Development of a Human Performance Evaluation Support System for Human Factors Validation of MCR MMI Design in APR-1400

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1. Introduction

As CRT-based display and advanced information technology were applied to advanced reactors such as APR-1400 (Advanced Power Reactor-1400), human operators' tasks became more cognitive works. As a results, Human Factors Engineering (HFE) became more important in designing the MCR (Main Control Room) MMI (Man-Machine Interface) of an advanced reactor. According to the Human Factors Engineering Program Review Model, human factors validation of MCR MMI design should be performed through performance-based tests to determine whether it acceptably supports safe operation of the plant [1]. In order to support the evaluation of the performance, a HUman Performance Evaluation Support System (HUPESS) is in development.

2. Human Performance Measures

In this work, six performance measures such as plant performance, personnel task, situation awareness, workload, teamwork, and anthropometric/physiological factors are considered for the evaluation of human performance [2]. Main measure and the complement measure are used for the evaluation of plant performance, personnel task, situation awareness, and workload. Only main measures are applicable to the others. The main measure is used to determine whether the performance is of success or fail where as the complement measure is used to compare and then scrutinize the performance among operators or shifts. In order to assess plant performance, several important process parameters (empirically 5 to 7) are selected by process experts. It is used as a main measure for the evaluation of the plant performance whether the values of the selected process parameters are operated within upper and lower limits or not. Beside, the discrepancy between ideal value and observed value in the selected process parameters is utilized to score the plant performance as a complementary measure. For an analytic and logical measurement of personnel task, a test scenario is hierarchically analyzed and then an optimal solution for the scenario is developed. The personnel task performance can be measured by observing and evaluating whether the detailed tasks of the solution are appropriately performed or not. Firstly, the detailed activities evaluated as necessary tasks for the safe operation are checked whether completed or not. If not, the personnel task performance can be considered as "fail" as a main measure. Also the complementary measure of the personnel task evaluates a score by assessing all the detailed activities including the necessary activities and the others. Subjective performance measures conventionally used for the evaluation of cognitive human performance such as situation awareness (SA) and workload (WL) are complemented with objective performance measures based on eye movement data such as eye fixation and blinking [3]. The teamwork and the anthropometric/ physiological factors are evaluated with tools of BARS and HFE V&V checklist, respectively [4]. The human performance is evaluated through a comprehensive testing program conducted by an independent, multidisciplinary team. The tests are based on scenarios representing various operating conditions of nuclear power plants (NPPs).

3. Human Performance Evaluations

Human performance can be assessed in simulator-based environment, as shown in Figure 1. The HUPESS acquire simulator's logging data regarding plant system events & status, operator activity events, or simulator events. The plant performance is evaluated with the plant-related logging data. The personnel task performance is evaluated with the operators' activities-related logging data and the data observed and collected by the evaluators during a test. With regard to cognitive measures, main measures of SA and WL are evaluated with tools of the KSAX and the NASA-TLX respectively [4] and the complement measures are evaluated with the eye movement data obtained from a eye tracking system. Teamwork and anthropometric/physiological factors are evaluated by evaluators by observing the operators' activities. In addition, the HUPESS supports statistical analyses for logical and defensible inference. HUPESS basically provide descriptive statistics such as mean, variance, chart, and graph of the collected performance data. ANOVA test is applied to identify human performance differences among shifts or test scenarios. If there is significant difference, post-hoc analysis such as tukey test is performed to find out the difference in more detail.

Linear regression and correlation analysis are utilized for the analysis of the eye movement data. Teamwork data are also analyzed with correlation analysis. In addition, all the activities occurring in the simulator-based environment are recorded by an audiovisual data recording system. The AV data are also available in real-time for the evaluators' data collection. Another strong point lies in the once-through process of HUPESS from measurements to analyses including statistical analyses of the human performance by real-time (or almost real-time).

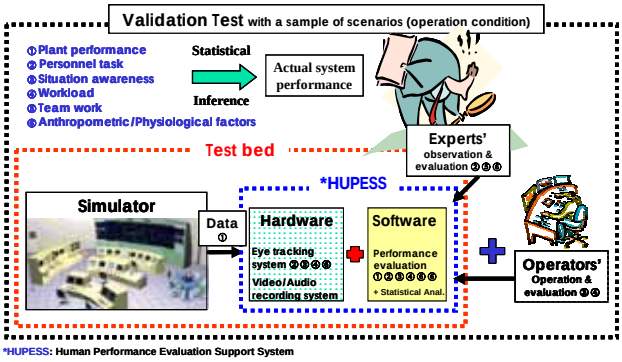

Figure 1. Environments of HUPESS

4. Hardware Configuration of HUPESS

HUPESS consists of two servers (one for standby), one data storage station, two stationary evaluation stations, four mobile evaluation stations, a set of four channel audio/visual recording system, and a set of eye tracking system, as shown in Figure 2. In the HUPESS server installed are an application software having main algorisms regarding the human performance evaluation, the acquisition of the logging data, and the data storage. The evaluators or the operators communicate with the HUPESS through the evaluation stations.

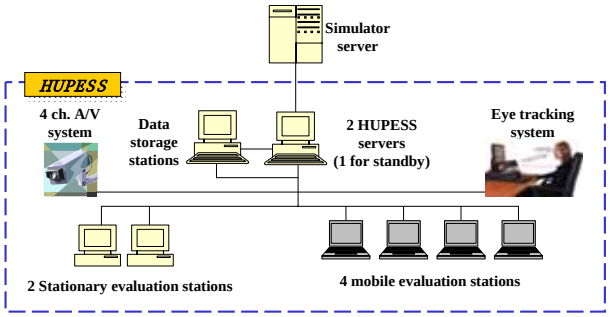

Figure 2. H/W Configuration of HUPESS

3. Conclusion

An integrated system design such as the MCR MMI design of APR-1400 can be validated through performance-based tests to determine whether it acceptably supports safe operation of the plant. A human performance evaluation support system, called HUPESS, is in development for the human factors validation of the MCR MMI design. Plant performance, personnel task, situation awareness, workload, teamwork, and anthropometric/physiological factors are evaluated for the human performance evaluation. Techniques generally used in various industries are adopted as main measures and some helpful techniques are developed in order to complement the main measures. Another strong point lies in the once-through process of HUPESS from measurements to analyses, which allow us to effectively perform the human performance evaluation and analysis.

ACKNOWLEDGEMENT

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