How to Measure Human Performance in Main Control Room of an Advanced NPP?

Jun Su Hạ and Poong Hyun Seong
Department of Nuclear and Quantum Engineering, KAIST
373-1, Guseong-Dong, Yuseong-Gu, Daejeon, South Korea, 305-701

1. Introduction

As CRT-based display and advanced information technology were applied to advanced reactor such as APR-1400 (Advanced Power Reactor-1400), human operators' tasks became more cognitive works. Human Factors Engineering (HFE) became more important in designing the MCR (Main Control Room) of an advanced reactor. In order to support the advanced reactor design certification reviews, the Human Factors Engineering Program Review Model (HFE PRM) was developed with the support of U.S. NRC [1]. The HFE PRM describes the HFE program elements that are necessary and sufficient to develop an acceptable detailed design specification and an acceptable implemented design and provides the review criteria for their evaluation [1]. One of the review elements is human factors verification & validation (V&V). The role of V&V evaluations in the HFE PRM is to comprehensively determine that the design conforms to HFE design principles and it enables plant personnel to successfully perform their tasks to achieve plant safety and other operational goals [2]. Integrated System Validation (ISV) is part of this review activity. An integrated system design is evaluated through performance-based tests to determine whether it acceptably supports safe operation of the plant. The performance- based tests are based on several human (operator) performance measures such as plant performance, personnel task, situation awareness, workload, team work, and anthropometric/physiological factors [2]. In this work, some techniques already developed in nuclear or other industry and new techniques are incorporated into a methodology for the human performance evaluation.

2. Human Performance Measures

In this work, the six major performance measures are considered as human performance measures, as shown in Figure 1. The six performance measures are evaluated through a comprehensive testing program conducted by an independent, multidisciplinary team [2]. The tests are based on scenarios representing various plant conditions.

2.1 Plant Performance

The plant performance can be measured by monitoring, analyzing, and evaluating important process parameters. The plant performance measure can be considered as a crew performance measure rather than individual performance measure. The data of the parameters can be obtained from log data of a simulator representing a NPP. Maximum or Minimum values of the parameters at the end of scenario or during the scenario are used to evaluate the plant performance: whether the value of the parameter of interest exceeds the setpoint value (or pre-defined value) or not. Time to complete the goal in a scenario is also used as a measure of plant performance. Discrepancy between ideal value evaluated in advance by experts and obtained value in the parameters of interest is used to score the activities of operators as a crew performance.

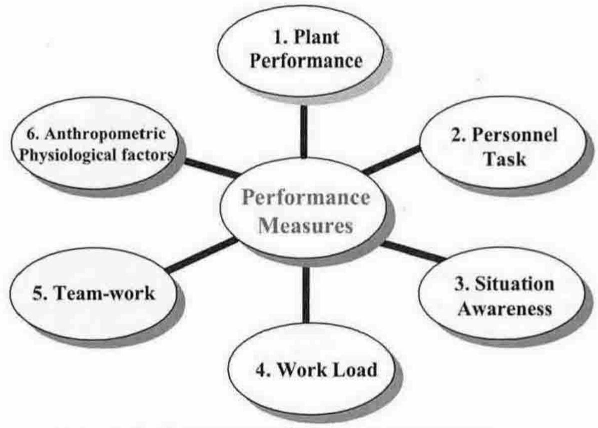

Figure 1. Human performance measures

2.2 Personnel Task

Primary tasks, secondary tasks and the sequence of tasks are considered for the evaluation of personnel task. Optimal solutions to scenarios are developed by process experts through scenario analysis on the basis of top-down approach and bottom-up approach. Check is made whether each activity in the optimal solution is satisfied or not. Optimal solution is made in a hierarchical form. Hence weights of activities in personnel task can be easily obtained by using some hierarchical techniques. Score on personnel task is evaluated with the weights.

2.3 Situation Awareness

M. R. Endsley defined situation awareness (SA) as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future [3]. In this work, KSAX [4], a modified subjective rating technique, is used for the evaluation of SA. The KSAX is inexpensive, easy to use, and non-intrusive. The subjective measure is complemented by a continuous measure based on eye tracking shown in Figure 2. Eye fixation in predefined areas of the human machine interface that is important for solving problems in complex systems can be considered as "perception" in SA. Time spent by operators on visual examination of relevant system components during critical time periods in the scenario can be considered as "comprehension" in SA [5].

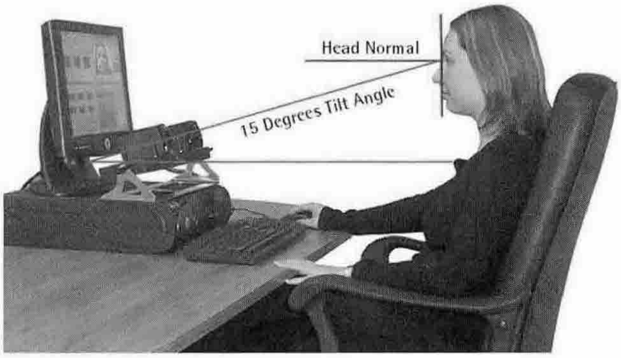

Figure 2. Eye tracking system

2.4 Workload

The term workload (WL) refers to the portion of the operator's limited capacity actually required to perform a particular task [6]. In this work, NASA-TLX, a subjective rating technique, is used to evaluate mental, physical, and temporal demand, self-estimated performance, effort, and frustration as WL. The subjective measure is, as similar to SA case, complemented by a continuous measure based on eye tracking such as blinks per minute, blink duration, blink interval time, eye fixations on a single target or areas of interest, fixation dwell time, or number of fixations.

2.5 Team Work

Behaviorally Anchored Rating Scale (BARS), which is a subjective rating technique, is used to measures team work. BARS is evaluated by human factors engineer, whereas KSAX and NASA-TLX are evaluated by operators. BARS questionnaire is composed of several questions regarding task focus/decision-making, coordination, communication, openness, and team spirit [4].

2.6 Anthropometric and Physiological factors

Concerns are given to visibility, audibility of indications, accessibility of control device, and design & arrangement of equipment. Many of these issues are the subject of evaluation conducted earlier in the design process. Attention should be focused on those anthropometric and physiological factors that can only be addressed during testing of the integrated system (e.g., the ability of the operators to effectively use the various controls, displays, workstations, or consoles in an integrated manner) [2]

3. Conclusion

An integrated system design such as a design of an advanced nuclear power plant can be validated through performance-based tests to determine whether it acceptably supports safe operation of the plant. As CRT-based display and advanced information technology were applied to the advanced reactor, human operators' tasks became more cognitive works. Hence, cognitive factors such as situation awareness and workload as well as plant performance, personnel task, teamwork, and anthropometric/ physiological factors should be evaluated for the integrated system validation. In this work, a methodology composed of the six performance measures is introduced and briefly explained. As a further work, acceptable statistical method will be developed for the inference process from the multiple measures into actual system performance and finally a human performance evaluation support system will be constructed based on the developed methodology.

ACKNOWLEDGEMENT

This work is supported by "The Development of the HFE V&V System for the Advanced Digitalized MCR MMIS" project.

REFERENCES

[1] J. O'Hara et al., Human Factors Engineering Program Review Model, NUREG-0711, Rev.1, 2002

[2] J. O'Hara et al., Integrated System Validation: Methodology and Review Criteria, NUREG/CR-6393, 1997.

[3] M. R. Endsley, Toward a Theory of Situation Awareness in Dynamic Systems, Human Factors, Vol. 37 (1), pp. 32-64, 1995.

[4] Sung Je Cho et al, The evaluation of Suitability for the design of Soft Control and Safety Console for APR1400, KHNP, TR. A02NS04.S2003.EN8, 2003.

[5] Asgeir Drøivoldsmo et al., Continuous measures of situation awareness and workload, OECD Halden Reactor Project, HPR-539, 1998.

[6] O'Donell, R. D. and Eggemeier F. T., Handbook of perception and human performance, Wiley and Sons, 1986.