Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

HuRECA: Human Reliability Evaluator for Computer-based Control Room Actions

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1. Introduction

As computer-based design features such as computer-based procedures (CBP), soft controls (SCs), and integrated information systems are being adopted in main control rooms (MCR) of nuclear power plants, a human reliability analysis (HRA) method capable of dealing with the effects of these design features on human reliability is needed. From the observations of human factors engineering verification and validation experiments, we have drawn some major important characteristics on operator behaviors and design-related influencing factors (DIFs) from the perspective of human reliability [1,2]. Firstly, there are new DIFs that should be considered in developing an HRA method for computer-based control rooms including especially CBP and SCs. In the case of the computer-based procedure rather than the paper-based procedure, the structural and managerial elements should be considered as important PSFs in addition to the procedural contents. In the case of the soft controllers, the so-called interface management tasks (or secondary tasks) should be reflected in the assessment of human error probability. Secondly, computer-based control rooms can provide more effective error recovery features than conventional control rooms. Major error recovery features for computer-based control rooms include the automatic logic checking function of the computer-based procedure and the information sharing feature of the general computer-based designs.

2. Major Design-related Influencing Factors of CBP and SC

Design-related influencing factors (DIFs) refer to the specific design features or design elements that affects occurrence of human errors. The DIFs for computer-based control rooms have been identified through the following steps: (1) literature review including NUREG/CR-6634 [3], NUREG-0700 [4], and NUREG/CR-6635 [5]. (2) identification of important influencing factors through the observation of operator behaviors under computer-based control rooms, (3) human error analysis based on task analysis of required operator actions [6], and (4) organization of the identified DIFs according to task types.

For example, the DIFs organized for a type of the procedural step, the so-called single static procedural step, of the CBP is illustrated as follows.

- Design factors of the main procedural step
  - Clearness of the instruction (especially in which decision-making is required)
  - Adequate provision of requisite information
  - Adequate representation of lists, hierarchical structure, and provision of check-off capability
  - Clear expression of the logical relationship between instructions and information items
- Design factors of the contingency-action (CA) step
  - Link of the CA actions at the correct main procedural step
  - Clearness of the instruction with its structure of whether the CA should be performed or not
  - Adequacy of the returning capability after the CA steps are finalized
  - Place-keeping capability when returned to the main procedural step
- Influence of warning or cautions
  - Influence of warning/cautions to alternative actions

The major DIFs for soft controls of advanced control rooms are identified as follow.

- The number of unit actions using soft controls
- Level of composite use between the safety-grade and the non-safety-grade soft controls
- The number of controlling mimic screen pages required for completing the task

Most of the identified DIFs for SC are associated with the interface management tasks, or secondary tasks, which are required for manipulating the user interface to access information or controls.

Besides these DIFs associated with CBP and SC, there are the DIFs that help error recovery. The error recovery DIFs are identified for each of diagnosis error and execution error.

- The diagnosis error recovery DIFs
  - The CBP's monitoring function including the automatic logic analysis function, the monitoring of continuously applicable procedure steps, etc.
  - Independent checking by the other operators due to information sharing capability of the CBP
  - Correction of judgmental errors though the key steps
- The execution error recovery DIFs
  - Error detection through the feedback information of the soft controls and the mimic information on the system/component status

– Error detection by the shift supervisor through the feedback information of the system/component status provided on the CBP

4. The HuRECA Method

The HuRECA method [7] was developed on the basic model of K-HRA [8]. The newly identified DIFs have been reflected into the K-HRA framework as performance shaping factors. For the quantification of diagnosis error probability, the following equation is used.

$$HEP_{diag} = Basic\_HEP_{diag} \times \Pi\, w_i\, (PSF_i) \qquad (1)$$

Instead of the quality of the paper-based procedure of K-HRA, the quality of the computer-based procedure is used in HuRECA. The detailed design level of the CBP is considered in determining the weighting factor (w_i) for the designed CBP. The value of the adjusting factor was determined through the elicitation of expert opinions using the analytic hierarchy process (AHP). An example decision tree for determining weighting or adjusting factor with respect to the designed level of the CBP is shown in Fig. 1.

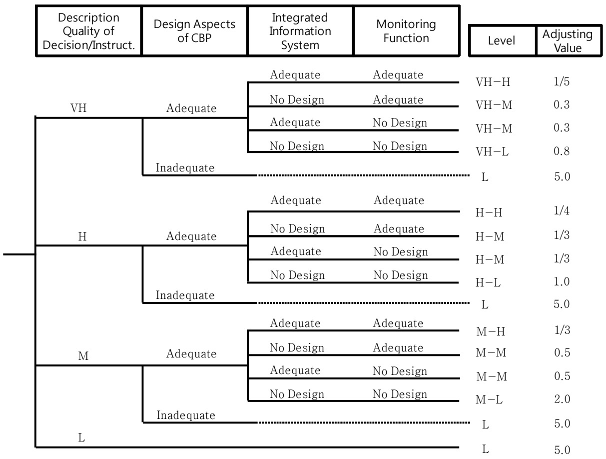

Fig. 1. An example decision tree for determining weighting factor with respect to the designed level of the computer-based system

For the quantification of execution error probability, the following equation is used.

$$HEP_{exec} = \sum\, [Basic\_HEP_{exec}(i) \times HEP_{rec}(i)] \times f(IM\_C) \qquad (2)$$

where, $Basic\_HEP_{exec}(i) = f$ (task type, stress level), $HEP_{rec}(i) = f$ (time urgency, MMI, supervision) and f(IM_C) = the adjusting factor assigned by the level of the interface management complexity.

As shown in eq. (2), the interface management complexity (IM_C) factor was newly introduced to reflect the effect of the workload associated with the task of managing the user interface on the execution error probability. Additionally, the error recovery factor was modified by considering the role of error recovery capability of the CBP.

5. Conclusions

The HuRECA method for assessing human reliability of the computer-based control room tasks has been introduced in this paper. This method can not only be used in human reliability analysis for probabilistic safety assessment of a newly designed plant, but also be used in the process of the human factors design of computer-based control rooms of a new plant.

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