Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2012

A Human Reliability Evaluation Tool for Main Control Rooms in Nuclear Power Plants

Seung Jun Lee, Jaewhan Kim, Wondae Jung
Korea Atomic Energy Research Institute
1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
sjlee@kaeri.re.kr

1. Introduction

Identification and quantification of main control room (MCR) operators' errors are important for preventing undesired situations and enhancing reliability of nuclear power plants (NPPs). Human errors could be predicted by human error evaluation methods and appropriate interface design and training/education programs can be made based on the evaluation results. The accident sequence evaluation program (ASEP) [1] and technique for human error rate prediction (THERP) [2] methods have been mainly used for the human reliability analysis (HRA) in the probabilistic safety assessment (PSA) of Korean NPPs.

The operational environments of these computerized MCRs (advanced MCRs) are totally different from those of conventional MCRs. The different interfaces require operators to perform different tasks for operating and maintaining plants. While only primary tasks are considered in conventional MCRs, secondary tasks such as interface managements are one of the major concerns of advanced MCRs. This computerized operational environment may make operation tasks more convenient but may make some controversial issues of human errors or cause new types of human errors. For the changed interfaces, different design-related influencing factors (DIFs) should be considered according to the design characteristics.

KAERI (Korea Atomic Energy Research Institute) developed a standard HRA method for the PSA of Korean NPPs. It is based on the ASEP and THERP methods [3]. For the advanced MCRs, the modified HRA method was proposed by KAERI based on the basic model of the HRA for conventional MCRs. The newly identified DIFs have been reflected into the conventional HRA framework as performance shaping factors (PSFs) [4].

2. An HRA Method for PSA

In the HRA method for conventional MCRs which was developed by KAERI, the human tasks of NPPs are classified into pre-initiating and post-initiating human failure events (HFEs). Post-initiating HFEs can be further subdivided into that for a diagnosis error and an execution error [3]. Detailed quantifications of pre-initiating HFEs are performed by using the unavailability equation of the THERP [2]. Detailed quantifications of the diagnosis error and the execution error for post-initiating HFEs are performed by using the following equations:

$$HEP_{diag} = Basic\_HEP_{diag} \times \prod w_i(PSF_i) \qquad (1)$$
$$HEP_{exec} = \sum [\, Basic\_HEP_{exec}(i) \times HEP_{rec}(i)\,] \qquad (2)$$

Where,

$Basic\_HEP_{diag} = f(\text{available time for diagnosis})$
$Basic\_HEP_{exec}(i) = f(\text{task type}(i), \text{stress level}(i))$
$HEP_{rec}(i) = f(\text{available time}(i), MMI(i), \text{supervisor recovery}(i))$

Basic HEP of a diagnosis error ($Basic\_HEP_{diag}$) is quantified according to the available time. 'w' is a weighing factor for the PSFs estimated by using the decision tree. Basic HEP of an execution error ($Basic\_HEP_{exec}$) is determined by the subtask types and stress level. Recovery HEP of an execution error (HEP_{rec}) is estimated by using the decision tree. Total HEP is summation of diagnosis HEP (HEP_{diag}) and execution HEP (HEP_{exec}).

3. HuRECA: Human Reliability Evaluator for Control Room Actions

As computer-based design features such as computer-based procedures, soft controls, and integrated information systems are being adopted in MCRs, an 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 DIFs from the perspective of human reliability [5,6]. New DIFs, related to computer-based procedures, soft controls and error recovery features, should be considered in developing an HRA method for advanced MCRs.

Most of the identified DIFs for soft control 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 computer-based procedure and soft control, there are the DIFs that help error recovery. The error recovery DIFs are identified for each of diagnosis error and execution error [4].

With the DIFs for computer-based MCRs, the HRA framework for conventional MCRs is modified as shown in Fig. 1.

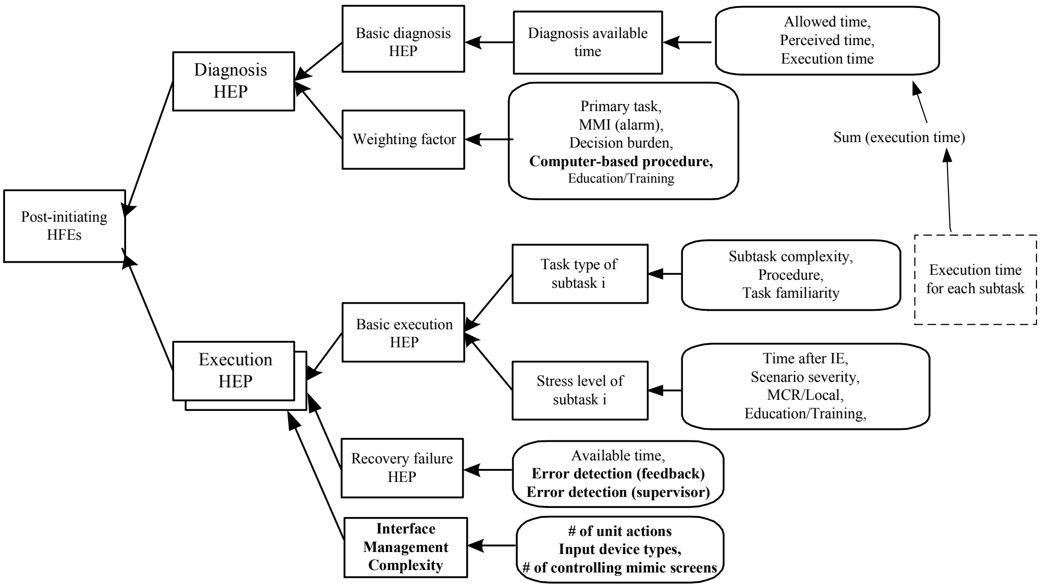

Fig. 1. The framework of HRA method for advanced MCRs.

While they have almost same structure and factors, some factors (e.g. interface management complexity) were added and different factors or decision trees were considered in some factors.

과제명 표준 원전 RM 모델 개발
과제기간 2011-09-01 ~ 2011-12-31
사건명 SDOPHEARLY
진단HEP 2.52E-02
최종HEP 1.09E-01
대상호기 신울진 3,4
분석모드 전출력 L1 PSA
수행HEP 8.40E-02

진단HEP 2.52E-02 확률 (mean)

단위작업내용	작업자	작업장소	수행시간	단위작업복잡도	평상시 수준	시간충분 원격판독부	단위작업유
SDS 제어전원 복구	SRO	MCR	2	보통	상	N/A	Step-by-Ste
SDS 차단 및 제...	RO	MCR	2	보통	상	N/A	Step-by-Ste

수행HEP 8.40E-02

최종 HEP 1.09E-01 = (진단 2.52E-02 + 수행 8.40E-02)

Fig. 2. A screen of the HuRECA

In this work, an HRA tool (HuRECA: Human Reliability Evaluator for Control room Actions) was developed as shown in Fig. 2. Both conventional MCRs and advanced MCRs could be evaluated by the HuRECA. The HuRECA was developed as a platform free tool which is executable on any devices and any operating systems.

4. Conclusions

In this work, the HRA methods for conventional and advanced MCRs were introduced. Basically, the HEP is calculated by two factors (diagnosis and execution HEP) in the both methods. Basic HEPs and PSFs are considered for determined diagnosis and execution HEPs. According to the MCR type, different PSFs are considered to reflect the characteristics. For example, computer-based procedure and interface management complexity are considered for computerized MCRs. 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. HRA for control rooms helps appropriate interface design and training/education programs based on the evaluation results.

REFERENCES

[1] A. D. Swain, “Accident Sequence Evaluation Program Human Reliability Analysis Procedure”, NUREG/CR-4772, S.N.L, 1987.

[2] A. D. Swain and H. E. Guttman, “Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications”, NUREG/CR-1278, S.N.L, 1983.

[3] W. Jung, D. Kang, “Development of a standard human reliability analysis method of nuclear power plants (in Korean)”, KAERI/TR-2961/2005, KAERI, 2005.

[4] J. Kim, S. J. Lee, S. C. Jang, “HuRECA: Human Reliability Evaluator for Computer-based Control Room Actions”, *Transactions of the Korea Nuclear Society Autumn Meeting*, October 27-28, 2011.

[5] J. Kim, S.J. Lee, S.C. Jang, “Human Performance and Human Error Characteristics for Event Diagnosis Tasks in an Advanced Main Control Room”, KAERI/TR-3913, 2009.

[6] J. Kim, S.J. Lee, and S.C. Jang, “Analysis of Human Error Potentials and Design-related Influencing Factors for Computer-Based Procedure and Soft Controllers to Develop Human Reliability Analysis Method for Advanced Control Rooms”, KAERI/TR-4207, 2010.