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Development of a framework to estimate human error for diagnosis tasks in advanced control room

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1. Introduction

In the emergency situation of nuclear power plants (NPPs), a diagnosis of the occurring events is crucial for managing or controlling the plant to a safe and stable condition [1]. If the operators fail to diagnose the occurring events or relevant situations, their responses can eventually inappropriate or inadequate [2]. Accordingly, huge researches have been performed to identify the cause of diagnosis error and estimate the probability of diagnosis error. D.I Gertman et al. asserted that "the cognitive failures stem from erroneous decision-making, poor understanding of rules and procedures, and inadequate problem solving and this failures may be due to quality of data and people's capacity for processing information" [3]. Also many researchers have asserted that human-system interface (HSI), procedure, training and available time are critical factors to cause diagnosis error.

As advanced main control room (MCR) is being adopted in NPP such as APR-1400, the operators may obtain the plant data via computer-based console as shown in Figure 1.

Fig. 1. Changes of control room by adopting computer-based technology in advanced MCR

In this regards, it is necessary to develop a framework to diagnosis error probability considering a new computer-based console in advanced MCR. For that, possible error types and its causes were identified and diagnosis error probabilities were obtained based on the simulation data extracted from advanced MCR.

2. Human performance model

Here, one of major cognitive process model proposed by a technique for human error analysis (ATHEANA) is used. The model is the information processing model that describes the range of human activities required to abnormal or emergency condition [4]. This model includes four cognitive steps: (1) monitoring/detection, (2) situation assessment, (3) response planning, and (4) response implementation as shown in Figure 2.

-Monitoring/detection: The activities involved in extracting information from the environments

-Situation Assessment: The activities involved in constructing coherent, logical explanation to account for their observations

-Response Planning: The process of making a decision as to what action to take

-Response Implementation: The specific control actions required to perform a task

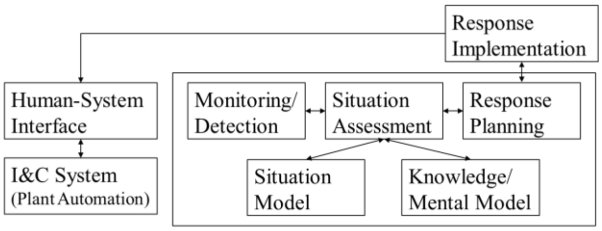

Fig. 2. Major cognitive activities underlying NPP operator performance

Each cognitive step may cause the errors which are deviations from some standard decision process that increase the likelihood of bad outcomes [5]. In this regards, based on this cognitive steps, diagnosis errors were identified.

3. Analysis of simulation data

In order to identify diagnosis error and its causes, simulation data were analyzed. Human factor engineering (HFE) verification and validation (V&V) for Shin-Kori unit 3&4 were performed from August to September, 2012. Six operating crews were participated in and four integrated system validation (ISV) scenarios including LOCA, SGTR 1&2 and SBO were tested. Verbal protocol analysis (VPA) was performed using the extracted simulation data. VPA is regarded as "a meticulous investigation in order to extract useful information about detailed cognitive process of human operators” [6]. In addition, task analysis was performed to identify the required tasks to mitigate the accidents and analyze diagnosis error which are derived from some standard information processing for each required task. There are ten tasks for four scenarios and diagnosis error was analyzed as shown in Table I.

Table I: Estimation of diagnosis error

Task ID	# of errors/# of opportunity
Task #1	0/4
Task #2	2/6
Task #3	0/5
Task #4	2/6
Task #5	0/5
Task #6	1/5
Task #7	0/6
Task #8	6/6
Task #9	0/6
Task #10	0/6

Also, causes for each diagnosis error were analyzed based on human factor (HF) issues identified from Lee et al., 2011 [7]. An analysis result of causes were shown in Table II.

Table II: Analysis of diagnosis error cause

Diagnosis errors	Causes
Error #1	-Problem due to lack of training about team cooperation and team communication
Error #2	-Operators’ situation awareness problem due to complexity of CPS -Problem due to lack of training with CPS
Error #3	-Problem due to lack of training about team cooperation and team communication -Operators’ situation awareness problem due to complexity of CPS
Error #4	-Problem due to increase level of cognitive workload in case of CPS failure -Problem due to workload induced by inconsistencies with other HSIs -Problem inherent in information display design
Error #5	-Operators’ situation awareness problem due to complexity of CPS
Error #6	-Legibility problem due to inappropriate format used in CPS
Error #7	-Legibility problem due to inappropriate format used in CPS
Error #8	-Legibility problem due to inappropriate format used in CPS
Error #9	-Legibility problem due to inappropriate format used in CPS
Error #10	-Legibility problem due to inappropriate format used in CPS
Error #11	-Legibility problem due to inappropriate format used in CPS

Here, errors from #6 to #11 were caused from same reason since all of them were occurred in Task 8 and this is due to short available time and legibility problem due to inappropriate format used in CPS. As a result of analysis, some useful insights to reduce diagnosis errors were provided. It shows the importance of training, and the better design for CPS and HSI.

4. Conclusion

In nuclear power plants, a diagnosis of the event is critical for safe condition of the system. As advanced main control room is being adopted in nuclear power plants, the operators may obtain the plant data via computer-based HSI and procedure. Also many researchers have asserted that HSI, procedure, training and available time are critical factors to cause diagnosis error. In this regards, using simulation data, diagnosis errors and its causes were identified. From this study, some useful insights to reduce diagnosis errors of operators in advanced main control room were provided.

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