Transactions of the Korean Nuclear Society Autumn Meeting

Gyeongju, Korea, October 26-27, 2023

A Study of Variability Effect of Performance Influencing Factors in Human Error Probability Quantification

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***Keywords:** Performance Influencing Factors (PIF); IDHEAS-G; SPAR-H; SGTR; ELAP

1. Introduction

Human Reliability Analysis (HRA) represents a methodical structure that involves assessing human performance and its effects on structures, systems and components in a complex engineering facility[1]. HRA has to do with human machine interaction in complex facilities during operation, maintenance and management. Due to the complexity of human behavior, it is challenging to predict with certainty how an individual would react in a particular situation. As such, performance-influencing factors (PIF) in HRA comes into play in describing or evaluating human behavior in a particular event context.

Numerous HRA methods employs PIFs to estimate the likelihood of HEP or to obtain qualitative insights of a situation. PIF states are characterized on varying scales, depending on the specific method used, typically ranging from low to high impact. HRA methods typically offer guidance on how to evaluate and apply a PIF[2].

The purpose of this paper is to analyze the effects of PIF in the quantification of human error probability (HEP) using two HRA methods (SPAR-H and IDHEAS-G) and two scenarios (steam generator tube rupture and extended loss of AC power).

2. Methodology

SPAR-H and IDHEAS-G HRA methods were employed to evaluate the HEP of two different event scenarios (SGTR and ELAP). The PIF was assigned based on the mapping from the previous study [3]. The figure 1 below depicts the overview of the methodology.

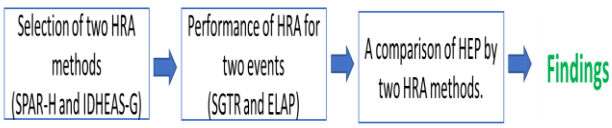

Figure 1 Overview of methodology

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2.1. SPAR-H

SPAR-H is a second-generation HRA method, which quantifies the human failure event (HFE) in two parts: the error probability attributed to diagnosis and the error probability attributed to action. It utilizes 8 PIFs in HEP computation.

(1) $\mathrm{HEP_{SPAR-H}} = \mathrm{P_{diagnose}} + \mathrm{P_{action}}$ [4]
(2) $\mathrm{P_{diagnose}} = \mathrm{HEP_{Base}} \times \mathrm{PIFs}$
(3) $\mathrm{P_{action}} = \mathrm{HEP_{Base}} \times \mathrm{PIFs}$

2.2. IDHEAS-G

This method consists of two parts to quantify the HEP. The error probability attributed to time uncertainty ($\mathrm{P_t}$) and the error probability attributed to the failure of the cognitive functions ($\mathrm{P_c}$). It requires the use of 20 PIFs and 5 cognitive failure modes (CFM) for HEP calculation. The base HEP in this method utilizes the cognitive failure mode base, which is built on the three PIF attributes: scenario familiarity ($\mathrm{P_{SF}}$), information availability and reliability ($\mathrm{P_{INF}}$) and task complexity ($\mathrm{P_{TC}}$) as shown in equation (8).

(4) $\mathrm{HEP_{IDHEAS-G}} = 1 - (1 - \mathrm{P_c})(1 - \mathrm{P_t})$ [5]
(5) $\mathrm{P_c} = 1 - \prod_{i=1}^{m}(1 - P_{CT_i})$ [5]
(6) $\mathrm{P}_{CT_i} = 1 - \prod_{j=1}^{n}\left(1 - P_{CFM_j}\right)$ [5]
(7) $\mathrm{P}_{CFM_j} = 1 - \sum_{i=1}^{n}(w_i - 1)$ [5]
(8) $\mathrm{P}_{CFM_{Base}} = 1 - (1 - P_{INF})(1 - P_{SF})(1 - P_{TC})$ [5]

3. Scenario Description and Analysis

3.1 SGTR (scenario 1)

SGTR is a design-based accident that involves the rupture of the steam generator tubes, which results to leak from the primary side to the secondary side. This accident requires operator actions to equalize the pressure between primary and secondary side to prevent steam generator overfill and release of radioactive material. The important human action considered for this study is the rapid heat removal and cooling of reactor coolant system (RCS) to shut down cooling system (SCS) entry temperature (176°C) with maximum cooling

3.2 ELAP (scenario 2)

The ELAP was presumed to have occurred on a PWR as a result of flooding due to a tsunami. Consequently, the use of a mobile generator was assumed to restore power and ensure the continued removal of heat from the reactor core. The human failure action considered was the failure to deploy the mobile generator.

4. PIF correlation for HEP quantification

Table 1 shows the correlation between the PIFs that are applicable for the computation of HEP using IDHEAS-G and SPAR-H for the two scenarios. In IDHEAS-G, available time is not regarded as PIF but rather calculated as the error probability attributed to time uncertainty.

Table 1 - PIF correlation table

Scenario	SPAR-H PIFs	IDHEAS-G PIFs
SGTR	Complexity	Task Complexity
	Procedure	Transfer Procedure
	Available Time	-
ELAP	Available Time	-
	Complexity	Task Complexity
	Experience / Training	Training; Scenario Familiarity;
	Work Process	Team and organizational factors

5. HEP quantification results

In other to compare the HEP results for both scenarios, the PIF correlation developed in the previous study [3] was utilized in assigning the PIFs for IDHEAS-G and SPAR-H. The applicable PIF correlation for SGTR and ELAP HEP quantification are shown in table 1. The results from the HEP calculation for SGTR shows a little variation using SPAR-H and IDHEAS-G. For ELAP, the variation in the HEP computation between IDHEAS-G and SPAR-H was found to be high. The HEP computation for the ELAP scenario using SPAR-H produces a lesser HEP compared to that in the SGTR scenario. This could be attributed to the broad definition of PIFs in SPAR-H, making it quite difficult to identify with scenarios that are outside the main control room (MCR). On the other hand, IDHEAS-G has PIFs that can readily be applied for events that occur outside MCR. The table 2 shows the summary of results of the HEP calculations for both scenarios using IDHEAS-G and SPAR-H.

Table 2 - HEP results using SPAR-H and IDHEAS-G

Scenario	HFE	SPAR-H (HEP)	IDHEAS-G (HEP)
Scenario 1 (SGTR)	Failure of rapid heat removal and RCS cooling	1.001×10^{-2}	1.32×10^{-2}
Scenario 2 (ELAP)	Failure to deploy the mobile generator	1.3×10^{-3}	1.86×10^{-1}

5. Conclusion

In conclusion, this study shows that IDHEAS-G and SPAR-H are adequate in determining the HEP for internal events (events that utilize the EOP). However, for external events, IDHEAS provides flexible and adequate PIF to quantify the HEP while SPAR-H seems more appropriate for internal events. From the results above, it is clear that HRA needs more development to enhance consistent HEP results for external events.

Acknowledgement

This work was supported by the 2023 Research Fund of the KEPCO International Nuclear Graduate School (KINGS), the Republic of Korea.

6. References

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