A Critique on the Effectiveness of Current Human Reliability Analysis Approach for the Human-Machine Interface Design in Nuclear Power Plants

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1. Introduction

Human Reliability Analysis (HRA) in cooperation of PSA has been conducted to evaluate the safety of a system and the validity of a system design. HRA has been believed to provide a quantitative value of human error potential and the safety level of a design alternative in Nuclear Power Plants (NPPs). However, it becomes doubtful that current HRA is worth to conduct to evaluate the human factors of NPP design, since there have been many critiques upon the virtue of HRA. Inevitably, the newer the technology becomes, the larger endeavors bound for the new facilitated methods. This paper describes the limitations and the obsolescence of the current HRA, especially for the design evaluation of Human-Machine Interface (HMI) utilizing the recent digital technologies. An alternative approach to the assessment of the human error potential of HMI design is proposed.

2. A Brief History of HRA Methods and Experiences

2.1 The First Appearance of HRA in NPPs

Human error has been one of the key criteria of the safety as well as the performance and efficiency of a system. Nowadays, it becomes afford to get more attentions in the aspect of the technological liability. A reliability assessment described in WASH-1400 in 1976 turned out to be a prophecy of TMI#2 incident in 1979. The probability model of an NPP revealed that human error is the most important contributor of the NPP risk, by more than 50%. After TMI, HRA became one of the indispensible elements of safety evaluation in form of PSA. Additionally, there have been many retrospective analysis and back-fitting actions such as ERF/SPDS and D-CRDR, against to the human error potential in NPPs. However, nobody was able to make sure how much these responsive actions might reduce the human error potential and which aspects of human error hazard were removed by them. In 1980's HRA could ride a common vehicle named Swain's HRA handbook (NUREG/CR-1278, 1983). THERP was imported directly from the military practice. And the HEP data tabulated in the handbook were established based on the 1960's military data due to the urgent demand in nuclear industry. Additionally, EPRI conducted an intensive simulator studies for gathering HEP data during the mid of 1980's, and resulted into a Time-Reliability Correlation (TCR) according to SRK paradigm proposed by Rasmussen.

2.2 Basic Failure Model for HRA

Current HRA utilize ASEP/THERP as a part of PSA. THERP incorporates the decomposition of human tasks in form of binary success/fail branch tree. ASEP has a failure model including mis-diagnosis and unsatisfied responses utilizing TRC model developed in 1980's

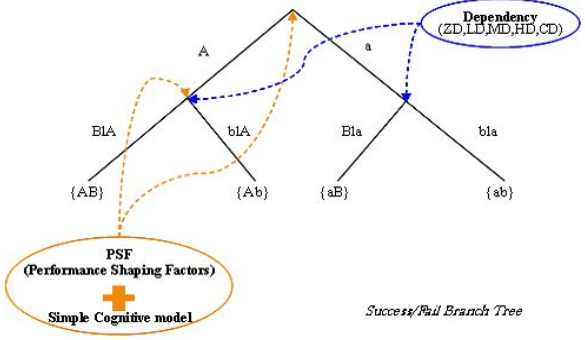
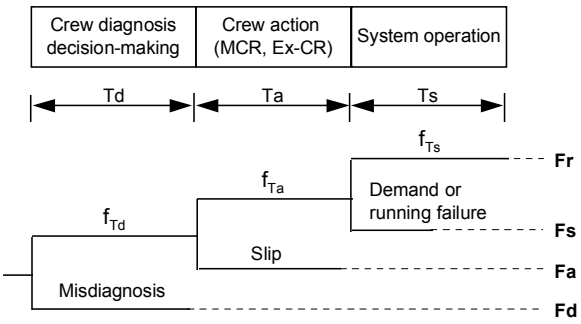


Fig.1. Typical THERP Model for HRA calculation [3]



Probability of Non-Success: $P_{NS} = (P_{Fd} + P_{Fa}) + P_{Fs} + P_{Fr}$
- P_{Fd} : Failure of Diagnosis of the event
- P_{Fa}: Failure of Action Executions
- P_{Fs} : Failure during Demand and Operation
- P_{Fr} : Failure of exceed the Response Time limits(TRC)

Fig.2. Typical Failure Model for HRA calculation [2]

2.3 Requirements on HRA and Modified Approaches

Almost all studies on the major accidents in NPPs emphasize the prominent importance of the human errors. The management of human factors in NPPs has become one of the burden factors during their operation as well as after the design and construction. NUREG-0800, NUREG-0711 and other regulatory documents specify HRA as an essential element of Human Factors Engineering Program Plan (HFEPP) for NPP Design. The consideration of human factors in NPP design is primarily focused to reduction of the human errors. However, it is not easy to find out a more effective HRA approach to the reduction of human error potentials within the HMI design to establish the engineering implementation plan for preventing them.

2.4 Efforts to the HRA and HEP

There are predictive, retrospective and managerial approaches to the human error studies. Although retrospective and managerial approaches such as HPES, HPIP, PSR, HFMP and other programs are still on-going and developing, HRA still is expected to remain as the most effective one for the purpose of predictive approach. New approaches for HRA such as GEMS (Generic Error Modelling System), SHERPA (Systematic Human Error Reduction and Prediction Approach), PHECA (Potential Human Error Cause Analysis), HRMS (Human Reliability Management System), CREAM (Cognitive Reliability & Error Analysis Method), and others have been proposed And sincere devotions for the HEP data gathering through the fairly long struggling processes of simulator studies including new taxonomy of PSFs still are developing internationally. However, they are not detailed enough to consider the change of HMI by introducing new digital devices. These slam-dunk efforts on HRA/HEP data and blunt application of HRA to the HMI design without more careful technical reviews could be out of the ultimate goal of human error studies, i.e. the recurrence prevention in NPPs.

3. A Critique on HRA and An Alternative HRA

HRA asks a more profound model and/or theory of human error mechanisms. Academic theories cannot provide the basis and model of human error mechanisms and their nature enough to explain an agreeable strategy to prevent its recurrences in the future. It might be beneficial to consider a different set of axiomatic statements for the human error studies and managements generally accepted by the practitioners in industries [4].

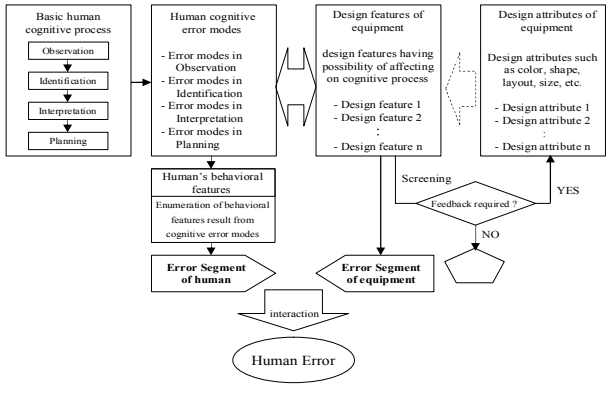


Fig.3. Overview of alternative HRA proposed for HMI design

Secondly, HEP data can neither be realistic nor exhaustive when considering recent drastic changes of digital devices that might be introduced to HMI of NPPs. The impact of HMI design changes to the human cannot be captured by PSFs and other sophisticated suggestions of the current HRA methods. An alternative approach outlined in the above Fig.3 might enhance the consideration of HMI design in more detailed manner.

Probability may be a good measure also for the human error potential, only when it can reflect the human behavior characteristics related to a specific goal. As Rasmussen had elucidated, the existing perspective on human errors should be shifted from the scientific, common-sensed, and attorney's one to more effectively focused one for the application purpose. And, human error is turned out to be more than human fallacies, such as slips, blunders, fumbles, and violations, and engineering of them should be extended to the behind of human fallacies themselves. Before conducting HRA for the HMI design, it is indispensable to specify what the real purpose of the efforts is.

Additionally, a lot of new types of human errors have been identified after the 1-st generation HRA proposed such as, avoidance errors, routine organizational violations, well-intended blunders, and so on. The more complicated the digital devices and technology become, the more various types of human errors should be studied before the quantification of human reliability.

4. Conclusions

A critique on the current HRA approach is discussed and an alternative approach is proposed especially for the consideration of the digital HMI design in NPPs. HRA is required as an essential element of HFE design for NPPs, and still is expected to remain as the most effective one for the purpose of predictive approach to the prevention of human errors in NPP design. More careful technical enhancements should be accomplished rather than the recent devotions for the HEP data and unpractical struggling of simulator studies.

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