A Systematic Approach to the Countermeasures for Human Errors in Nuclear Power Plants

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1. Introduction

There are a number of human error (HE) events that are uncontrollable and hard to handle because of the fact that the nature of events may have been threatened or very intensive. It is strongly required that more systematic studies should be performed to grasp the whole picture of current situation for hazard factors in nuclear power plants (NPPs).

One of the most frequently used techniques for NPPs is an event investigation analysis based on INPO's human performance enhancement system (HPES), and Korean human performance enhancement system (K-HPES) in Korea, respectively. Those analysis methods associated with HE in NPPs may be different with explanation of accidents happening and an establishment of counter-plan. In the interest of them, we should consider events with all information about system conditions and system movements. The objective of this paper is to propose an approach aiming to reduce the loss from HEs through a macro-ergonomic approach; a systematic barrier against hazard factors in NPPs by establishing procedures. The procedures are first to grasp influent elements of events using person and system approach, secondly to derive countermeasures according to systematic barriers. Then, a case study for human error in NPPs using the proposed approach is performed for verification purposes.

2. Methods & Approaches for HE Study

2.1 HE Analysis Methods

Studies on HE analysis are classified into three types; quantitative approaches, qualitative approaches, and managerial approaches, according to an access method. Quantitative approaches use methodologies for the data management of HEs aiming at the computation of error probabilities. These techniques are grouped by two types of generations.

The first generation methods for HE are accident investigation and progression analysis, confusion matrix, operator action tree, socio-technical assessment of human reliability, expert estimation, etc. The second generation methods are cognitive reliability and error analysis method, a technique for HE analysis, generic error modeling system, Rasmussen's model, cognitive event tree system, cognitive environment simulator, etc. Quantitative analyses are insufficient to connect between a status analysis and a cause analysis, and hence they are general analysis methods rather than concrete analysis methods in application.

Qualitative analyses grasp cognitive behavioral characteristics through studies on theoretical and experimental HE as a psychological side. This approach focuses on theoretical characteristics of a cognitive act, and proposes only a high-level alternative plan like design concept of an error countermeasure. Therefore this approach has a limit for application to HE field in NPPs.

Lastly, for the managerial approaches having a report type, what is most frequently used technique in NPPs, is HE management system collecting and managing human error cases and analyzing human errors to make practical application of analyzing results. Theses are, for instance, incidents reporting system (IRS) of IAEA and OECD/NEA, HPES, K-HPES, and Japan human performance enhancement system (J-HPES), etc. A result of HE analysis from this approach works toward diminution of HEs through the improvements of the system, design, and work procedures. However, this approach is still not sufficient for a practical report system, and is open to variation due to subjective judgments by analyzers' temperaments.

2.2 Approaches to HE Investigation

(1) Person Approach & System Approach

The HE problem may be viewed in two ways, the person approach and the system approach (Reason 2000 [5]). Each has its model of error causation and each model gives rise to quite different philosophies of error management. The person approach focuses on the errors of individuals, blaming them for forgetfulness, inattention, or moral weakness. The system approach concentrates on the conditions under which individuals work and tries to build defenses to avert errors or mitigate their effects. Table 1 shows an example for the person approach and the system approach.

Table. 1. An example for the person approach and the system approach

Person Approach	System Approach
Wrong judgment	Structural design error
Insufficiency of period checkup and maintenance	Valve fail-open failure
Deficiency of system comprehension	Insufficiency of safety culture
Unsatisfactory subject selection for period tests	Insufficient human factors V&V
Unsatisfactory training	Failure in H/W, S/W
Insufficient procedure management	Fault signal delivery in W/S
	Insufficient transmission of accident cases
	Unsatisfactory procedure
	Protecting cover

Deficiency of supervisor's control Stress	Safety sign Unsafe of valve manipulation Function loss of local control panel

(2) Socio-technical Approach

Figure 1 shows a flow of loss prevention in socio-technical system. In order to evaluate the reliability of a socio-technical system, it is important to evaluate the system with a number of paths that correspond to a realistic sequence of events that could occur during the system's operation. The events in NPP are reconstructed and possible paths of the events are also conducted in this approach. There are many interfaces among departments or individuals that may not be clear and a communication error may intervene in high reliability organizations. Therefore, all possible interfaces should be performed carefully in an analysis for safety.

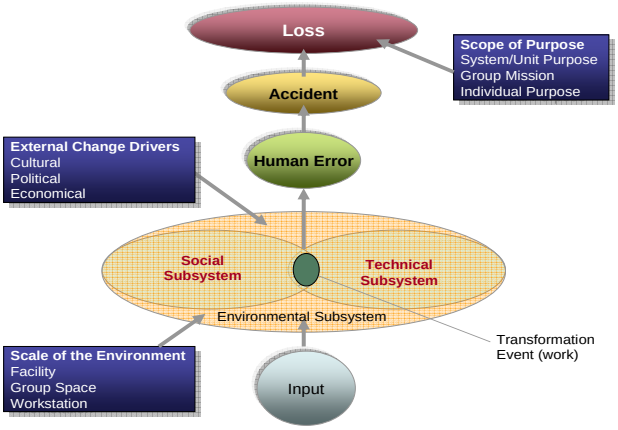

Fig. 1. Socio-technical approach for barriers

(3) Approach for Countermeasure

The dependency and the potentiality of the hazards in NPPs are defined by enumerating the relative factors of the events as shown in Figures 2. The procedure in this research can search more hazardous factors as well as causal factors in each case than the preceding HEA so it may be considered as a better method for generating more effective countermeasures [1][4].

2.3 The relationship between performance and function

A large number of empirical studies based on these concepts have been conducted, and such enthusiasm for empirical investigation goes on in these days. A number of researchers have raised concerns regarding the reliance on self-reports of psychosocial work conditions for measuring job strain. Also, a significant theoretical and methodological amount of criticism has been raised.

A best performance comes from optimum level of the pressure and the function as shown in figure 3.

hazard factors	results of hazard	causes	countermeasures
• wrong judgement	• faulty operation of pressure discharge valve of low-pressure turbine #1 and stopping valve #2	• deficiency of control system comprehensive • structural design error • unsatisfactory facilities training	• procedure improvement • technical training about MCR control system • setting up protecting cover to preventing unintentional manipulation • safety sign
• pressure rising MSR "A", "B"	• rupture disk burst	• stopping valve close in low-pressure turbine #1 • A design that MSR rupture disk can burst in the high pressure	• safety countermeasures for human error prevention • human factors review for Fail-open failure conditions • procedure supplementation for possible items of Fail-open failure • plans for modifications of pressure discharging process
• insufficiency of period checkup and maintenance	• high-pressure turbine control valve #1 shut	• control valve(③/#1 and low-pressure turbine#1 shut abnormally by steam bursting • high-pressure turbine control valve#1 shut	• checkup and maintenance of hydrogen leak in generator winding • human factors review for the conditions of Fail-open failure • procedure supplementation about possible items of Fail-open failure
• structural design error	• valve Fail-open failure	• insufficient human factors V&V • failure in H/W, S/W and human FMEA-based design	• human factors V&V implementation for remote control system • H/W, S/W, and human FMEA-based design • confirmation of normal status and construction of systemic procedure about abnormal management in installation of remote control system
• valve fail-open failure	• function fail of local control panel	• fault signal delivery in W/S	• training about signal delivery of remote control system • adding notices about signal delivery of remote control system to procedures
• inadequate periodic tests and maintenance of W/S and network	• networking error between Workstation and local control panel	• unsatisfactory subject selection for period tests	• adding systems related to fail-open valve to periodic tests
• insufficiency of safety culture	• faulty judgement selection (shutdown rebooting)	• insufficient transmission of accident cases	• safety culture establishment about work culture and reporting customs

Fig. 2. Countermeasures for each hazard factors

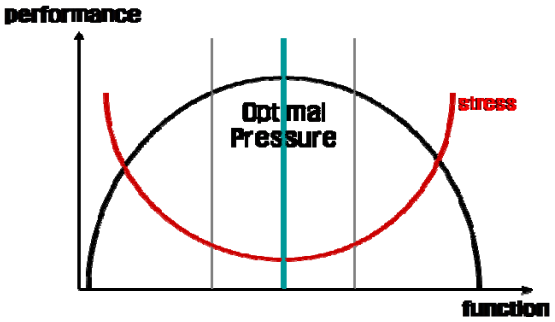

Fig. 3. Theoretical optimal function

3. Discussions

This research proposes an effective systematic approach that derives countermeasures by integrated approaches as safeguards representing possible paths to loss in NPP. A level of function to reduce HEs has been studied associated with function and performance as safety of NPPs.

For further research, it is needed to investigate more case studies, and measure the quantitative data using the method in this research.

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