A Human Performance Analysis on Emergency Tasks of a Nuclear Power Plant

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1. Introduction

Considering risk-informed activities that require the probabilistic safety assessment (PSA) quality to be as high as possible, an HRA should be performed by using a systematic method with realistic plant specific data to meet the requirements for risk-informed applications. In order to obtain more objective HRA results, data extracted from real experiences or simulators is essential [1].

To support HRA activities and researches, we have developed a human performance database, OPERA (Operator Performance and Reliability Analysis) [2]. This paper introduces a study to analyze an operators' performance time, which is the most crucial input for estimating a human error probability of a post-initiating human failure event

2. Importance of the Operators' performance time

According to the result of the PSA of a reference plant, whose HRA was undertaken by using the ASEP HRA [3], a human error was a major contributor to the plant safety. Fig.1, the result of the normalized F-V importance analysis, shows the contribution of each event category to the total core damage frequency (CDF) of the reference plant's PSA and as shown the human error events contribute 44% to the CDF.

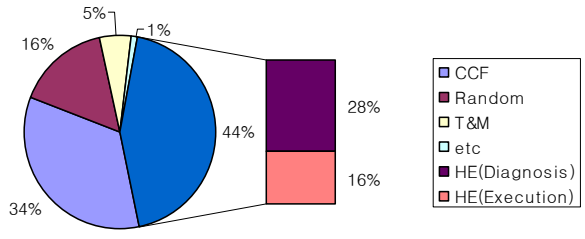


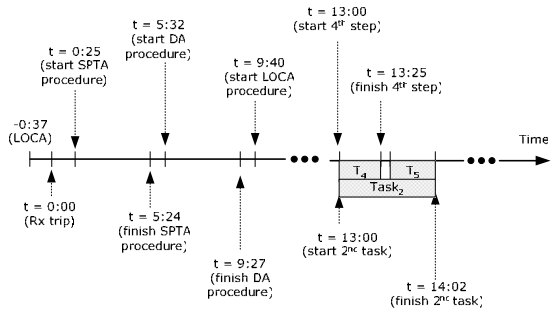
Fig.1. Event contributions to core damage frequency of a reference plant (based on normalized F-V importance)

In the ASEP HRA, the method used for the HRA of the reference plant, the error probability of a human failure event can be quantified by assessing two parts, a diagnosis and an execution, separately. The figure also shows that 28% of the total CDF is caused by the diagnosis parts of the human failure events. For estimating the error probability of a diagnosis part, however, the most significant factor is the available time for a given task.

Time pressure is one of the significant PSFs in most HRA methods. In THERP and ASEP HRA, the methods provide a function of the time where the diagnosis error probability of a given human failure event can be estimated by using the available time for the diagnosis of an event. Therefore, a diagnosis failure probability mainly depends on the available time for a given task. Consequently, operators' performance time is a critical input to an HRA

3. Data Collection and Analysis

Data collection and observation of an operators' emergency behavior have been conducted under simulated accident conditions. The simulator used for the data collection was a full-scope simulator of a reference plant. In total 112 simulation records have been collected from six accident scenarios, LOCA(loss of coolant accident), SGTR(steam generator tube rupture), LOAF(loss of all feed water), ESDE(excessive steam demand event), LOOP(loss of off-site power), and SBO(station blackout). The data collected from the simulator training of a reference plant, and in total 24 different operating crews participated in the study.



T_4, T_5: response time for Step 4 and 5
$Task_2$: response time for Task 2 (Task 2 consists of Step 4 and 5)

Fig. 2. An example of time-line analysis

To extract a human response time for each emergency task and related procedural step(s), we used two task analysis methods, a time-line analysis and a verbal

protocol analysis [4]. We identified what procedure and which steps the operating crew had performed by using a verbal protocol analysis of the simulated records, and extracted the human response time of each procedural step by a time-line analysis. Fig.2 shows a time-line analysis for the LOCA scenario as an example.

4. Analysis Result

Among the several inputs for an HRA, time is one of the most important data from the viewpoint of an error probability. From the time-line analyses, operators' performance time data were obtained, which include the time to perform the procedure of a SPTA (standard post-trip action), the procedure of a DA(diagnosis action), and the time to execute the response tasks and steps described in the optimal recovery procedures(ORPs). Table 1 shows the response time for the SPTA and DA procedures.

Table 1. Operators' execution time of the SPTA and DA procedure

Procedure	Initiating Event	Number of data	Perfor. Time (second)	
			Mean	Std.Dev.
SPTA	All events	112	196.2	72.8
DA	LOCA	28	135.8	47.8
	SGTR	23	195.9	106.7
	ESDE	23	182.4	72.4
	LOAF	18	137.2	89.8
	LOOP	10	106.7	39.9
	SBO	10	101.3	55.3

After diagnosing an occurring event, SRO (Senior Reactor Operator) chooses a relevant ORP and follows the procedure step-by-step to mitigate the event. Operators' performance times of the procedural steps included in the ORPs have been analyzed by a time-line analysis. We basically extracted the execution time of each step and calculated the performance times of the emergency tasks that are defined by a task analysis of the EOPs. The performance time analysis mainly focused on the emergency tasks that would be required in the early phases of accidents or transients. A part of the operators' performance times on the emergency tasks in the ORPs is summarized in Table 2.

Table 2. Operators' execution time of each task

IE	Task descriptions	Procedure Steps	Perfor.time(sec)	
			Mean	SD
LOCA	Delivery of a sufficient SI flow	4-5	565.3	200.5
	Checking criteria for RCP stoppage	6-7	592.8	200.1
	Isolating break location (in/out side containment)	8-13	848.9	272.1
	Securing the integrity of a containment	11-13	808.3	249.4
	Cooling down RCS	15-19	923.0	311.7
	Maintaining RCS conditions within the limit of post accident PT curve	20	988.0	253.4
	Removing voids from RCS	27-28	1245.7	499.3
	Isolating SIT	39	1998.6	738.6
	Preventing LTOP event	40	2448.0	1023.6
SGTR	Delivery of a sufficient SI flow	4-5	576.4	345.3
	Checking criteria for RCP stoppage	6-7	616.7	313.7
	Initial cooling down the hot-leg temperature of RCS	8-10	687.3	179.2
	Identifying and isolating a faulty SG	11-14	1188.3	182.9

5. Conclusion

A human performance database, OPERA, has developed to support HRA activities and researches in NPPs. The operators' performance time is the most crucial input to estimate a human error probability of a post-initiating human failure event. We has collected data and analyzed the operators' execution time of emergency tasks in NPPs. The results obtained from this study will be used not only for the input of an HRA but also for a study on the prevention and reduction of human errors.

References

[1] Wondea Jung and Daeil Kang, Development of a standard human reliability method of nuclear power plants, KAERI/TR-2961/2005, KAERI, 2005..
[2] Jinkyun Park, and Wondea Jung, A database for human performance under simulated emergencies of nuclear power plants, Nuclear Engineering and Technology, 2005, Vol.37(3), p491-502.
[3] Swain A., Accident sequence evaluation program human reliability analysis procedure, NUREG/CR-4772, USNRC, 1987.
[4] B. Kirwan, and L. K. Ainsworth, A guide to task analysis, Taylor & Francis, 1992.