A study on Fire HRA for Korean Nuclear Power Plants

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1. Introduction

A Human Reliability Analysis (HRA) is generally defined as a structured approach used to identify potential Human Failure Events (HFE) and to systematically estimate the probability of those errors using data, models, or expert judgment. An HRA is developed for a Probabilistic Safety Assessment (PSA) since an HRA is needed to model the as operated portion and a PSA reflects the as-built and as-operated plant. A fire hazard has been recognized to be a major challenge to safe operation of NPPs. Therefore, many researches for a fire risk quantification in nuclear power plants (NPPs) have been performed. As part of efforts for a fire risk quantification, NUREG/CR-6850 was developed to document state-of-the-art methods, tools, and data for the conduct of a fire PSA for a commercial NPP application [1]. NUREG-1921 was also developed to provide a method and associated guidance for conducting a fire HRA to use as explicit guidance for estimating Human Error Probabilities (HEPs) for HFEs under fire conditions, building on existing HRA methods [2].

In Korea, a research has been performed to establish a technology system for performance-based fire PSA, to develop HRA technologies for the fire PSA, and to develop an experimental technology on the spread of fire in reduced multi-compartment situations. For the development of fire HRA technologies, we reviewed existing related research reports such as NUREG-1921 and the K-HRA method, a standard method for HRA of a domestic level 1 PSA developed at the Korea Atomic Energy Research Institute (KAERI), and fire related procedures in domestic NPPs [3]. Then, we developed a guideline for the fire HRA required for a fire PSA of domestic NPPs based on the K-HRA method [4].

The purpose of this paper is to introduce the fire HRA method we developed for domestic NPPs briefly. In particular, the focus was on describing the modifications of the K-HRA, taking into account the fire situation of domestic nuclear power plants.

2. Fire HRA Process for Korean NPPs

Based on the review of NUREG-1921, we partially revised the methodology of the report in light of fire situations in domestic NPPs and apply the modified method to a fire HRA of a domestic NPPs. The modifications include the type of HFE, screening criteria, and the selection of analysis method for a quantification. Fig. 1 shows the process of the fire HRA method for domestic NPPs.

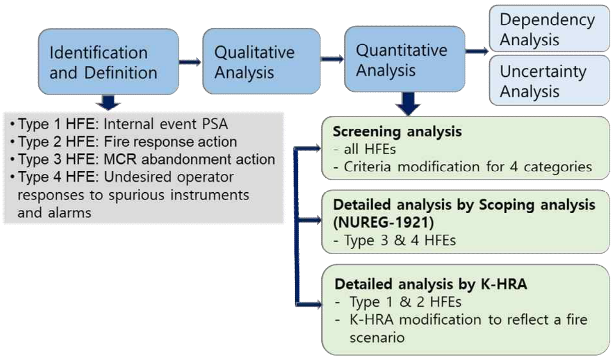

Fig. 1. Process of fire HRA for Korean NPPs

The followings describe the differences between NUREG-1921, a recent NRC and EPRI's joint research output about fire HRA, and the fire HRA methodology we developed for domestic nuclear power plants.

2.1. Identification of HFEs

We defined four types of HFE for a fire HRA while NUREG-1921 classified HFEs into three categories. We subdivided the HFE from fire response action including Main Control Room Abandonment (MCRA) action into two types: HFEs from fire response action and HFEs from MCRA action for application to domestic NPPs. This is to maintain consistency with a quantification analysis since we adopted different methods for quantitative analysis of two groups: Type 1 and 2 HFEs and Type 3 and 4 HFEs.

- Type 1 HFE: HFEs from the existing internal event PSA
- Type 2 HFE: HFEs from fire response action
- Type 3 HFE: HFEs from MCRA action
- Type 4 HFE: HFEs from undesired operator responses to spurious instruments and alarm

2.2. Screening criteria

We defined 70 minutes as the time to divide long-term and short-term, while the NUREG-1921 uses 60 minutes. Based on the suppression curve table of NUREG-1921, for the "All Fires" category, the 99th percentile fire suppression value corresponds to a time of 70 minutes. Therefore, we modified the time to divide the long-term and short-term for a screening analysis. In NUREG-1921, it was difficult to match the definition of 'set' of screening criteria with the definition of HFE, which caused confusion in application. We redefine the definition of 'set' to eliminate such confusion.

2.3. Quantification

A scoping analysis, which uses decision-tree logic and a look-up table for the appropriate HEP value is a new simplified quantification approach developed specifically for NUREG-1921, which addresses fire specific aspects of operator performance. In this research, due to the limitation of the K-HRA method, we applied the scoping analysis for the quantification of Type 3 HFEs and Type 4 HFEs defined previously, instead of the detailed analysis, when they were not screened out by the screening analysis. That is, the final detailed quantification analysis of HFEs from MCRA actions, and from undesired operator responses to spurious instruments and alarms, is the scoping analysis for the domestic fire HRA. Type 1 HFE and Type 2 HFE are quantified using the K-HRA method. To apply the K-HRA method to a fire HRA, we modified the Performance Shaping Factors (PSFs) of K-HRA to reflect fire situation and fire effect based on fire procedures of domestic NPPS and interviews with MCR operation experts.

3. K-HRA Modification

The K-HRA divides a task into diagnosis and execution, and then adds both HEPs (diagnosis part and execution part) of an HFE. For HEPs of diagnosis and execution, the effects of related PSFs are evaluated and weighted. In this research, we made an effort to reflect a fire scenario in the K-HRA method. To this end, we investigated fire procedures and interviewed plant operation experts. Therefore, we modified the PSF selection rules provided by the K-HRA to reflect a fire situation and the effect of domestic NPPs. Table 1 shows the considerations of fire situation, related K-HRA PSFs of which modifications are required, and their modification strategies.

Table 1. Modification strategy of K-HRA PSFs for fire HRA

Considerations of fire situation	Related K-HRA PSF	Modification Strategy
Impact on STA (Shift Technical Advisor)'s absence in MCR due to a fire brigade interaction	Basic Diagnosis HEP	Amendment to a formula for diagnosis HEP by K-HRA method
	Cue perceived time	Modification by • STA's unique task • The existence of STA's duty agent during his/her absence • Cue occurrence time
Fire effects on the operator's path to local site	Execution time	Extended travel time to local due to alternative path navigation and preparedness of related equipment
Increased stress /complexity	Stress level	Application based on interview with operators
	Subtask complexity	
Protective clothing/ equipment	Execution time	Time to wear a protective clothing
	MCR/Local	Hazard environment
Decrease of staff in MCR	Supervisor	Reduced supervisory capability due to staffing in MCR
Parallel use of EOP with fire procedure	Procedure	Application based on interview with operators

4. Conclusions

The purpose of this paper is to describe the fire HRA method we developed for domestic NPPs briefly. We focused on the modifications of the K-HRA, taking into account the fire situation of domestic NPPs. For the purpose, we investigated fire procedures as well as the recent fire HRA research result by NRC and EPRI and interviewed plant operation experts. Based on the information, we modified the PSF selection rules of the K-HRA to reflect a fire situation in domestic NPPs.

We plan to perform a case study of a domestic NPP based on the fire HRA method developed in this research and give feedback on the guideline based on the case study result.

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