Human System Interface Test for Elastic Tile Alarm Display of SMART Alarm and Indication System

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1. Introduction

The SMART main control room (MCR) is a digital control room adopting the computer-based technologies. While existing analog-based control rooms include a thousand of alarm tiles, indicators, and controllers, the SMART MCR is the compact and digital control room with the adoption of visual display unit (VDU)-based monitoring and control equipment.

However, this digital control room has the limitation that the display space is not sufficient for displaying all the indication and alarm information. In order to overcome this limitation, NUREG-0700 [1] recommends applying the alarm filtration and suppression techniques to the alarm systems. In this regard, many alarm systems including the SMART alarm and indication system (AIS) adopted the advanced alarm processing techniques such as the alarm filtration and suppression.

Although many alarm filtration and suppression techniques reducing the nuisance alarms are applied to the alarm systems in order to overcome the insufficient display space, there is still another issue that how fast and accurate the operator can recognize filtered and suppressed alarms. In this regard, the SMART AIS adopts the new display method called an elastic tile alarm display (ETD) which is a new interface and specific for the SMART.

In this paper, since the ETD method which expands and reduces the alarm windows is the unique concept for the SMART and is not validated, the human factors engineering (HFE) evaluation for ETD human system interface (HSI) features is performed to validate its effectiveness.

2. Elastic Tile Alarm Display

The SMART AIS adopts the elastic tile alarm display (ETD) method to assist the operators' alarm recognition. As similar to the other alarm systems, the tile alarm has the shape of a rectangle, which contains the graphic objects combined with the alarm descriptions.

The SMART ETD is designed as follows (see the Figure 1).

- Four layers of alarm windows (4x4), for reactor operator (RO) and assistant operator (AO) separately, is displayed on the ETD. In addition, each alarm window consists of the description and alarm tiles. Each SMART alarm window consists of 50 (10×5) alarm tiles.
- The initial display of the ETD is composed of an alarm window consisting of 50 alarm tiles and does not display the alarm descriptions of the alarm tiles.
- When an alarm is activated, the alarm flashes on the ETD. To recognize the flashing alarm, the operator has to click the flashing alarm window. Once clicked, the alarm window expands as shown in Figure 1 within 1 second. When an alarm window is expanded, the adjacent alarm windows are reduced while the clicked alarm window is sufficiently enlarged for the operator to read and recognize the alarm description. Each tile alarm stops flashing and indicates the acknowledged status when an operator clicks it. If there is no click event for 10 seconds after all tile alarms are acknowledged, the display shall return to the initial ETD automatically.

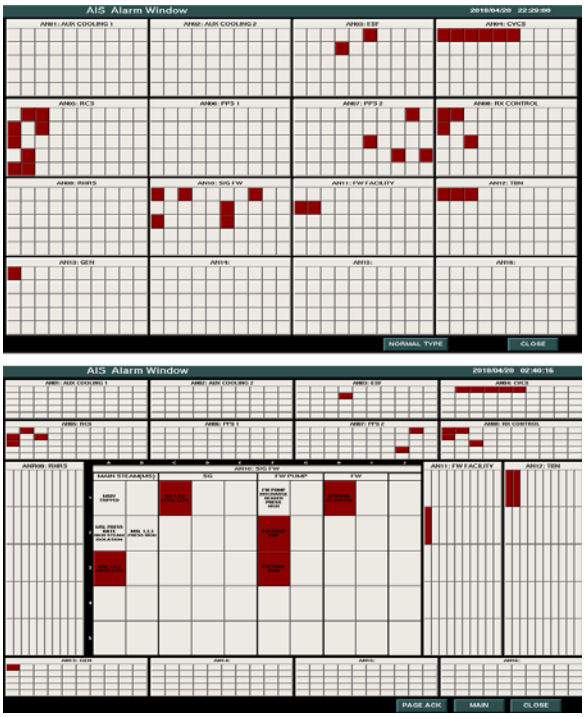

Fig.1. Configuration of ETD.

3. Human System Interface Test for Elastic Tile Alarm Display

3.1 Test-Bed

The test-bed for the HSI test is prepared using the VDU based displays. The simulator for the HSI test is used as compact nuclear simulator (CNS) which is modeled based on the three-loop PWRs, 993MWe, Kori unit 3&4. We considered the CNS can be used as the test simulator for the evaluation of HSI features of ETD for the SMART. The test-bed consists of the following equipment as shown in Figure 2.

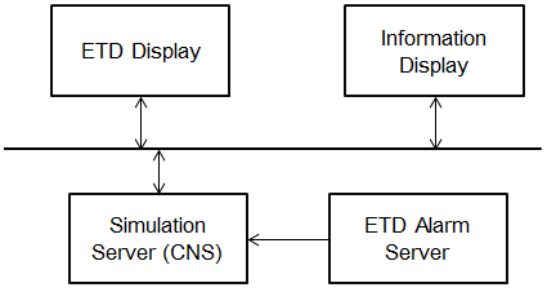

Fig. 2. Configuration of the Test-Bed

3.2 Test Methodology

3.2.1 Constraints and Limitations

The purpose of this HSI test is to validate the usability of the display method adopted from the SMART alarm display, called ETD. There are many kinds of usability test method such as the comparison usability test, questionnaire survey, and so on. In this study, although the comparison usability test is considered as a kind of objective method, the comparison usability test such as the usability comparison between the commercial NPP alarm display and the SMART alarm display is not performed since the results of this comparison may be sensitive. For this reason, the HSI usability test in this study is performed by comparing the instructor's performance and subjects' performance in terms of performance time dimension when using ETD display method. Moreover, we adopts the definition of the reference performance time related to the instructor's performance in the validation criteria.

3.2.2 Test measurement

The following performance measurements are used to evaluate the usability of ETD method. The performance measurements used in this HSI test is described as follows.

- Accuracy and completeness: 1) Accuracy of alarm tile acknowledgement, 2) Accuracy of alarm window acknowledgement
- Performance time: 1) Time to find the designated alarm tiles and alarm windows, 2) Time to finish all tasks in the scenario.

3.2.3 Validation Criteria

The HSI test is designed to verify whether the subjects' performance is satisfied with the validation criteria. The validation criteria used in this HSI test are as follows.

- Accuracy and completeness: subject's alarm recognition accuracy should be accomplished as 100% accuracy
- Performance time: subject's performance time should be within the reference performance time (the baseline performance time), which is average task performance time performed by the instructor, subtracted by the time for its standard deviation.
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3.2.4 Test Scenario

The HSI test scenario is selected based on the operating experts' experiences and operating procedures considering the malfunction of the CNS. Each subject performs one scenario twice. The brief explanation of the scenario and the associated alarms/alarm windows are as follows.

- Verify the reactor trip
  PRZ LOW PRESS & P-7 RX TRIP alarm at AN07 window
  CONTROK BANK LOW-LOW LIMIT alarm at AN08 window
- Verify the turbine trip
  TBN TRIP P-4 alarm at AN12 window
- Verify the ESF actuation
- PRZ PRESS LO SI alarm at AN03 window
- Verify the status of secondary system/steam generators
  SG 1,2,3 LEVEL LOW alarm at AN10 window
  FW PUMP TRIP alarm at AN10 window
- Verify the status of primary system/pressurizer
  PRZ PRESS LOW alarm at AN05 window
- ETD alarm window navigation tasks
  Main window to AN04 window (CVCS)
  AN04 window (CVCS) to AN13 window (GEN)
  AN13 window (GEN) to AN11 window (FW FACILITY)
  AN11 window (FW FACILITY) to AN05 window (RCS)
  AN05 window (RCS) to AN10 window (S/G FW)
  AN10 window (S/G FW) to AN08 window (RX CONTROL)
  AN08 window (RX CONTROL) to AN07 window (PPS2)

3.3 Test Implementation

The number of subjects participated in this HSI test is nine. All subjects consist of male and have the enough knowledge about overall NPP systems. The average age of the subjects is 29.78 (±3.71). According to the instruction of the information display, the subjects navigate alarm windows and acknowledges specific alarm by focusing on the activated alarms on the ETD. In the information display, the information of the alarm window navigation and the specific alarm that the subjects should acknowledge are provided.

4. Results

In this HSI test, it is validated that the subjects can recognize alarm tiles and windows without any difficulty using the ETD method which expands and reduces the alarm windows in the AIS (i.e., How accurate and fast the operator can recognize alarm tiles and window in the ETD.).

4.1 Accuracy and Completeness

Table I shows total number of task given, and total number of task performed by the subjects. As shown in Table I, total number of task given to the subjects is 486. During the HSI test for the scenario, the subjects performed all 486 tasks successfully without any difficulty which means that the subjects accomplished 100% accuracy in performing the task within the scenario.

This result implies that the ETD display feature that expands and reduces the alarm windows does not have negative effects on selecting what the subjects want and performing the given tasks. Moreover, it is obvious that the subject performance is good enough in terms of the accuracy performance dimension.

Table I: Result of Accuracy and Completeness in Scenario

Task (Ideal Path) of Scenario	Total Number of Task Given	Total Number of Task Performed
Screen Navigation to AN07 (PPS 2)	18	18
Alarm Tile Acknowledgement of PRZ LOW PRESS & P-7 RX TRIP	18	18
Screen Navigation to AN08 (RX CONTROL)	18	18
Alarm Tile Acknowledgement of CONTROK BANK LOW-LOW LIMIT	18	18
Screen Navigation to AN12 (TBN)	18	18
Alarm Tile Acknowledgement of TBN TRIP P-4	18	18
Screen Navigation to AN03 (ESF)	18	18
Alarm Tile Acknowledgement of PRZ PRESS LO SI	18	18
Screen Navigation to AN10 (S/G FW)	18	18
Alarm Tile Acknowledgement of SG 1,2,3 LEVEL LOW	18	18
Alarm Tile Acknowledgement of FW PUMP TRIP	18	18
Screen Navigation to AN05 (RCS)	18	18
Alarm Tile Acknowledgement of PRZ PRESS LOW	18	18
Screen Navigation to AN04 (CVCS)	18	18
Alarm Window Acknowledgement of AN04 (CVCS)	18	18
Screen Navigation to AN13 (GEN)	18	18
Alarm Window Acknowledgement of AN13 (GEN)	18	18
Screen Navigation to AN11 (FW FACILITY)	18	18
Alarm Window Acknowledgement of AN11 (FW FACILITY)	18	18
Screen Navigation to AN05 (RCS)	18	18
Alarm Window Acknowledgement of AN05 (RCS)	18	18
Screen Navigation to AN10 (S/G FW)	18	18
Alarm Window Acknowledgement of AN10 (S/G FW)	18	18
Screen Navigation to AN08 (RX CONTROL)	18	18
Alarm Window Acknowledgement of AN08 (RX CONTROL)	18	18
Screen Navigation to AN07 (PPS2)	18	18
Alarm Window Acknowledgement of AN07 (PPS2)	18	18
Total	486	486

4.2 Performance Time

In this HSI test, the accuracy and performance time are measured to validate the ETD method. However, the performance time is supplementary measure since how accurate alarm is recognized is more important than how fast alarm is recognized in terms of the alarm recognition.

The performance times in this HSI test are divided into three categories such as total time to find the designated alarm tiles, total time to find the designated alarm windows and time to finish all tasks in the scenario.

4.2.1 Reference Performance Time

Above of all, the reference performance time was measure to evaluate that the subject performance times are satisfied with the performance time validation criteria. The reference performance time is measured as follows.

- Total time to find the designated alarm tiles: 01:09 (mm:ss)
- Total time to find the designated alarm windows: 00:41 (mm:ss)
- Time to finish all tasks in the scenario: 01:54 (mm:ss)

According to the validation criteria, subjects' performance time should be within the reference performance time.

4.2.2 Subject Performance Time

The subject performance times are divided into total time to find the designated alarm tiles, total time to find the designated alarm windows and time to finish all tasks in the scenario. In this result, it is verified that the subjects' performance times (Time to finish all tasks in the scenario) are satisfied with the validation criteria of the reference performance time of the scenario. In order to verify that the subject performance times are satisfied with the validation criteria, t-test were performed as shown in Table II and III.

Table II: Statistic of total time to finish all tasks in the scenario

	N	Avg	Standard Deviation	Standard Error of Avg.
S_Total time	18	71.3333	13.66404	3.22064

Table III T-test results of total time to finish all tasks in the scenario

	Reference Performance Time = 114 sec					
	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval	
					Lo.	Up.
S_Total time	-13.248	17	.000	-42.66	-49.5	-35.9

As shown in Table III, the subject performance times such as the total time to finish all tasks in the scenario were satisfied with the performance time criteria with statistical significance (p=0.00).

This result implies that the ETD display feature does not have negative effects on performing the given tasks with in the required times. Moreover, it is obvious that the subject performance is good enough in terms of the performance time dimension. However, since the subjects' performance time was compared with the reference performance time based on the instructor performance time, and this result would be largely affected by the reference performance time, much more studies should be performed to support the result of performance time when using the ETD method.

5. Conclusions

In order to validate the ETD method of the SMART AIS, the HSI test of the ETD was performed in terms of the validation of the human performance such as the accuracy, and temporal efficiency. The results of the HSI test imply that the subject can recognize alarm tile and window without any difficulty using the ETD method in terms of the accuracy as well as recognize alarm tile and window within the required time. Accordingly, although much more HSI test regarding the ETD method should be performed to support its validity, based on the result of this HSI test, the conclusion could be drawn that the ETD method is applicable to the SMART AIS as the tile alarm display method.

REFERENCES

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