Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Considerations of HRA for Domestic Fire PSA

Sun Yeong Choi & Dae Il Kang

Korea Atomic Energy Research Institute, Integrated Safety Assessment Div., Daedeok-daero 989-111, Yuseong-Gu, Daejeon, Republic of Korea, 305-353
sychoi@kaeri.re.kr

1. Introduction

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 probabilistic safety assessment (PSA) for a commercial NPP application [1]. It was conducted as a joint activity between the Electric Power Research Institute (EPRI) and the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) under the terms of an NRC/EPRI Memorandum of Understanding (MOU).

A human reliability analysis (HRA) is generally defines as a structured approach used to identify potential human failure events (HFEs) and to systematically estimate the probability of those errors using data, models, or expert judgment. An HRA is developed for a PSA since an HRA is needed to model the as operated portion and a PSA reflects the as-built and as-operated plant.

The NUREG/CR-6850 developed high-level guidance on the process for identifying HFEs and for including them in the fire PSA. The guidance also defined a process for assigning quantitative screening values to these HFEs. It outlined the initial considerations of performance shaping factors (PSFs) and related fire effects that may need to be addressed in developing best-estimate human error probabilities (HEPs). However, it did not identify or produce a method to develop best-estimate HEPs given the PSFs and the fire-related effects. For an explicit guidance for estimating HEPs for HFEs under fire conditions, building on existing HRA methods, another report, NUREG-1921 was developed to provide a method and associated guidance for conducting a fire HRA [2].

In Korea, a research has been performed to establish a technology system for performance-based fire PSA, to develop computerization and HRA technologies for fire PSA, and to develop an experimental technology on the fire spread in the reduced multi-compartments [3]. We plan to develop a procedure to provide a guidance for a fire HRA required for a domestic fire PSA based on K-HRA method that is a standard method for HRA of a domestic level 1 PSA developed by Korea Atomic Energy Research Institute (KAERI) [4].

The purpose of this paper is to investigate the fire-HRA method of NUREG-1921 describing the state-of-art fire HRA method and to list considerations to develop a fire HRA technology for a domestic fire PSA.

2. Fire HRA Process by NUREG-1921

The objective of NUREG-1921 is to develop methods and supporting guidelines for estimating HEPs for HFEs following fire-induced initiating events of a PSA based on existing HRA information such as HRA process and methods and the screening method included in NUREG/CR-6850.

The scope of the fire HRA focuses on post-initiating event (dynamic) HFEs; these are grouped into the following categories:

- Internal events HFEs: events accounting for actions from, or associated with, the internal events PRA, typically using the normal (non-fire) set of emergency operating procedures
- Fire response HFEs: events reflecting failures of actions added to the fire PRA, typically from fire procedures, fire response plans or pre-plans. These actions include those associated with a main control room (MCR) abandonment
- HFEs corresponding to undesired response to spurious actuation or spurious instrumentation

Figure 1 shows high-level steps and related them to HRA subtasks for the fire HRA process provided in NUREG-1921. There exist some changes in NUREG-1921 from the original NUREG/6850 HRA developments.

- Identification and definition: The fire HRA process is unchanged from NUREG/CR-6850. However, as previously mentioned, NUREG-1921 introduces different categories of HFEs in order to better understand the influence of the procedures from which the actions are invoked.
- Qualitative analysis: NUREG-1921 has addressed qualitative HRA explicitly and has devoted an entire section to this step.
- Quantitative analysis: For fire HRA, this report provides three levels of quantification, screening, scoping, and detailed HRA. Although the levels are presented sequentially, it is not required that an HRA analyst progress through them sequentially or use all of the methods. If the analyst finds the

screening and scoping methods to be too conservative or limiting, the analyst is encouraged to use one of the more detailed HRA methods. The scoping analysis is a simplified HRA quantification approach developed specifically for NUREG-1921 which provides an additional guidance beyond the screening analysis.

- Recovery, dependency, and uncertainty: These are aspects of fire HRA that were not addressed in NUREG/CR-6850.

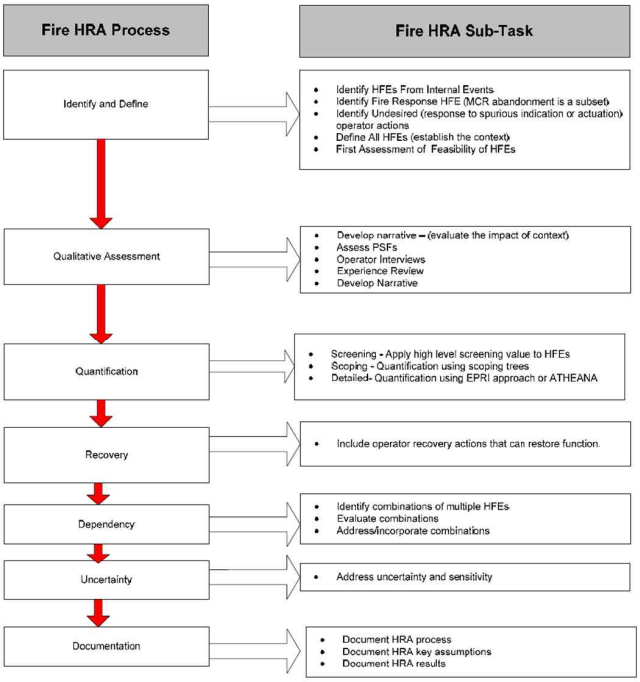

Fig. 1. Fire HRA Process by NUREG-1921

3. Considerations of Fire HRA for Domestic Fire PSA

We plan to develop a procedure to guide a fire HRA process based on K-HRA for a domestic fire PSA as mentioned above. To this end, we investigate the existing documents to describe a fire HRA for US NPPs and fire related abnormal operating procedures/alarm response procedures (AOPs/ARPs) in domestic NPPs. We also gathered various opinions about improvements of K-HRA to apply for a fire HRA through HRA experts meetings (Fig. 2).

In the K-HRA method, it is assumed that human error probability can be assessed by analyzing diagnosis part and execution part separately. And the method categorizes human tasks of a NPP into pre-initiating and post-initiating HFEs. Pre-initiating HFEs are the human errors which are occurred in daily routine tasks such as tests, maintenances and calibrations during normal operation. Such kind of routine tasks are performed based on a procedure and a pre-defined task plan, so the role of diagnosis part of human behavior is almost negligible. Thus diagnosis error does not need to be assessed for the pre-initiating HFEs. On the other hand, human tasks related to post-initiating HFEs need both parts of human behavior, diagnosis and execution. According to the human behavior model, the standard method has two separate analysis processes for pre-initiating and post-initiating HFEs. Also a set of PSFs is used in the qualitative and quantitative analysis of the method.

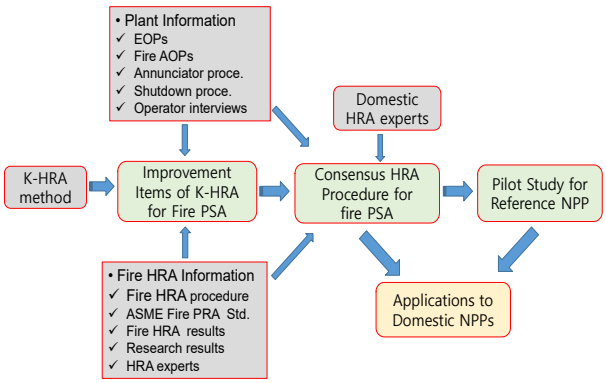

Fig. 2. Flowchart for the development of Fire HRA Procedure

As a pre-work to develop a fire HRA procedure for domestic fire PSA, we made efforts to investigate considerations for applying fire HRA to a domestic fire PSA. They may be improvements of K-HRA method or the fire HRA guidance by NUREG-1921, since the fire HRA process eventually would be developed based on K-HRA and K-HRA is developed for level 1 PSA. The improvements are as follows:

- NUREG-1921 focuses on three kinds of post-initiating event (dynamic) HFEs as mentioned above. The category for HFE types needs to be more detailed. In particular, fire response HFEs should be distinguished between a situation in which a fire originated inside a MCR and one outside the MCR. Operator's behaviors are considered different when a fire occurs inside the MCR and outside the MCR. Therefore, we plan to consider HFEs of both cases.
- The criteria for feasibility assessment needs to be established to reflect domestic NPP environments since the feasibility assessment is a continuous action step throughout the fire HRA. For example, there exist a fire brigade in domestic NPPS and two kinds of AOPs for a general fire and an MCR fire. From those things, the characteristics of domestic NPPs related to fire response are different from those of the US NPPs.
- Two phase approach needs to be conducted for quantifying HFEs. The first of the two phase analysis can be either a screening analysis or a scoping analysis by NUREG-1921 and also needs to be more refined. There are three kinds of HEP quantification methods which are screening analysis, scoping analysis, and detailed analysis in NUREG-1921. Although the levels are presented sequentially,

it is not required that an HRA analyst progress through them sequentially or use all of the methods.

- PSFs and factors for dependency analysis needs to be modified to reflect fire scenario in a domestic NPPs. In addition to the existing PSFs provided in K-HRA, PSFs which reflects the fire characteristics should be considered. Examples are as follows:
  - Modification of allowed time or perceived time due to an STA's response to a fire
  - Modification of weighting factor due to a burden of an MCR evacuation
  - Modification of stress level due to a fire suppression status

4. Conclusions

We have performed a research to develop a computerization program for the construction of fire PSA model and an HRA technology for a domestic fire PSA. We plan to develop a procedure to provide a guidance for a fire HRA required for a domestic fire PSA based on K-HRA.

In this paper, we described a fire HRA method by NUREG-1921 and some considerations of fire HRA for a domestic fire PSA. With these results, we are to develop a procedure to guide a fire HRA process for domestic NPP application.

Acknowledgement

This work was supported by Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant funded by the Korean government, Ministry of Science, Ict & future Planning (MSIP). (Grant Code: 2017M2A8A4016659)

REFERENCES

[1] R. P. Kassawara and J. S. Hyslop, EPRI/NRC-RES Fire PSA Methodology for Nuclear Power Facilities, NUREG/CR-6850, 2005.
[2] S. Lewis and S. Cooper, EPRI/NRC-RES Fire Human Reliability Analysis Guidelines, NUREG-1921, 2012.
[3] D. I. Kang, Annual Project Research Report for Development of Domestic Specific Performance-based Fire Protection Technology, 2017.
[4] W. Jung, D. I. Kang and J. Kim, Development of a standard method for Human Reliability Analysis of Nuclear Power Plants, KAERI/TR-2961/2005.