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Human Performance Evaluation when using Human System Interface applying Priority Unit Selection Logic for Responding Multi-Unit Severe Accidents

Inseok Jang [a*], Chang Hwoi Kim [a]
[a] *Accident Monitoring and Mitigation Research Team, Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea*
[*] *Corresponding author: isjang@kaeri.re.kr*

1. Introduction

In order to mitigate multi-unit severe accidents efficiently, Korea Atomic Energy Research Institute (KAERI) has developed the information displays based on the severe accident management guidelines (SAMGs) and regulatory guide (R.G) 1.97 rev.5 [1]. During the development phase for the information displays, a priority unit selection logic for responding multi-unit severe accidents was applied as one of the multi-unit monitoring strategies. In addition, using the various simulated instrumentation signal, the implementation of the priority unit selection logic on the information displays was verified. However, the improvement of human performance when using the human system interface (HSI) applying the priority unit selection logic has not been validated yet.

In this regard, the situation awareness of the subjects who participate in the human performance evaluation test are measured with and without HSI applying the priority unit selection logic. Then, based on the difference between the two situation awareness scores, the improvement of human performance when using HSI applying priority unit selection logic is validated.

2. Priority Unit Selection Logic and Related Information Displays

2.1 Priority Unit Selection Logic

The priority unit selection logic applied to the information displays in this study is based on the specific monitoring parameters and their setpoints in the SAMGs [2]. In case that multi-unit severe accidents occur, the priority unit selection logic automatically selects the units that have to be monitored and controlled as an important order. Basic rules for the priority unit selection logic are based on the general accident phenomena. Table 1 shows the suggested priority unit selection logic [3].

Table 1: Priority unit selection logic

Priority	Parameter	Criteria with setpoints	Decision
1	CET	CET1>371.1	
2	CET	CET2>648.9	In case, more than 2 units are over CET1, Apply this criteria
3	Containment Radiation (CR)	CR = Y/N CR= 0 or 1	In case, more than 2 units are over CET2, Apply this criteria
4	Containment Pressure (CP)	CP1>1336 cmH2O	In case, more than 2 units are over CET2 criteria, and CR criteria Apply this criteria
5	Containment Pressure (CP)	CP2>8577.5 cmH2O	In case, more than 2 units are over CET2 criteria, CR, and CP1 criteria Apply this criteria
6	CET	CET value	In case, more than 2 units are over CET2, CR, CP1, and CP2, Apply this criteria

This priority unit selection logic can be changed by adding new monitoring parameters, deleting existing parameter, or modifying the order of parameters in Table 1.

2.2 Information Display applying Priority Unit Selection Logic

The suggested priority unit selection logic is applied to the information displays using the color and numeric coding. In case that, any unit exceeds the setpoint of criteria in Table 1, the color coding (yellow warning) is provided to the associated units as shown in upper part of Fig. 1. In addition, if two or more units exceed the identical setpoint, the units that have to be monitored as the important order (numeric coding in Fig. 1) are selected using the priority unit selection logic in Table 1

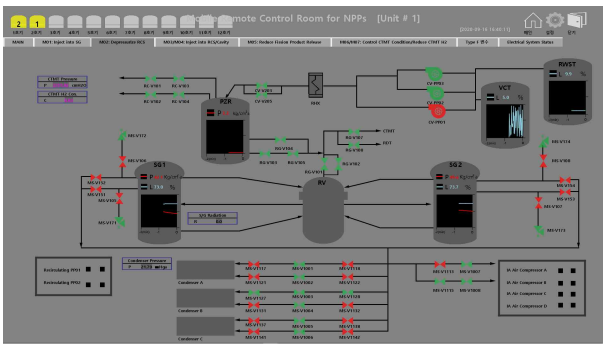

Fig. 1. Information display applying priority unit selection logic

3. Human Performance Evaluation when using Information Display applying Priority Unit Selection Logic

3.1 Experiment Scenario and Performance Measure

The experiment scenario contains the independent severe accidents that occur at seven NPP units simultaneously. The initial events of these severe accidents consist of large loss of coolant accident (LOCA), medium LOCA, small LOCA, loss of off-site power (LOOP), steam generator tube rupture (SGTR), loss of all feedwater (LOAF), and station blackout (SBO). For the human performance test responding multi-unit severe accidents, the process variables of each initial event are obtained from the accidents analysis and these process variables are utilized as the multi-unit severe accident simulations.

In order to evaluate the human performance in the experiments, the situation awareness rating technique (SART) is used. The SART is a quick and easy self-rating situation awareness (SA) measurement technique. The SART consists of the three groups of dimensions such as demands on attentional resources (D), supply of attentional resources (S), and understanding of the situation (U). Three groups of dimensions contain 10 questions as follows.

- D: a combination of complexity, variability and instability of the situation
- S: a combination of arousal, focusing of attention, spare mental capacity and concentration of attention
- U: a combination of information quantity, information quality and familiarity of the situation

Each question is rated by the subjects as a likert scale of 1 to 7 (1=low, 7=high) and total SA is calculated using the following formula [4]:

$$SA = U - (D - S)$$

The range of SA score can be obtained from -14 (minimum) to 46 (maximum) according to the formula above.

3.2 Experiment Implementation and Result

The purpose of this human performance evaluation is to confirm whether or not the support function such as the priority unit selection logic has a positive effect on the human performance. Accordingly, ten subjects participate in the human performance evaluation test using the prepared experiment scenario described in Section 3.1 and their situation awareness are measured with and without the support function of priority unit selection logic. Fig. 2 briefly shows the HSI with and without the support function of priority unit selection logic. In addition, subjects' situation awareness scores are shown in Table 2.

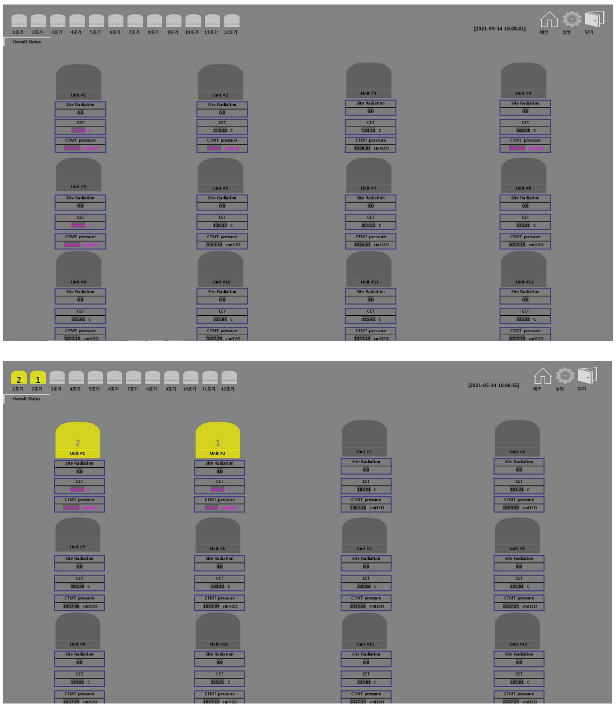

Fig. 2. HSI with and without the support function of priority unit selection logic

Table 2: Subjects' situation awareness scores with and without support function of priority unit selection logic

Subject	SA score without support function (SF)	SA score with support function (SF)
S1	13	28
S2	2	29
S3	10	28
S4	12	24
S5	6	20
S6	-7	43
S7	11	21
S8	3	40
S9	10	28
S10	11	29
Mean	7.1	28

As shown in Table 2, average SA score with support function is higher than average SA score without support function. In order to validate the mean difference between two sets of SA scores, the paired sample t-test was performed as shown in Table 3.

Table 3: Paired samples t-test

	Paired Differences			t	df	Sig. (2-tailed)
	Mean	SD	Std Error Mean			
Pair 1: w/o SF - w/ SF	-20.9	12.59	3.98	-5.249	9	0.001

Based on the result of paired sample t-test, the absolute value of t is larger than 1.96 and p-value is smaller than 0.05, it is possibly said that mean difference between two sets of SA scores is statistically meaningful resulting that the support function of priority unit selection logic is helpful to improve the human performance when the subjects are monitoring the multi-unit severe accidents

4. Conclusions

In order to respond the multi-unit severe accidents, the HSI applying the priority unit selection logic was developed to provide the information which unit has to be monitored first. In this study, the effectiveness of this HSI in terms of the human performance was validated by subjects' situation awareness measurements and their paired sample t-test. Based on the results of paired sample t-test in Section 3.2, it can therefore be said that the HSI applying the priority unit selection logic is the one of the support tools to enhance the human performance to respond the multi-unit severe accidents although more studies should be performed for more concrete establishment.

REFERENCES

[1] I. Jang, and C. H. Kim. Development of Information Displays based on Severe Accident Management Guidelines and R.G 1.97 rev.5, Transactions of the Korean Nuclear Society Virtual Spring Meeting, May 13-14, 2021.
[2] Severe Accident Management Guidelines.
[3] I. Jang, and C. H. Kim. Development of Mobile MCR Human System Interface for Severe Accident Management, KAERI/TR-8425/2020.
[4] N. A. Stanton, P. M. Salmon, G. H. Walker, C. Baber, and D. P. Jenkins. Human Factors Methods: A practical Guide for Engineering and Design, Ashgate, Hampshire, 2005.