Developing a standard method for human reliability analysis of nuclear power plants

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1. Introduction

According as the demand of risk-informed regulation and application increase, the quality of a probabilistic safety assessment (PSA) has become more important. As part of enhancing the PSA quality, a study started to standardize the process and the rules of human reliability analysis (HRA) which was known as a major contributor to the uncertainty of PSA. This paper introduces the development of a standard HRA method for quantifying human error probability [1].

The study was carried out with three stages; 1) assessing the level of quality of the HRAs in Korea and identifying the weaknesses of the HRAs, 2) determining the requirements for a standard HRA method, 3) developing the process and rules for quantifying human error probability.

2. Quality of Current HRA

Since the risk-informed applications use the ASME PSA standard [2] to ensure PSA quality, the standard HRA method was developed to meet the ASME HRA requirements with 9 high level and 34 supporting items. The ASME requirements were used to assess the quality of the Korea Standard Nuclear Plant (KSNP) PSA [3]. Several HRA experts participated in the evaluation of HRA of KSNP PSA. Table 1 shows the quality level of KSNP HRA. Risk-informed applications generally require the level of category II or III.

Table 1 Quality of KSNP HRA

Category	# of requirements	Level of KSNP HRA
Pre-initiating HFEss	15	• Category III : 0 • Category II : 5 • Category I : 8 • < Category I : 2
Post-initiating HFEs	19	• Category III : 3 • Category II : 7 • Category I : 7 • < Category I : 2
Total	34	• Category III : 3 • Category II : 12 • Category I : 15 • < Category I : 4

More than 50% was equal or below category I as a whole, so it is necessary to upgrade the HRA for risk-informed applications. Most items rated category I or less, however, were related to not methodological aspects but plant specific information. Since the KSNP PSA was performed during the stage of plant design and construction, the HRA could not use the plant specific information.

3. Requirements for the Standard HRA Method

At first, technical requirements were clarified to develop the standard HRA method based on the review of the KSNP HRA. Most important guides to the requirements are the uses of plant specific information on MMI design/operating practices and the documentation of all technical bases. And also one specific goal of the standard HRA method is to meet the quality of category II of ASME standard because most risk-informed applications generally require that level of quality.

All of 34 technical requirements of ASME standard are directly applied to develop the standard HRA method. It consists of 15 items for pre-initiating human failure events (HFEs) and 19 items for post-initiating HFEs.

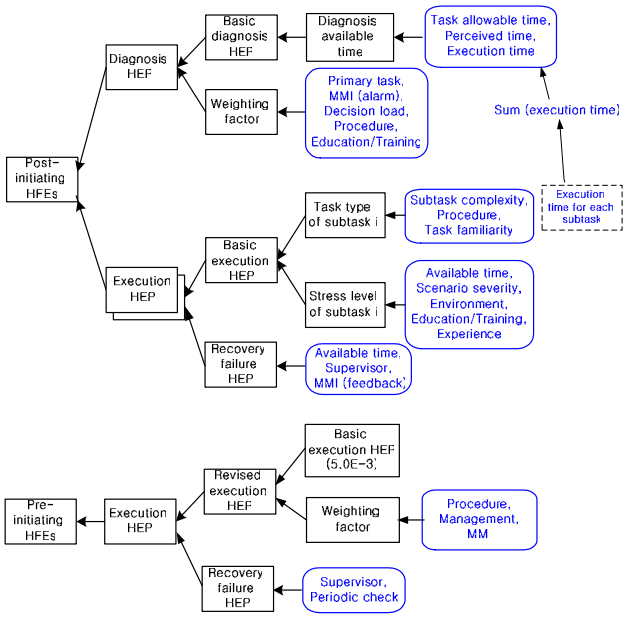

Fig. 1 Framework of the standard HRA method

4. Framework of the Standard HRA Method

Fig. 1 shows the framework of the standard HRA method. One of the arguing points in HRA is the selection of performance shaping factors (PSFs). The standard method selected PSFs based on the systematic review on conventional HRA methods [4] and ASME requirements. A set of comprehensive PSFs, as shown in the box on the right side of Fig. 1, is used in the qualitative and quantitative analysis of the standard method.

In the standard method, it is assumed that human error probability can be assessed by analyzing diagnosis part and execution part separately. And the method separates human tasks of NPPs into pre-initiating and post-initiating HFEs. Pre-initiating HFEs are the human errors which are occurred in daily routine tasks such as tests, maintenances and calibrations during normal operation. That kind of routine tasks are performed based on procedures and pre-defined task plan, so the role of diagnosis part of human behavior is almost negligible. Therefore diagnosis error does not need to be assessed for the pre-initiating HFEs. On the other hand, human tasks related to post-initiating HFEs need both parts of human behavior, diagnosis and execution. According to the human behavior model, the standard method has two separate analysis processes for pre-initiating and post-initiating HFEs.

Diagnosis human error probability (HEP), HEP(D), can be estimated as follows.

$$\text{HEP(D)} = \text{Basic HEP(D)} * \text{M (weighting factor)}$$

where, Basic HEP(D) = *f* (diagnosis available time)
M = *f* (MMI, education/training, procedure)

Basic HEP of diagnosis error can be represented as a function of the available time for task diagnosis. M is a weighting factor on which is fixed by considering some PSFs related diagnosis process, level of man-machine interface (MMI), quality of education / training, level of procedure. The standard method provides the decision tree for M as shown in Fig. 2.

The standard method also presents a framework for analyzing execution HEP. To assess the execution HEP, HRA analyst breaks down the execution part of a task into a sequence of sub-tasks. A set of technical rules to split the execution part is presented in the standard method. Execution HEP can be estimated as follows.

$$\text{HEP(Ei)} = \sum [\text{Basic HEP(Ei)} * \text{HEP(R)}]$$

where, Basic HEP(Ei) = *f* (task type(i), stress level(i))
HEP(R) = *f* (recovery potential (i) by supervisor or worker himself)

The standard HRA method explicitly provides all kinds of rules and decision information needed to do HRA. It covers the dependent analysis of HRA..

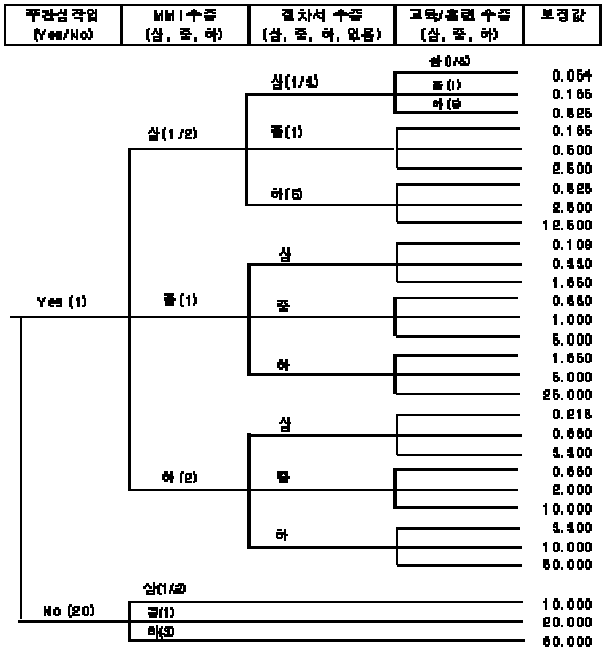

Fig. 2 Decision tree for M (weighting factor) of diagnosis HEP

5. Conclusion

This paper presents the standard HRA method which was developed by KAERI with HRA specialists in KOPEC and KINS. The standard method focuses on standardizing the process, PSFs and decision rules to minimize the uncertainty caused by HRA analysts. Several case studies and sensitivity analyses were carried out by different HRA analysts to evaluate the technical adequacy and the usability of the method. And also KAERI used the standard method to perform HRA for upgrading the KSNP PSA model.

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