Examples of Unsafe Act Identification from Simulator Training Records for Interfacing System Loss of Coolant Accident

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1. Introduction

Operation experience of socio-technical systems, such as NPPs (Nuclear Power Plants) demonstrated that the accidents or incidents of such systems are catastrophic resulting in massive casualties, severe environmental damage, and enormous financial losses. Operating procedures such as EOPs (Emergency Operating Procedures) and AOPs (Abnormal Operating Procedures) have been developed to maximize the operator's performance during emergency/abnormal situations of critical-safety systems. In this regard, it is very important to point out that one of the significant factors causing accidents or incidents is an inappropriate human performance of operating personnel working in the socio-technical systems [1-2]. Consequently, a huge amount of effort has been spent to reduce the possibility of human error, and one of the most disseminated approaches is to conduct an HRA (Human Reliability Analysis). Therefore, a lot of efforts to collect HRA data by using a simulator of NPP have progressed [3-4].

We developed a standardized guideline to specify how to gather HRA data from simulator training records, and created IGT (Information Gathering Template) specifying what kinds of measures should be observed during the simulations [5] and defined UA (Unsafe Act) and describe the UA identification method under interactions between crew members to suggest a practical UA type classification scheme under a procedure driven operation [6]. We also developed a framework for data collection and analysis to produce HEPs. The framework is named HuREX (Human Reliability data Extraction) system in Fig. 1 [7].

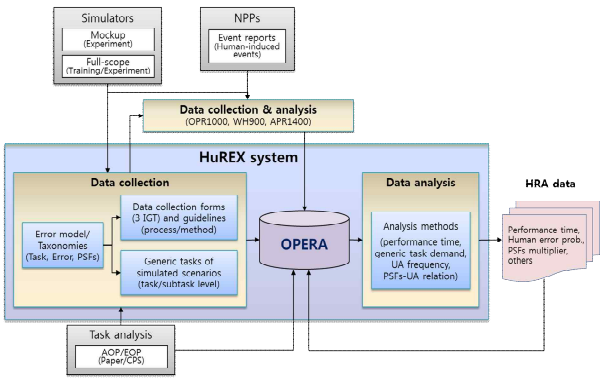

Fig. 1. HuREX - Overview

The purpose of this paper is to present examples of UA candidates and UAs based on UA identification criteria we provided with the ISLOCA (Interfacing System Loss of Coolant Accident) scenario simulator training records.

2. Methods and Results

This section describes how to identify UAs based on a UA definition and presents examples of UAs and UA candidates.

2.1 Identification of UA candidates and UAs

A UA is defined as an inappropriate human behavior that has a potential for leading the safety of NPPs toward a negative direction in this research. From this concern, all kinds of deviations from the following operating procedures can be regarded as UA candidates, because these operating procedures contain many tasks to be done by operating personnel, which are very important to reduce the consequences of accident sequences.

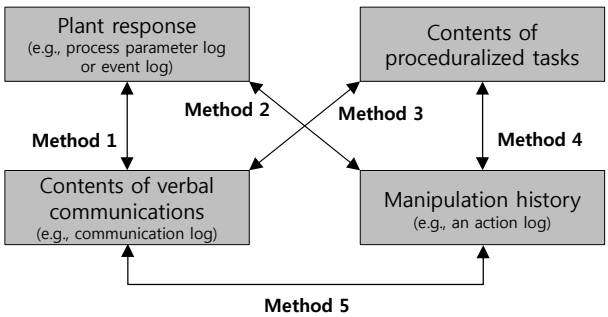

Fig. 2. Criteria for identifying UA candidates from simulation records

Fig. 2 illustrates five methods to distinguish UA candidates from simulator training records based on supplementary information (i.e., various kinds of logs recordable from a full-scope simulator). After the supplementary information is secured, the behaviors of MCR operators can be scrutinized in detail along with progress of each simulation record. For example, if we are able to compare a process parameter log with a communication log, it is possible to clarify whether a BO (Board Operator) reports what an SS (Shift

Supervisor) wants to know with a correct reading (i.e., Method 1). Similarly, the comparison between a communication log and an action log can be used to manifest whether or not a BO manipulated a wrong device (i.e., Method 5).

After UA candidates are selected based on Fig. 2, UAs leading to the negative consequences are identified among the UA candidates. The consequences by a UA are defined as follows:

- Inappropriate procedure progression
  - Inappropriate procedure selection
  - Inappropriate step selection
- Inappropriate execution
  - Inappropriate component manipulation
  - Inappropriate announcement

2.2 Example of UA grouped by consequence

In this section, we describe examples for screening UA candidates and determining UA under an ISLOCA scenario. For the case study, we collected data on simulated emergency operation training for the two kinds of scenario at a Westinghouse 3-loop PWR (Pressurized Water Reactor).

UA leading to inappropriate procedure selection

A UA leading to an inappropriate procedure selection occurred during the procedure transfer from E-0 (EOP for reactor trop or safety injection) to E-1 (EOP for loss of reactor or secondary coolant). Fig. 3 shows the related procedure instruction. During performing the 'Action/expected response' part in Step 24.0 of E-0, an SS instructed Step 25.0, even though an RO reported that the containment radiation was abnormal. The SS should transfer to E-1 based on the instruction of 'RNO' part of Step 24.0. Therefore, this behavior was selected as a UA candidate by Method 3 in Fig. 2 and a UA due to its consequence resulting in an inappropriate procedure transfer.

ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED (RNO)
24. Check If RCS is Intact • Containment radiation - NORMAL • Containment pressure - NORMAL • Containment recirculation sump level - NORMAL	Go to E-1, LOSS OF REACTOR OR SECONDARY COOLSNT, Step 1.

RCS: Reactor Coolant System

Fig. 3. EOP Instruction Related to UA Leading to Inappropriate Procedure Selection

UA leading to inappropriate step selection

This example describes a UA leading to inappropriate step selection. For one crew, a BO reported that the pressures in all SGs were decreasing and for another crew, a BO answered that the RCS pressure was increasing during Step 9.0 of E-1 in Fig. 4. The both cases did not meet the set points, so SSs should instruct the RNO part of Step 9.0. They, however, instructed Step 10.0 without performing the RNO part of Strep 9.0.

ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED (RNO)
9. Check If RCS and SG Pressure: • Check Pressure in All SGs – STABLE OR INCREASING • Check RCS Pressure – STABLE OR DECREASING	Return to Step 1.

RCS: Reactor Coolant System
SG: Steam Generator

Fig. 4. EOP Instruction Related to UA Leading to Inappropriate Step Selection

UA leading to inappropriate execution

This UA shows an inappropriate behavior related to inappropriate component manipulation, in particular an EOO (Error of Omission). Fig. 5 shows the related step instruction. An SS instructed 'Action/expected response' part in Step 1.2 of E-1 to check the RCP trip parameter (pressure) and a BO responded that the RCP pressure was 104. Since the containment was adverse due to radiation in containment, the pressure was satisfied with the set point. Therefore the SS should instruct 'Action/expected response' part of Step 1.3; however, he did not direct the part. Instead, he instructed the 'RNO' part of Step 1.2 to cause an inappropriate component manipulation. That is, all RCPs which should have stopped continued on.

ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED (RNO)
1. Check If RCPs Should Be Stopped:	
1. SI pumps - AT LEAST ONE RUNNING 1. Charging/SI	1. Go to Step 2.
2. RCP Pressure - LESS THAN 96 kg/cm^2 (105 kg/cm^2 FOR ADVERSE CONTAINMENT)	2. Go to step 2.
3. Stop all RCPs	

RCP: Reactor Coolant Pump
SI: Safety Injection

Fig. 5. EOP Instruction Related to UA Leading to Inappropriate Component Manipulation (1)

Another example for a UA leading to inappropriate component manipulation occurred while performing Step 3.1 of E-1 in Fig. 6. A crew performed the RNO part of the step since the SG narrow range level indicators read 0%. After performing the RNO part of Step 3.1, an SS should instruct the 'Action/expected response' part of Step 3.2. The SS, however, instructed Step 4.0 without performing Step 3.2. As a result, the intact SGs' narrow range level exceeded 50%. That is, the UA resulted in inappropriate component manipulation.

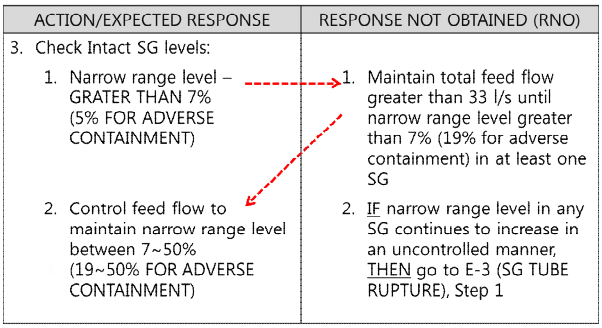

Fig. 6. . EOP Instruction Related to UA Leading to Inappropriate Component Manipulation (2)

2.3 Example of UA candidate but not UA

In Fig. 7, an SS instructed the 'Action/expected response' part of Step 15.3 and Step 16.0 of E-0 after the 'Action/expected response' part of Step 15.2, however, the SS should instruct 'Go to Step 16' based on the 'RNO' part of Step 15.2 since the RCS pressure did not meet the set point. Four of ten crews involved in the case study showed similar behavior, from Step 15.2 to Step 15.3, even though the RCS pressures were greater than the set point. So we regarded the behavior as a UA candidate, however, we did not classify the UA candidate into a UA. The reason is that performing the task of 'checking the flow of RHR pumps' does not cause any consequence of UA mentioned in Section 2.1. In addition to the RHR pumps were idling at that time.

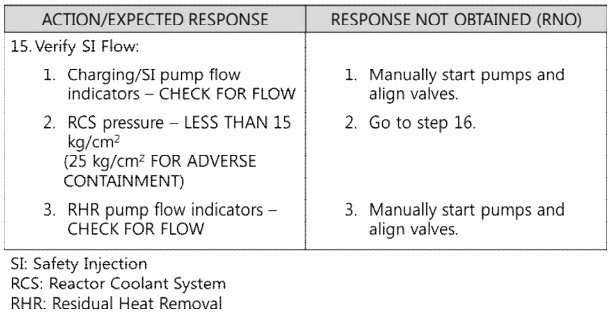

Fig. 7. Example UA Candidate but Not UA

3. Conclusions

In this paper, we described a process to identify UAs as well as UA candidates during an AOP/EOP operation with simulator training records. We presented examples of UA candidates and UAs grouped by consequences based on UA identification criteria. Based on this research, we are to achieve insights about the UA pattern and procedure instruction in which UAs occurred frequently. With this result, we are to analyze the root cause of UAs to find a way to reduce UAs.

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