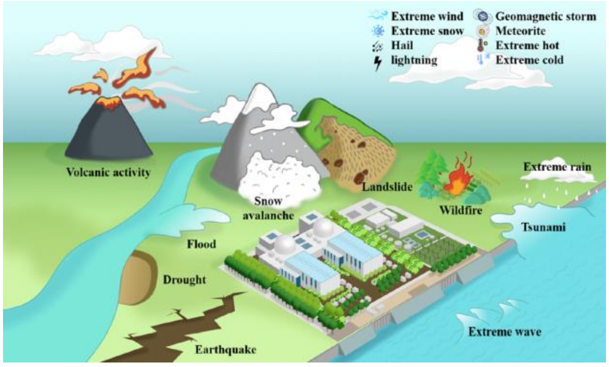

Fig. 1. Conceptual illustration of the effects of various natural hazards on a virtual nuclear power plant. (adopted from [1])

Unlike other sites, however, some greenfield sites below the surface may require consideration of new single and multihazard risk quantification for the site selection of SMRs. For underground SMR for instance, atmospheric hazards (e.g., extreme wind, snow, rain) may effect little, and a combination of geophysical hazards can be a major threat. The underground installation could mitigate the above-ground hazards but not below-ground hazards [5]. While some of the preliminary studies were performed for the underground NPP design [6-7], the single and multihazard risk that may occur in the underground site is not extensively investigated yet.

Also, underwater SMR may require investigating the multihazard combination which is neglected in site selection of NPPs (e.g., Subaerial landslide). To date various studies had been performed to investigate the offshore NPPs [8], however, extensive studies on multihazard perspective had not been performed yet.

4. Conclusions

The critical need of investigating the effect of combined external hazards in the site selection of SMRs is raised in the global nuclear safety communities. However, it is identified in the literature that for both conventional NPPs and SMR further research efforts is required to understand the phenomena and its effect on NPP sites. In addition, it is found that the potential site location of innovative SMRs such as underground and offshore may not be covered by conventional single and multihazard analysis performed for the conventional NPPs.

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