KAERI'S RESEARCH ACTIVITIES ON HRA

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Human error has been known as a major contributor to the risk of a nuclear power plant (NPP), but the technical basis for human reliability analysis (HRA) is relatively weak compare to other parts of a probabilistic safety assessment (PSA). The Korea Atomic Energy Research Institute (KAERI) has carried out researches on HRA to build a Korean specific technical basis of HRA. We developed a Korean standard HRA method, K-HRA, to reduce the uncertainty caused by analyst's subjectivity, and revised it to make another method for the HRA of a new NPP with an advanced main control room. In addition, KAERI has been developing an HRA database using the empirical data obtained from simulators and event reports, and ultimately use the data for generating human error probabilities for the HRAs of NPPs in Korea.

I. INTRODUCTION

According as the demand of risk-informed regulation and application increase, the quality of a PSA has become more important. As a part of efforts to enhance the quality of a PSA in Korea, a series of research activities has been carried out to support an HRA that is known as a major contributor to uncertainty in PSA results.

This paper briefly introduces three research activities that have been performed by KAERI: (1) a standard HRA method, (2) simulator studies for HRA purpose, and (3) a pilot HRA study for advanced main control room (MCR) with digital human system interfaces (HSI).

II. DEVELOPMENT OF A STANDART HRA METHOD

Before the middle of 2000s, ASEP and THERP HRA methods were mainly used for HRA of a NPP in Korea. However, there was a considerable inconsistency in estimating human error probability (HEP) among HRA analysts in spite of using same methods. We found that most of the inconsistency were caused by lack of standardized rules and/or criteria to apply the HRA methods. To resolve this problem, KAERI developed a standardized HRA method called K-HRA, for the PSAs of NPPs in Korea. Afterward, a modified K-HRA method, HuRECA (Human Reliability Evaluator for Control Actions), was developed to support the HRA for a new NPP that has fully digitalized HSIs in a MCR.

II.A. K-HRA Method

The K-HRA method [1] is a Korean standard HRA method developed by HRA experts of KAERI, KINS, and KEPCO-E&C for HRA applications in Korea. The K-HRA method follows the framework of the ASEP HRA method, but has modified quantification rules with systematic decision trees and clear criteria for deciding the level of performance shaping factors (PSFs). It provides a systematic process and standardized forms with a set of quantification rules and criteria for estimating HEP, which could help an HRA analyst to apply the method without big variation.

In the K-HRA method, it is assumed that human error probability can be assessed by analyzing diagnosis part and execution part separately. And the method categorizes human tasks of a NPP into pre-initiating and post-initiating human failure events (HFEs). Pre-initiating HFEs are the human errors which are occurred in daily routine tasks such as tests, maintenances and calibrations during normal operation. Such kind of routine tasks are performed based on a procedure and a pre-defined task plan, so the role of diagnosis part of human behavior is almost negligible. Thus 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. We identified PSFs of the K-HRA method based on the systematic review on conventional HRA methods and ASME PRA requirements [2]. A set of comprehensive PSFs is used in the qualitative and quantitative analysis of the method.

II.B. HuRECA Method

HuRECA (Human Reliability Evaluator for Control Actions) [3] is a modified K-HRA method for the HRA of an advanced MCR. HuRECA was based on the K-HRA method, but has modified quantification rules and criteria derived from considering advanced HSI features such as computerized procedure system (CPS) and soft control (SC). The method provides a majority of PSFs based on the K-HRA method, however, it further represents more attributes of computer-based design features such as CPS and SC to reflect the these features in estimating HEPs. The method provides both screening and detailed assessment rules of HEPs in PSA applications. It also provides guidance on using task analysis and other structured analysis tools for the qualitative assessment of human actions. The quantification process estimates an error probability for the diagnostic and execution phases of human actions. The diagnostic phase uses the ASEP time/reliability correlation and provides for adjustments through the use of PSFs linked by decision trees. The execution phase is modeled using step-by-step analysis of individual tasks. For both phases, an extensive guidance is provided as to the assessed strength of the PSFs.

The range of PSFs and the use of explicit reference scales allow it to be used directly without high expertise of HRA. It provides guidance for all stages of the HRA, including use of qualitative tools to identify actions, screening, detailed analysis, incorporation in PSA and documentation.

III. DEVELOPMENT OF HRA DATABASE

A fundamental issue in HRA is a lack of empirical data in terms of either HEP or lower level information that can be used to estimate HEPs. To resolve the problem, several organizations in the world have tried to generate HEP database to support HRA. KAERI also has carried out research to collect data of human performance and reliability from simulators and event reports for HRA in Korea. KAERI's research on HRA database can be divided into two phases as follows.

III.A. Phase I Study - OPERA

In the Phase I (2001~2006) study, KAERI collected simulation records from the full-scope training simulator of OPR1000 type NPPs to understand the way of human behavior and to analyze human performance under emergency scenarios. The data collection was started from 2001 and continued for about 6 years. During this period, almost 160 simulation records have been collected from 12 accident scenarios including six DBAs. And we also analyzed about 50 human induced events to identify root causes of human error. The information of human performance obtained from interviews with operators or task analysis on the emergency operating procedures (EOPs) was also collected and stored in the OPERA (Operator Performance and Reliability Analysis) DB [4]. From the OPERA we can extract quantitative data such as event diagnosis time, task execution time of each procedural step that could be used as direct inputs for HRA. We could also generate qualitative data such as task goals and steps defined in the EOPs of a reference plant, error types and causes, communication patterns and so on. Among several data derived from the simulator study, operators' performance time data was used as an input for the HRA of PSA projects in Korea.

III.B. Phase II Study - HuREX

During the Phase II (2012~2016), we designed the simulator study to generate a specific HEP data that could be directly used for the HRAs of Korean NPPs. KAERI has developed a framework of data collection for HRA called HuREX (Human Reliability data Extraction) [5]. The HuREX is a framework (or a system) for HRA data collection from simulators or event reports to generate HRA data including HEP values. It provides a process, methods, and taxonomy to answer the questions - what information should be gathered, how to collect and analyze them to produce HRA data that can be used directly to perform an HRA or to develop a new HRA method as technical bases.

The process of HuREX can be divided into two parts: data collection and data analysis. The data collection part comprises a method, process, and guideline that are needed to identify human error and to gather all relevant information about task and context from simulator records or event reports. Simplified cognitive model and taxonomies of task and error are also supplied for the data collection. All the information gathered through the data collection process is stored in the HRA database named of OPERA (Operator Performance and Reliability Analysis). Second part, data analysis, provides methods for analyzing the collected data statistically to generate a final set of HRA data that includes performance times and HEPs of generic tasks in emergency procedures.

IV. A PILOT STUDY FOR HRA OF ADVANCED MCR

Advanced MCR of an NPP has been designed using digital and computer technologies. Computerized interfaces for providing and displaying plant information, soft controls for providing control inputs to the plant devices, computer-based procedures replacing paper-based procedures, and operator support systems for automating tasks and reducing the workload of operators are the most representative features of an advanced MCR [6]. Among the several features, soft control seems to be a critical feature that affects human performance and reliability since most operational actions in an advanced MCR is performed by soft control.

HRA has become a hot issue in Korea during the licensing process of the first NPP of APR1400 with fully digitalized HSIs. Because the APR1400 NPP uses new HSIs such as CPS and SC, the HRA should consider the effect of the new interfaces on HEPs. However, it was hard to find an appropriate method and/or data for the HRA over the world, KAERI has conducted researches on HRA issues of the advanced MCR to understand the characteristics of human performance and error in the advanced MCR environment. As a pilot study, we performed a simulator study to scrutinize the types of error and their possibilities regarding soft control task that could not be observed in conventional type MCR. The pilot study was undertaken using a compact nuclear simulator (CNS) that has fully digitalized HSIs.

From the study, empirical data of erroneous human actions with regard to soft control was collected and examined. The empirical data was analyzed to identify error modes and their causes, and to estimate the HEP of each error mode when using soft control in an advanced MCR. This empirical study will be helpful to verify whether soft control has positive or negative effects on human performance and will be able to provide a technical basis for the HRA of an advanced MCR if more data are collected in the future.

V. CONCLUSIONS

This paper briefly summarized three research activities on HRA that have been performed by KAERI: (1) a standard HRA method for the PSA of Korea, (2) a simulator study for HRA purpose, and (3) a pilot study for the HRA of an advanced MCR with digital HSIs. As a further study, we are planning a research project that focuses on the development of a technical basis for the HRA of Korean NPPs using the HuREX framework and the OPERA DB.

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