Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Comparison of Unsafe Acts Identified from Simulator Training Record Analysis under ISLOCA and MLSB+SGTR Scenarios

Sun Yeong Choi*, Yochan Kim, Jinkyun Park, Seunghwan Kim, and Wondea Jung

Korea Atomic Energy Research Institute, Integrated Safety Assessment Div., Daedeok-daero 989-111, Yuseong-Gu, Daejeon, Republic of Korea, 305-353
sychoi@kaeri.re.kr

1. Introduction

It is well known fact that human error is one of the most critical factors affecting the safety of complex systems such as NPPs (Nuclear Power Plants), aviation industries, offshore industries and transportation systems including railway systems [1-3]. For this reason, it is natural to put in a huge amount of effort to enhance their safety through managing the possibility of the occurrence of human error. In this light, one of the most established approaches is to conduct an HRA (Human Reliability Analysis). Accordingly, various kinds of HRA methods have been developed for several decades. In addition, in the case of the nuclear industry, extensive effort has been spent to collect sufficient data that are helpful for conducting HRA (i.e., HRA data) from the full-scope simulator of NPPs[4].

For this reason, we published a standardized guideline to specify how to gather HRA data from simulator training records and crated IGT (Information Gathering Template) specifying what kinds of measures should be observed during the simulations [5]. We also defined inappropriate human behavior (or UA; Unsafe Act) for HRA data collection and showed case study to identify USs with simulator training record [6].

The purpose of this paper is to compare UAs identified from human performance analysis with simulator training record under an ISLOCA (Interfacing System Loss of Coolant Accident) and a SGTR (Steam Generator Tube Rupture) immediately following an MSLB (Main Steam Line Break) scenarios for a Westinghouse 3-loop plant.

2. Methods and Results

2.1 UA Identification

We defined that an UA is an inappropriate human behavior that has a potential for leading the safety of NPPs to a negative direction. From this concern, all kinds of deviations from the following operating procedures such as AOP (Abnormal Operation Procedure) and EOPs (Emergency Operation Procedure) 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. After UA candidates are selected, UAs leading to the consequences mentioned above are identified among the UA candidates. The consequences of a UA are defined as follows:

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

We also classified UAs by considering crew interactions under a procedure driven operation and simulator training environment.

Table 1. UA Classification

Type of UA	Type of UA - Details	UA Performer
Instruction UA	• Missing instruction • Wrong instruction	SS (Shift Supervisor)
Reporting UA	• Missing report • Wrong report	BO (Board Operator)
Execution UA	• Missing manipulation • Wrong manipulation • Wrong object • Unauthorized manipulation • Missing announcement • Wrong announcement	BO

2.2 ISLOCA and MSLB+SGTR Scenarios

For the case study, two kinds of scenarios are selected. We collected data on simulated emergency operation training for the two kinds of scenario at a Westinghouse 3-loop PWR (Pressurized Water Reactor). One of the two kinds of scenarios is an ISLOCA, which requires a cognitive operator performance since a related symptom often occurs in more than two kinds of systems and its occurrence frequency is relatively low. The summaries of the EOPs used for the simulated scenario are shown below:

- Emergency guideline, E-0 for reactor trip or safety injection (step number 24.0)
- Emergency guideline, E-1 for loss of reactor or

secondary coolant (step number 11.0)

- Emergency Contingency Action guideline, ECA-1.2 for loss of reactor coolant outside containment vessel

In the above mentioned list, the step number means the step for procedure transition to the next procedure. The other scenario is an SGTR immediately following an MSLB. An MSLB and nearly coincident SGTR will cause an immediate reactor trip. After entering E-0, operators would transfer to E-2, E-3, and ECA-3.1 sequentially. Table 2 shows the conditions of EOP transitions for the MSLB+SGTR Scenario. The summaries of the EOPs used for the simulated scenario are listed below:

- Emergency guideline, E-0 for reactor trip or safety injection (step number 22.0)
- Emergency guideline, E-2 for faulted SG isolation (step number 6.0)
- Emergency guideline, E-3 for SGTR (step number 5.0)
- Emergency Contingency Action guideline, ECA-3.1 for SGTR with a loss of reactor coolant subcooled recovery desired

2.3 Unsafe Acts Identified from Case Study under ISLOCA and MSLB+SGTR Scenarios

For a case study we collected simulator training data for MSLB+SGTR and ISLOCA with eight MCR operation crews and ten MCR operation crews respectively. Table 2 summarizes the number of UAs and recoveries from the two kinds of case studies on the ISLOCA and on MSLB+SGTR scenarios for a WH-3 loop PWR. For the MSLB+SGTR scenario, a total of 46 UAs occurred from eight cases of simulations, while total 30 UAs occurred from ten simulations for ISLOCA. From Table 2 which summarizes the two kinds of case study results of the UA classification during a procedure-based operation, the following insights are drawn.

- The total number of UAs for the MSLB+SGTR case study is higher than that of the UAs for the ISLOCA case study. The average number of UA occurrences per each team for the MSLB+SGTR and the ISLOCA scenarios is 5.75 and 3.0, respectively.
- From the standpoint of the UA consequences, 70% of the UAs cause inappropriate manipulations and 25% cause inappropriate progression of procedures. For the MSLB+SGTR, 87% of UAs result in an inappropriate manipulation, while for the ISLOCA, 50% and 43% of UAs result in an inappropriate manipulation and an inappropriate progression of procedures, respectively.
- The number of recoveries for the MSLB+SGTR and the ISLOCA are 20 and 4 respectively. Almost of them are recoveries of inappropriate manipulations. In particular, there are no recoveries on inappropriate announcements. For the MSLB-SGTR, 43% of UAs are recovered, while 13% are recovered for the ISLOCA.
- An instruction UA by SS dominates the UA analysis results. The portions of instruction UAs for the MSLB+SGTR and ISLOCA scenarios are 76% and 83%, respectively. Among the instruction UAs, the number of missing instructions is higher than that of wrong instructions.

3. Conclusions

In this paper, we compared UAs identified from human performance analysis with simulator training record under an ISLOCA and a SGTR immediately following an MSLB scenario for a Westinghouse 3-loop plant. We also analyzed recovery actions for the identified UAs. The total number of UAs and recoveries are different in scenarios and MCR operating crew. However, we find some distinguishing facts about UA. We expect that the results in this paper can provide information for some practical aspects including training

Acknowledgement

This work was supported by Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant funded by the Korean government, Ministry of Science, Ict & future Planning (MSIP). (Grant Code: 2012M2A8A4025991)

REFERENCES

[1] Choi, S. Y., and Park, J., Operator behaviors observed in following emergency operating procedure under a simulated emergency. Nucl. Eng. Tech., 44(4), 379-386, 2012.

[2] Deacona, T., Amyottea, P.R., and Khanb, F.I., Human error risk analysis in offshore emergencies. Saf. Sci., 48(6), 803–818, 2010.

[3] Celika, M., Cebib, S., Analytical HFACS for investigating human errors in shipping accidents. Accid. Anal. Prev. 41, 66–75, 2009.

[4] Chang, J., and Lois, E. Overview of NRC's HRA data program and current activities, PSAM12, 2012.

[5] Park, J., W. Jung, S. Kim, S.Y. Choi, Y. Kim, and V. N. Dang, A guideline to collect HRA data in the simulator of nuclear power plants, KAERI/TR-5206/2013, 2013

[6] Park, J., S.Y. Choi, Y. Kim, S. Kim, and W. Jung, The definition of an unsafe act and the associated analysis guideline with respect to training records collected from simulated off-normal conditions, KAERI/TR-5966/2015, 2015.

Table 2. Number of UAs and Recoveries from Case Study

Consequence of UA	UA Type	MSLB+SGTR		ISLOCA	
		# of UAs	# of Recoveries	# of UAs	# of Recoveries
Inappropriate manipulation		40	20	13	2
	Instruction UA-Missing instruction	16	6	8	2
	Instruction UA-Wrong instruction	11	6	2	
	Reporting UA-Wrong report	3	1	2	
	Execution UA-Missing manipulation	5	4		
	Execution UA-Wrong object	1	1		
	Execution UA-Unauthorized manipulation	4	2	1	
Inappropriate progression of procedure		4		15	2
	Instruction UA-Missing instruction	4		10	2
	Instruction UA-Wrong instruction			3	
	Reporting UA-Wrong report			2	
Inappropriate announcement		2		2	
	Instruction UA-Missing instruction	1		2	
	Execution UA-Missing announcement	1			