Issues in Human Performance Evaluation for the Validation of Advanced Control Rooms

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1. Introduction

As processing and information presentation capabilities of modern computers are increased, modern computer techniques have been gradually introduced into the design of advanced control rooms (ACRs) of NPPs (nuclear power plants) [1]. The design of instrumentation and control (I&C) systems for various plant systems is also rapidly moving toward fully digital I&C [2]. For example, CRT(or LCD)-based displays, large display panels (LDP), soft-controls, a computerized procedure system, and an advanced alarm system were applied to the ACR of APR-1400 (Advanced Power Reactor-1400) [3].

In this paper, addressed are challenging issues associated with the introduction of the new technologies to the ACRs. Also strategies about how to cope with these issues are discussed briefly in each chapter.

2. Three Important Trends in the Evolution of ACRs

As O'Hara and Robert [4] pointed out, there are three important trends in the evolution of ACRs such as increased automation, development of compact and computer-based workstations, and development of intelligent operator aids. Increases in automation result in a shift of operator's roles from a manual controller to a supervisor or a decision-maker. The role change is typically viewed as positive from a reliability standpoint since unpredictable human actions can be removed or reduced. Thus the operator can better concentrate on supervising the overall performance and safety of the system by automating routine, tedious, physically demanding, or difficult tasks. However inappropriate allocation of functions between automated systems and the operator may results in adverse consequences such as poor task performance, out-of-loop control coupled with poor situation awareness, and so on [5]. In addition, the shift in the operator's role may lead to a shift from high physical to high cognitive workload, even though the overall workload can be reduced. Computer−based workstation of ACRs, which has much flexibility offered by software−driven interface such as various display formats (e.g., lists, tables, flow charts, graphs, etc.) and diverse soft-controls (e.g., touch screen, mice, joy sticks, etc.), is thought to affect the operator performance as well. Information is typically presented in pre-processed or integrated forms rather than raw data of parameters and much information is condensed in a small screen. In addition, the operator has to manage the display in order to obtain data and information which he or she wants to check. Hence poorly designed displays may mislead and/or confuse the operator and thus increase excessively cognitive workload, which can lead to human errors. Due to these changes of the operating environment, the operator's tasks in an ACR are conducted in a different way from the conventional one. Hence when a MMI (man-machine interface) design validation (i.e., ISV: integrated system validation) of ACRs is conducted, enhanced attention should be paid to operator task performance. Also cognitive measures such as situation awareness and workload should be deliberately evaluated.

3. Criteria for Human Performance Evaluation

The performance measures represent only the extent of the performance in the relevant measures. Hence the acceptability of the performance in each of the measures should be evaluated on the basis of performance criteria. The literature [5] summarizes approaches to establishing criteria, which vary based on types of comparisons such as requirement referenced, benchmark referenced, normative referenced, and expert-judgment referenced. The requirement referenced approach is the clearest one among the four approaches, because specific values in the plant parameters required by technical specification and time requirements for critical operator actions can be used as criteria. When the requirement referenced comparison is not applicable, the other approaches are typically employed. There was a project for the ISV of a modernized NPP CR (control room) which is based on the benchmark referenced comparison [6]. The CR of the 30-year-operated NPP was renewed with modernization of the major part of the CR MMI. In the project, it was judged that the human performance level in the existing CR could be used as an acceptance criterion for the human performance in the modernized CR. On the other hand, if a totally new CR (i.e., an ACR) is considered for the ISV, this approach is also applicable. For example, if the operator workload in an ACR is not exceeding that in a reference CR (conventional one) which is identified as

acceptable, this can be used as criteria for the benchmark referenced comparison. However the benchmark approach is thought not to cover all the issues coupled with the new types of problems coupled with new technology. Hence countermeasures to cope with this weakness should be considered for the ISV. In the normative approach, the performance is compared to the norms established under the same or equivalent conditions. There has been too little study on the human performance in nuclear industry to apply the normative approach. Finally, the expert-judgment referenced comparison is based on the criteria established through the judgment of SMEs (subject matter experts). However, there are few human factors experts and studies in the area of ACR design.

4. Implications for HRA in ACRs

Little study has been conducted on this area. With respect to the automation, there has been discussed whether increased automation eliminates human errors or not. As the role of operator is shifted to the higher level, human errors are also expected to be in higher functional level. In addition, the introduction of new technology may be coupled with new categories of human error. In a study on aircraft cockpit automation, it is observed that if the pilot is not provided with enough information with which to make decisions, or decisions are automatically made without providing the rationale to the pilot, the pilot's ability to stay ahead of the aircraft is lost [7]. One of the issues related to HRA (human reliability analysis) is modeling human action. The effect of the role shift of the operator on human performance and the new types of error are not well understood. Error quantification is also considered as a critical issue. There are few databases for the quantification of human errors related to ACRs. A countermeasure can be a simulation study, even though it has challenging issues. The effect of performance shaping factor in simulator is different from that in real-world (e.g., stress, noise, distractions, and so on). Very unlikely events are expected to occur and the operator expects them (unlike in real world). The operator' s attention is aroused to the initial detection of problems, which means that underarousal, boredom, and lack of vigilance will not be significant. There is also limited understanding of the effects of new technologies on human performance. The nuclear industry has little experience with the operator performance in ACRs. HRA methodology frequently depends on the judgment of SMEs to assist in human action modeling, development of base case HEPs (human error probabilities), and evaluation of the importance and quantitative effects of PSFs (performance shaping factors). However, there are few human factors experts in the area of ACR design.

5. Discussions and Conclusion

In this paper, challenging issues regarding human performance in ACRs are addressed. When an ISV of ACRs is conducted, attention should be paid to these issues, because the regulatory body is expected to consider these issues very critical. Regarding the relation between the human performance and the human errors, the human error can be considered as a kind of the human performance. However the human error is related to the results (product) of the operators' activities. The human performance includes the product and the process (how that result was achieved). Hence the study on the human performance should provide the theoretical and empirical background for the study on the human error. Even more, the study on the human performance should be designed so that the results of the human performance evaluation can be used for the study on the human error.

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