# A Case study on the Quantification of Fire-specific Human Failure Events through Scoping Analysis

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## 1. Introduction

Since it was recognized that the fire hazard was a major challenge to safe operation of NPPs, many researches for a fire risk quantification in nuclear power plants (NPPs) have been performed. As part of such research efforts, NUREG/CR-6850 was developed to conduct of a fire probabilistic safety assessment (PSA) under a joint research between the U.S. Nuclear Regulatory Commission (NRC) and the Electric Power Research Institute (EPRI) [1]. For a fire human reliability analysis (HRA) to support a fire PSA proposed by NUREG/CR-6850, NUREG-1921 was developed [2]. Reflecting the fire PSA trend, several researches have been carried out in KAERI based on NUREG-6850 [3-4]. And also a fire HRA guideline for a fire PSA of full power operation of domestic NPPs was developed in 2018 by the (KAERI) based on the NUREG-1921 [5] and performed case study for quantification with the K-HRA method [6]. K-HRA method is a standard method for HRA of a domestic level 1 PSA developed by KAERI [7]. For the fire HRA, K-HRA was modified to reflect fire situation and effects.

One of the major characteristics of the fire HRA guideline developed by KAERI is to apply a scoping analysis that was developed in NUREG-1921 for a detailed quantification of some kind of fire human failure events (HFEs). Scoping analysis is a new fire HRA quantification approach to assign human error probabilities (HEPs) to new HFEs identified specifically for the fire PSA and to HFEs carried over from the internal events analysis that survive quantitative screening. In this paper, we performed a case study with scoping analysis for a detailed quantification.

The purpose of this paper is to introduce a scoping analysis and the process of the scoping approach to assign HEP through the case study.

## 2. Scoping Analysis in Fire HRA Guideline for Application to Domestic NPPs

Fig. 1 shows the overview of a fire HRA guideline for a fire PSA of domestic NPPs. The fire HRA process can be grouped into 'Identification and Definition of HFE', 'Qualitative analysis', and 'Quantitative analysis'. The quantitative analysis is classified into two kinds of analyses consist of 'screening analysis' and 'detailed analysis'. Based on the HFE type, scoping analysis by NUREG-1921 or K-HRA method are selected for the detailed quantification.

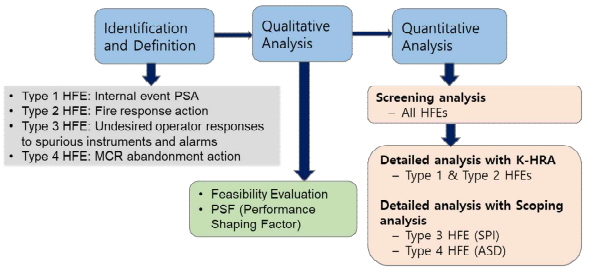



Fig 1. Overview of Fire HRA Guideline developed by KAERI

As described in Fig. 1, we defined four types of HFE for a fire HRA:

- Type 1 HFE: HFEs from the existing internal event PSA
- Type 2 HFE: HFEs from fire response action
- Type 3 HFE: HFEs from undesired operator responses to spurious instruments and alarms
- Type 4 HFE: HFEs from main control room abandonment (MCRA) action

For a detailed quantification, scoping analysis is applied to Type 3 HFE and Type 4 HFE when they are not screened out by the screening analysis. The K-HRA method developed for quantification of HFEs for level 1 PSA considers a diagnosis error part and an execution error part to estimate an HEP. Since Type 3 and Type 4 HFEs in Fig. 1 are very special HFEs that can only occur in a fire situation, we decided to apply the scoping analysis for quantification of those HFEs.

Fig. 2 shows the selection scheme for scoping HRA from NUREG-1921. In the scoping fire HRA quantification approach, HFEs are treated based on conditions within the MCR, the location of the diagnosis and execution of the actions associated with the HFE (MCR or ex-CR), and the condition of relevant instrumentation. For the four kinds of transfers (ASD, SPI, INCR, and EXCR), NUREG-1921 provides decision-tree logic and descriptive text to guide the analyst to the appropriate HEP value. The minimum criteria for D1 question are as follows:

- Procedure: There should be plant procedures covering each operator action being modeled
- Training: Operators should have received training on the actions being performed

- Availability and accessibility of equipment: All equipment and tools needed to perform the actions should be readily available and accessible

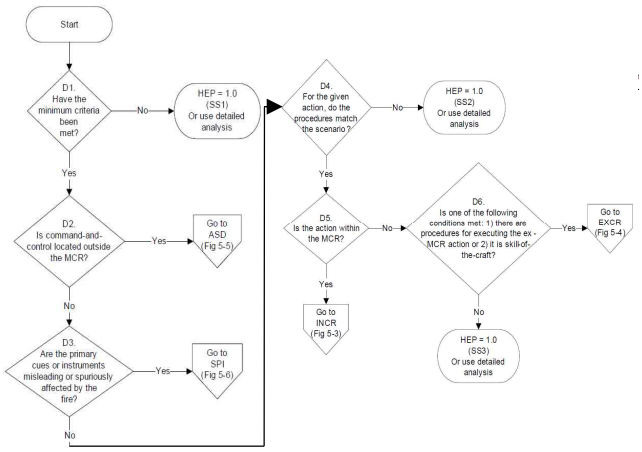



Fig 2. Scoping HRA Selection Scheme by NUREG-1921

With the fire HRA Guideline for application t domestic NPPs, ASD (Alternative shutdown) part fc Type 3 HFE and SPI (Spurious instrumentation) part fo Type 4 HFE are used.

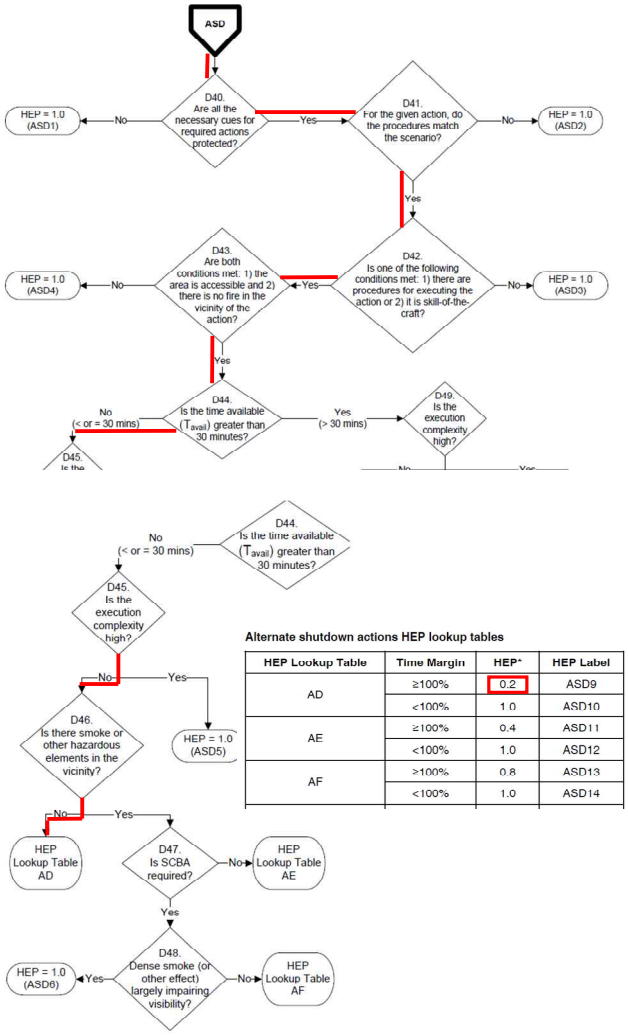
### 3. HEP Quantification with Scoping Analysis

In this paper, an example of the case study we performed was described. We defined an HFE, 'SWITCH-H-RSP' for the case that an operator fails to establish control at remote shutdown panel (RSP) after leaving MCR due to fire. The scoping approach is a simplified HRA method that requires only a few performance shaping factors (PSFs) to be assessed.

Fig 3 show the scoping approach to quantify HEP for the HFE and Table 1 shows related question list. For the analysis, we interviewed a shift supervisor (SS) and a technical shift advisor (STA) having more than 15 year MCR operations of OPR1000 plant

Table 1. Example of Scoping Approach for an ASD HFE

| ID | Question | Answer | Evidence of Answer |
|---|---|---|---|
| D40 | Are all the necessary cues for required actions protected? | Y | Operator's judgment |
| D41 | For the given action, do the procedures match the scenario? | Y | Operator's judgment |
| D42 | Is one of the following conditions met: 1) there are procedures for executing the action or 2) it is skill-of-the craft? | Y | Abnormal Operating Procedure (AOP) |
| D43 | Are both conditions met: 1) the area is accessible and 2) there is no fire in the vicinity of the action? | Y | RSP and MCR are located in different floors |
| D44 | Is the time available ($T_{avail}$) greater than 30 minutes? | N | Timeline (Fig. 4) |
| D45 | Is the execution complexity high? | N | Operator's judgment |
| D46 | Is there smoke or other hazardous elements in the vicinity? | N | RSP and MCR are physically separated |




Alternate shutdown actions HEP lookup tables

| HEP Lookup Table | Time Margin | HEP* | HEP Label |
|---|---|---|---|
| AD | ≥100% | 0.2 | ASD9 |
| | <100% | 1.0 | ASD10 |
| AE | ≥100% | 0.4 | ASD11 |
| | <100% | 1.0 | ASD12 |
| AF | ≥100% | 0.8 | ASD13 |
| | <100% | 1.0 | ASD14 |

Fig 3. Scoping Approach for quantification of 'SWITCH-H-RSP'

In Fig. 3, final HEP is estimated at 0.2 through the lookup table, 'AD'. To this end, the evaluation of time margin is required. Fig. 4 shows the related time margin assessment. The value of time parameter in Fig. 4 were from NUREG-1921 and operator interview.

Based on the time margin equation in NUREG-1921, time margin of 'SWITCH-H-RSP' exceeds 100%.

$$Time\ Margin = \frac{T_{avail} - T_{req}}{T_{req}} \text{X } 100\% = \frac{23-2}{2} \text{X } 100\% \geq 100\%$$

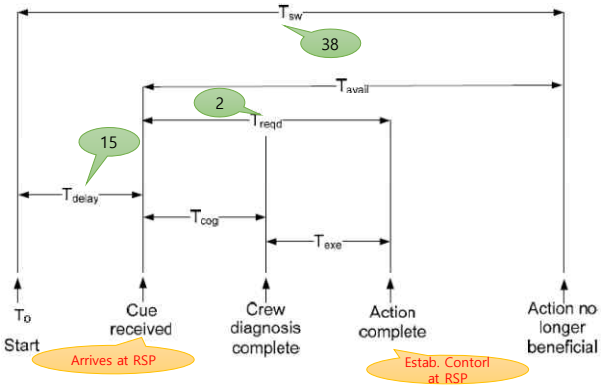



Fig 4. Timeline of 'SWITCH-H-RSP'

## 4. Conclusions

The purpose of this paper is to introduce a scoping analysis developed by NUREG-1921 and to describe the scoping approach process to assign HEP through a case study. As mentioned above, the scoping fire HRA quantification approach allows the assignment of HEPs to new HFEs identified specifically for the fire PSA and to HFEs carried over from the internal events analysis that survive quantitative screening. For the case study with scoping analysis, an MCRA related HEF (SWITCH-H-RSP) which is to describe an operator's error to establish control at RSP after leaving MCR due to a fire was selected. We investigated related AOP and interviewed MCR operators to understand the situation. The HEP of 'SWITCH-H-RSP' was estimated as 0.2. To this end several PSFs were considered:

- Do the procedures match the scenario?
- Response execution complexity
- Time available
- Levels of smoke and other hazardous elements in action areas
- Accessibility

Scoping is intended to provide less conservative HEPs than screening but requires less time and effort than a detailed HRA analysis. However, this simplified approach is appropriate only if the fire scenario being evaluated is not cognitively complex or challenging, since the scoping approach requires only a few PSFs to be assessed. In case of a HFE related to 'Decision to Abandon MCR' due to a loss of control (LOC), the scoping approach should not be used to quantify any failures associated with making this decision.

Recently, two kinds of reports about quantification analysis for HFEs related to MCRA were published [8-9] and also revised report about qualitative analysis for those HFEs was published by NRC and EPRI [10]. Those reports provided a guidance on how to develop the HEP for the HFE that represents the decision to abandon an MCR following a fire-induced scenario. The current HRA methods did not adequately address the operators' reluctance to abandon the MCR. We also did not consider the operators' reluctance. However, reluctance was considered to be an important factor for many NPPs. Therefore, we should investigate the methodology and decide how to reflect the methodology for an application to a fire HRA of domestic NPPs.

## Acknowledgement

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