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Preliminary Quantifications of Human Failure Events Affected by an Internal Fire Event

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1. Introduction

The previous fire Probabilistic Safety Assessment (PSA) for domestic nuclear power plants (NPPs) did not explicitly address human failure events (HFEs) affected by an internal fire event. Recently, USNRC and EPRI developed guidance, "Fire Human Reliability Analysis Guidelines, NUREG-1921", for estimating human error probabilities (HEPs) for HFEs under fire conditions. NUREG-1921 provides three approaches to the quantification of HFEs: screening, scoping, and detailed HRA. Screening is based on the guidance in NUREG/CR-6850, with some additional guidance for scenarios with long time windows. Scoping is a new approach to quantification developed specifically to support the iterative nature of fire PSA quantification. In this paper, preliminary analysis results of HFEs previously modeled in an internal event PSA for UCN 3&4 NPPs using the scoping approach of NUREG-1921 are introduced.

2. Scoping analysis method

The scoping method is developed to alleviate some of the conservatism of the screening approach and may be used in lieu of the screening approach if potentially less conservative initial HEPs are desired. The scoping method uses a decision-tree logic and descriptive text to guide the analyst to the appropriate HEP values.

The scoping method provides flowcharts for four categories of actions associated with the following HFEs:

- New and existing Main Control Room (MCR) actions
- New and existing ex-MCR actions
- Actions associated with using alternate shutdown means (ASD)
- Actions relating to the error of commissions (EOCs) or error of omissions (EOOs) as a result of incorrect indications (SPI)

When the scoping fire HRA approach is used, minimum criteria must be satisfied, and the time margin, key conditions and performance shaping factors are to be addressed

If the criteria covered within this scoping procedure are not met, the analyst must use a more detailed HRA evaluation method. The minimum criteria for the use of the scoping method are as follows:

- Procedures. There should be plant procedures (e.g., fire procedures, EOPs, ARPs, AOPs,and/or NOPs) covering each operator action being modeled
- Training. Operators should have received training on the procedures being used and the actions being performed
- Availability and accessibility of the equipment: All equipment and tools needed to perform the modeled human actions during a fire should be readily available and accessible

The time margin is the difference between the total available time and the time required. Fig.1 shows each of the terms in the timeline. The time margin is calculated using Eq. (1).

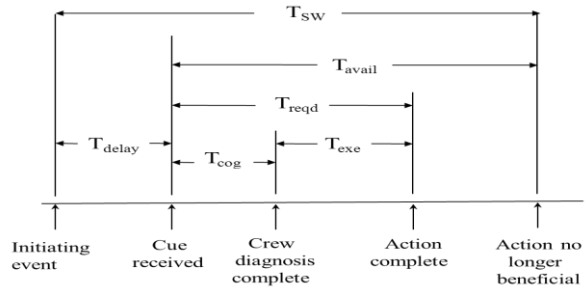

Fig 1. Timeline illustrating T_{sw}, T_{delay}, T_{avail}, and T_{reqd}

$$\text{Time Margin(TM)} = \frac{[(T_{SW} - T_{delay}) - (T_{cog} + T_{exe})]}{(T_{cog} + T_{exe})} \text{ x } 100\% \quad (1)$$

Conditions and PSFs that can affect the human performance must be considered. Key performance shaping factors are as follows:

- Do the procedures match the scenario?
- Response execution complexity
- Timing of cues for the action relative to expected fire suppression time
- Time available
- Levels of smoke and other hazardous elements in action areas
- Accessibility

3. Analysis results

In this study, only pre-existing human actions modeled in an internal event PSA for UCN 3&4 were quantified using the scoping method of NUREG-1921.

The following approaches were employed for performing the scoping HRA of pre-existing post-accident HFEs considered in an internal event PSA model:

- Make a list of pre-existing post-accident HFEs considered in an internal event PSA model.
- Exclude HFEs not relating to a fire event.
- Local manual recovery actions of motor operated valves are not considered.
- Instrumentation equipment relating to HFEs is modeled using an 'OR' gate. Figure 2 shows the fault tree representing the failure of instrumentation equipment relating to HFEs. If the instrumentation components or their cables are damaged by a fire, they are modeled using the following Eq.(2):

  $$a \Rightarrow a + \sum \%R_k * P\%R_k\text{-}a \quad (2)$$

  where $\%R_k$ = fire frequency event of fire scenario or compartment k; a = basic event for the random instrumentation component failure; $P\%R_k\text{-}a$ = fire damage events for the basic event relating to the equipment or cables
- If the probabilities of HFEs quantified using the scoping method are lower than those of pre-existing HFEs in the internal event PSA model, the probabilities of HFEs under a fire condition are estimated as two times the HEPs for pre-existing HFEs.

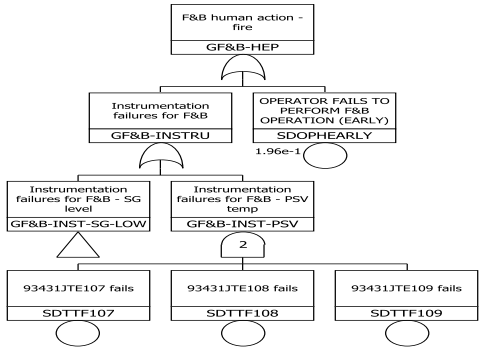

Fig. 2 Example of fault tree representing the failure of instrumentation equipment relating to HFEs

Based on the information of the HRA results for UCN 3&4, a preliminary scoping analysis was performed. Table 1 shows the analysis results of important human actions under fire conditions. As shown in Table 1, the quantification results of HFEs under a fire condition are higher than those of pre-existing HFEs in the internal event PSA model.

4. Concluding remarks

This paper introduces the analysis results of HFEs previously modeled in an internal event PSA using the scoping approach of NUREG-1921. From this study, we can confirm that the applications of the scoping method to the HFEs modeled in an internal event PSA are easy and simple compared with the detailed HRA method. Furthermore, it provides reasonable HEP values. One of challenging areas for the utilization of the scoping method in a fire PSA for the domestic NPPs is insufficient information on the timeline analysis of the accident progression.

Acknowledgements

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References

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Table 1. Preliminary quantification results of pre-existing human actions affected by a fire

Event name	**HEP (internal)**	event description	**Scoping analysis(Fire)**		suppressed or not	complex or not	T_{sw}	T_{delay}	T_{cog}	T_{exe}	Margin (%)
AFOPHALTWT	**4.19E-03**	Operator fails to arrange alternate water source	**1.00E-02**	EXCR15	Yes	complex	540	180	10	40	620
EGOPHDG01E	**1.02E-02**	Operator fails to start AAC DG-01E & connect at 1E 4.16KV BUS	**1.00E-01**	EXCR36	No	complex	60	10	5	15	100>
FSOPVSIAS	**1.10E-03**	Operator fails to manually generate SIAS	**1.00E-02**	INCR26	No	simple	>30min	<5min	<5min	1min	100>
MSOPHSR	**1.08E-03**	Operator fails to remove steam (ADV/TBV)	**5.00E-03**	INCR11	Yes	complex	90	20	1	2	2233.3
SCOPHSDCOP	**1.15E-03**	Operator fails to initiate shutdown cooling	**5.00E-03**	INCR11	Yes	complex	300				
SDOPHEARLY	**1.96E-01**	Operator fails to perform F&B operation (early)	**2.50E-01**	INCR15	No	simple	23	10	5	3	62.5