PROPOSALS TO REDUCE HUMAN ERROR PROBABILITY REGARDING THE USE OF PORTABLE EQUIPMENT DURING MULTI-UNIT ACCIDENT RESPONSES

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EXTENDED ABSTRACT

The objective of this study is to make several proposals to reduce human errors on utilizing portable equipment during multi-unit accident responses, ultimately in order to reduce the multi-unit core damage frequency (CDF). For this purpose, several suggestions are made in order to reduce the human error probabilities (HEPs) on using the portable equipment during accidents such as multi-unit accidents and beyond design basis external events (BDBEEs).

To assess the improvement in nuclear power plant (NPP) safety, multi-unit human/organizational reliability analysis (MU-HRA) methodology developed in Korea Atomic Energy Research Institute (KAERI) was used. The developed MU-HRA methodology 1) performs the target human failure event (HFE) sub-task identification using System Theoretic Process Analysis (STPA), 2) simulate off-site workers arrival time estimation using agent-based modeling (ABM), and 3) estimates the HEPs of portable equipment human failure by grouping the HFE sub-tasks into three categories for the HEP estimation: a) diagnostic errors (DEP) in situation assessment, b) communication errors (CEP) during information transfer and response-related instruction activities between organizations and personnel, and c) execution errors (EEP) arising from various individual measures for applying the portable equipment during the BDBEE accident responses. These are shown in Fig. 1 and Eqn. 1, and details of these methodologies are included in [1]-[3].

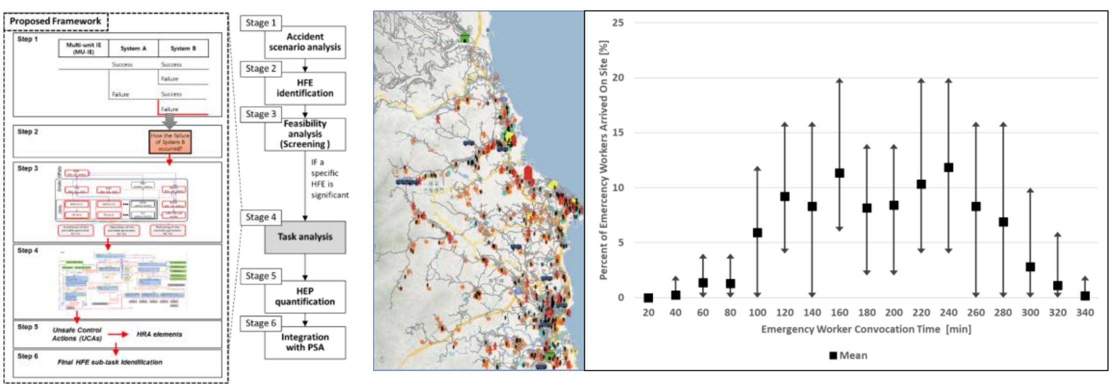

FIGURE 1. Examples of HFE Sub-Task Analysis Framework using STPA and Off-Site Workers Arrival Time Estimation using ABM

$$HEP_{total} = DEP + CEP + EEP \tag{1}$$

The proposals/suggestions to improve accident responses were assessed in a case study based on the east coast nuclear power plant site in Korea. Note that the Korean emergency response guidelines/procedures are not set in stone yet, so the initial condition assumed current state-of-knowledge in Korean portable equipment emergency responses. On behalf of those assumptions, there are five proposals to reduce the HEP regarding the use of portable equipment during multi-unit accident responses.

1) Let the minimum staffing level required to transfer, move, install, and operate the portable equipment during the multi-unit accident response be on site at all times (i.e., no requirement for mobilization of the off-site workers)
2) Operate the arrived off-site workers/personnel at a site-level, not at a twin-unit level (i.e., share the workers at a site-level for the operation of portable equipment).

3) Improve the DC battery capacity and mandatorily set in the procedure the non-essential load shedding to enable the required AC recovery time of 8 hours or more
4) Install fixed and seismic-resistant pipes to more easily connect the portable pumps
5) Minimize the number of portable equipment vehicles for transfer (e.g., reduce from 2~3 trucks/cars into 1)

Preliminary results on the maximum reduction in HEPs for different level of NPP accident (one unit, twin-unit, and site-level) and different earthquake categories (G1, G2, G3, and G4, where higher category means stronger external hazard i.e., earthquake and less means for emergency response) are shown in Fig. 2. Maximum reduction means reduction in HEPs for the units which may not be able to perform full portable equipment emergency response since offsite workers may arrive on time (i.e., no credit for off-site workers). The reason why there is a noticeable drop in HEP reduction between categories G1-G3 versus G4, because G4 is the most extreme external hazard case and thus has highest HEP values regardless of applying the proposed strategies (e.g., having workers on time and doing all those improved strategies may still not have as great of impact for the worst cases of external hazards).

The results and insights from this study can be utilized for other NPP sites to improve their accident responses using portable equipment, by assessing the organizational/human errors required in the multi-unit risk model.

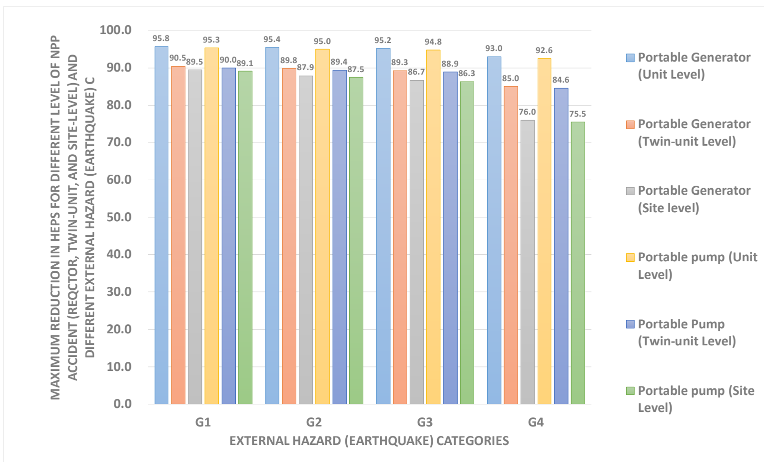

FIGURE 2. Preliminary Results on the Maximum Reduction in HEPs for Different Level of NPP Accident (One Unit, Twin-Unit, and Site-Level) and Different Earthquake Categories (G1, G2, G3, And G4)

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REFERENCES

[1] S.W. Kang, J. Kim, J. Park, J.W. Park, and S.M. Shin, "A Framework to Identify the Catalog of Important Tasks Reflecting Interorganizational Characteristics Regarding the Deployment of Portable Equipment," IEEE Access, **13**, 65690-65703 (2025).
[2] S. W. Kang and J. Park, G. Kim, G. Heo, and S. Jang, "Proposal to Estimate the Mobile Equipment Installation Time during a Multi-unit Accident Management using an Agent-Based Model," 2023 Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, Oct. 26-27 (2023).
[3] J. Kim, S.W. Kang, Y. C. Kim, J. Park, and H.G. Lim, "Multi-unit Human and Organizational Reliability Analysis Method under Various Emergency Organization Structures assuming Staffing Availability," KAERI/TR-10991/2025, Technical Report in Korean (2025).