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HRA Data Collection from the Simulations of Abnormal Situations

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1. Introduction

It is widely recognized that reliability of operators are critical to complex socio-technical systems [1]. For this reason, human reliability analysis (HRA), which aims to identify unsafe actions (UAs) that contribute to risks of the systems and assess the failure rates of the actions, has been conducted [2, 3].

Although many techniques of HRA have been developed and used in many years, many reports indicated lack of database for supporting empirical bases of HRA methods [1, 4]. Thus, there have been recent efforts to collect data about human reliability from plant experience, simulator experiment or qualification, and laboratory experiments [3]. As one of these efforts, KAERI also established a guideline to collect information about human reliability and performance shaping factors from simulators [5]. This guideline particularly presented a set of worksheets that allows comprehensively gathering objectively observable information in simulations of emergency situations.

This paper reports the process and preliminary results of the data collection from the simulations of abnormal situations based on the developed worksheets in KAERI database guideline. We analyzed operator behaviors of the sixteen experiments for the two kinds of abnormal situations: RCP (reactor coolant pump) cyclone filter blockage and CDP (condensate pump) valve stuck. The UAs of operators were identified and quantified.

2. Data Collection Process

2.1 Simulation Data

We analyzed the behaviors of operators in the main control room of an OPR 1000 under abnormal situations. The operation team of OPR 1000 consists of five operators: a shift supervisor (SS), reactor operator (RO), turbine operator (TO), electric operator (EO), and shift technical assistant (STA). When cues of abnormal situations were recognized, the operators should find out related abnormal operating procedures (AOPs) and follow the procedures to cope with the situations. If the operators aware urgency of the situations, they can also take rapid actions before following a procedure.

The eight operation teams of OPR 1000 participated in the experiments for each scenario. For the scenario of CDP valve stuck, a situation of simultaneous closes of the valve (CDV201) before the condensate polishing system and the bypass valve (CDV200) of the condensate polishing system. The operators should find out the cause of problem and request a local operator to open CDV200 within 10 minute. If necessary, the operators can cut reactor power back. The AOP for low flow of condensate tanks describes all actions to be conducted. For the scenario of RCP cyclone filter blockage, the cyclone filter after the high pressure cooler in RCP 1A seal injection flow was blocked. The operators should find out the cause of problem and trip the RCP 1A when the inlet temperature of seal coolers reaches the trip level. The AOP for loss of RCP seal describes various actions to be conducted for similar situations, but it does not describe any symptom and measure related to the blockage of the cyclone filter.

From the sixteen simulations, the behaviors and communications of control room operators were recorded. In addition, the associated events such as manipulations or alarms annunciated and the process parameter such as pressure or temperature of important component were obtained.

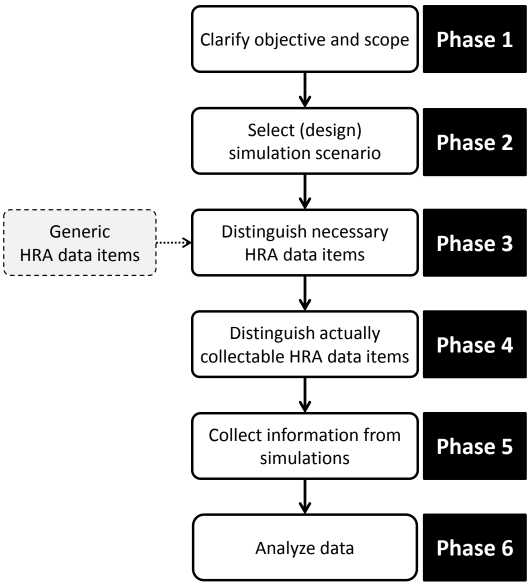

Fig. 1. The overall process to collect information for HRA data [5].

2.2 Worksheets and Analysis Process

To accumulate qualitative HRA data, the obtained records were analyzed and converted to worksheets designed in the KAERI guideline. Fig. 1 shows the process to develop the HRA data worksheets. The worksheets were developed by following phase one to five of the process for ISLOCA (Interfacing System

Loss of coolant accident) scenario, an emergency situation.

The worksheets include plant level information worksheet, timeline worksheet, and task level worksheet. The contents of the worksheets can be summarized by Table I.

Table I: Data Items of Worksheets [5]

Work sheet	Category	Data item
Plant level	Plant & simulation overview	Plant/simulator name
		Plant type
		Operating mode
		Simulation date
		Ingress/injection time of initiating event
		Simulation completion time
		Crew/shift/team name
	Crew (…)	Age
		Work experience of plant operation (yr)
		Work experience in current position/role (yr)
		Certified License
		Work experience in current team (yr)
	Training & education	Simulator training frequency
		Training experience on the scenario
	Environment	Simulation environment
	Observed response	Observed procedural path
	Scenario	Simulation mode
		Initiating event
		Multiple initiating events
		Failed system or component
		Failed/masked alarm or indicator
		Scenario/event summary
		Expected Procedural path
		Allowable time
	Crew characteristics and dynamics	Leadership of SS
		Cooperative attitude
		Supervising level of STA
		Independent checker
		Procedure compliance
		Communication level
Time line	Contents of communication	Start time of utterance
		End time of utterance
		Operating personnel
		Utterance
	Action log	Related action log
	Procedure & Task	Related procedure
		Related step
		Responsible person of step
		Task type
		Component type
	UA	UA candidate
		Code of UA or recovery
		Related UA/recovery
		(Situation) Description
Task level	UA information	UA code
		UA overall description
		UA effect
		Related UA/Recovery Code
		Recovered UA
		Recovery timing
	UA type	Reporting UA
		Instruction UA
		Manipulation UA
	UA Initiator	UA performer
		Related operator (causality)
	Plant/ system state	Failed system/ component
		Failed alarm/ indicator/display
		Failed switch/controller
	Time pressure	Time pressure
	Task familiarity	Task familiarity
	Task complexity (diagnosis)	UA occurred during the performance of a contingency action part
		The type of state identification
		Note or caution
		Change of procedure strategy
		Procedure conformity
	Task complexity (execution)	Number of detailed instructions
		Number of manipulations
		Component manipulation mode
		Continuous action step
	Procedure quality (clarity)	Confusing statement
		Multiple constraints
		Clarity of decision-making criteria
	Procedure quality (description)	Description of object
		Specification of means
	HMI & Information quality	Information clarity
		Feedback information
	Communication quality	Procedure compliance
		Precise instruction
		Controversial expression
		Standard terminology
		Communication level
		Reporting omission
	Recovery information	Recovery code
		Recovery description
		Recovery worker
		Time to recovery
		Recovery cue
		Recovery Initiator

Using the worksheets, the data items of the plant level worksheet and the data items in communication contents, action log, and procedure & task of the timeline worksheet were obtained, first. All kinds of deviations were then extracted by comparing communication contents, actions log, process parameter data and procedures. The UAs were determined among the deviations by considering rationales of human behaviors such as procedures, the expert judgment, the thermal-hydraulic analyses, success criteria used in the PSA, and the status of CSFs. The identified UAs were then investigated in detail and the task level worksheet was written for each UA.

Some instructions in AOPs were not explicitly represented; hence, to analyze the simulations of abnormal situation based on the worksheets, which were developed for proceduralized processes, the related AOPs were formalized to be analyzed. The instructions of AOPs were distinctly numbered and the recognition of significant alarms and search of proper procedures were supplemented to the early tasks of the instructions.

2.3 Taxonomy of UAs

The taxonomy of UAs was defined to quantify the frequency of UAs. Because the purpose of data collection is to support HRA, some HRA techniques such as THERP [6], ASEP [7], K-HRA [8], SPAR-H [9], HEART [10], HCR [11], Phoenix [12] and CBDT [13] and existing HRA databases such as operating experience data by GRS[4] and CORE-DATA [14] were reviewed. By considering the taxonomy of human error in these references, the taxonomy that is based on the structure of crew failure modes in the Phoenix method [12] and reflects generic task characteristics like THERP and ASEP method [6, 7]. Table II shows taxonomy of UAs.

Table II: Taxonomy of UAs

UA types	Task type
Failure of information gathering and reporting – checking discrete state (omission error, commission error)	Alarm
	Indicator
	Synthetically evaluation
Failure of information gathering and reporting – measuring parameter (omission error, commission error)	Reading simple value
	Comparison of parameter
	Evaluating trend
Failure of situation assessment and instruction (omission error, commission error)	Transferring procedure
	Operating control
	Communicating
Failure of diagnosis (omission error, commission error)	-
Failure of manipulation – omission error	Two-position control
	Rotary control
	A set of sequential operation
	Dynamic
Failure of manipulation – wrong device	Two-position control
	Rotary control
	A set of sequential operation
	Dynamic
Failure of manipulation – wrong direction	Two-position control
	Rotary control
	A set of sequential operation
	Dynamic
Failure of communicating to external agent (omission error, commission error)	-
Unauthorized control	-

3. Probability of UAs

Based on the taxonomy of UAs, the probabilities of UAs were estimated by the following equation [2].

$$P_{UA} = \frac{n_i}{m_i} = \frac{n_i}{n_i + 0_i}.$$

Here, n_i is the frequency of UAs observed in situations of UA type i, m_i is the number of the total possible situations of type i, and 0_i is the frequency of situations of type i where no UA is observed.

The examples of obtained probabilities are shown in Table III. The fourth column shows the probabilities presented in the human error probability in THERP database in similar situations or contexts in the given UA type. To easily compare the probabilities in this study with in THERP [6], total 0_i and n_i for task types in some UA types were calculated as well.

Table III: Examples of Obtained Probabilities

UA	0_i	n_i	P_{UA}	THERP
Failure of information gathering and reporting(commission) – (total: checking & measuring)	175	1	0.006	~0.004
Failure of information gathering and reporting(commission) – checking discrete state (total)	112	0	0	~0.003
Failure of information gathering and reporting(commission) – checking discrete state(alarm)	72	0	0	–
Failure of information gathering and reporting(commission) – checking discrete state(indicator)	40	0	0	–
Failure of information gathering and reporting(commission) – measuring parameter (total)	63	1	0.016	~0.005
Failure of information gathering and reporting(commission) – measuring parameter (comparison)	63	1	0.016	–
Failure of information gathering and reporting(omission) –(total: checking & measuring)	175	0	0	–
Failure of manipulation – wrong device (total)	26	0	0	~0.0005

4. Conclusion

Because the number of simulations was limited and data of various situations will be obtained continuously, it is uncertain to conclude the resulted probabilities. However, in this study, it was revealed that the designed worksheets were feasible to collect HRA data, especially in abnormal situations. The defined taxonomy of UAs was unambiguous to distinguish actions of operators and quantify the probabilities. Based on the worksheet, operator behaviors in many different kinds of scenarios will be analyzed and the relations between human reliabilities and the observed factors will be also investigated.

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