INTEGRATED HRA ANALYZING FRAMEWORK USING A GENERIC TASK DATABASE

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It is known that human errors of operating personnel working in a main control room are one of the important factors causing incidents or accidents in nuclear power plants. In order to decrease human errors, therefore, all information related to the human errors taken by operators in a power plant should be systematically gathered and analyzed. Korea Atomic Energy Research Institute (KAERI) is carrying out research to develop a data collection framework to build a Human Reliability Analysis (HRA) database that can be engaged as the technical bases to generate human error probabilities (HEPs) and performance shaping factors (PSFs). To calculate the HEP from human performance data that performed by simulated experiments, the number of human errors occurring on experiments and total number of tasks conducted are required. The estimation method to obtain the total task conduction number using direct counting is not easy to realize and maintain its data collection framework. To resolve this problem, an indirect method that enables an estimate of the total number of conduction based on instructions of the operating procedures of nuclear power plants were proposed. This paper describes an integrated HRA analyzing framework using a generic task database in order to effectively estimate the number of task conductions based on operating procedures. The number of task conduction based on the operating procedures for an HEP estimation was enabled through the generic task database and framework. To verify the applicability of the framework, a case study for the simulated experiments was performed and analyzed using graphic user interfaces developed in this study.

I. INTRODUCTION

It is recognized that one of the significant factors causing incidents or accidents is the human errors of operating personnel working in the main control room of nuclear power plants. In order to reduce human errors, therefore, all information on the human errors taken by operators in the power plant should be systematically collected and examined in its management. Korea Atomic Energy Research Institute (KAERI) is developing a data collection framework to establish a Human Reliability Analysis (HRA) database that could be a technical bases to generate human error probabilities (HEPs) and performance shaping factors (PSFs) [1][2]. The HRA database is a storage which maintains all human performance data collected from plant operating experiences or full-scope simulations. To calculate HEP from human performance data that performed by simulated experiments, the number of human errors occurred on experiments and total number of tasks conducted are required for HEP calculation. In general, the measuring total number of task conductions cannot be performed easily because the whole operation logs of each experiment should be analyzed by the HRA analyst while the number of conduction errors can be easily counted from the experimental reports that contains human induced error activities during on simulation. In order words, the estimation method to get the total task conduction number using direct counting is not easy to realize and maintain its data collection framework. To resolve this problem, this study suggests a generic database structure and integrated analyzing framework that enables to estimate the total number of conduction based on instructions of operating procedures of power plants. As a result of the study, the essential table schema was designed to the generic task database which stores generic tasks, a list of procedures and hierarchical structure of each detailed task, and other essential supporting tables.

II. GENERIC TASK DATABASE ON OPERATING PROCEDURES

The HRA database is a storage which maintains all human performance data gathered from plant operating experiences or full-scope simulations [3]. There are many approaches to estimate a HEP representing performance of operating personnel, the simple way is divide a total conduction number by the number of errors from various operating experiences. However, getting the total conduction number and the number of errors is not easy from the operating experiences. In general, the measuring total number of task conductions is difficult because the whole operation logs from operating experiences should be examined while the number of conduction errors can be easily counted from the operating error reports. Therefore, getting operator performance data from the plant simulator is more usual than getting from existing operating experiences. To calculate HEP from human performance data that performed by simulated experiments, the number of human errors occurred on simulated experiments and total number of tasks conducted are required for HEP calculation. Likewise, the measuring total number of task conductions performed on simulation has same difficulty because the whole operation logs of each experiment should be analyzed by the HRA analyst while the number of conduction errors can be easily counted from the experimental reports [4]. The estimation method to get the total task conduction number using direct counting is not easy to realize and maintain its data collection framework. To resolve this problem, we suggest an indirect method and a database structure that enables to estimate the total number of conduction based on instructions of operating procedures of nuclear power plants. In order to measure the total number of task conduction during emergency situations of simulated environment, we designed essential table schema to the generic task database which store standardized generic tasks that extracted from each instruction of operating procedures, procedure lists to include the links between each steps and global unique index to the generic task and a hierarchical structure of each generic tasks for visualizing to the user interfaces, and other supporting tables.

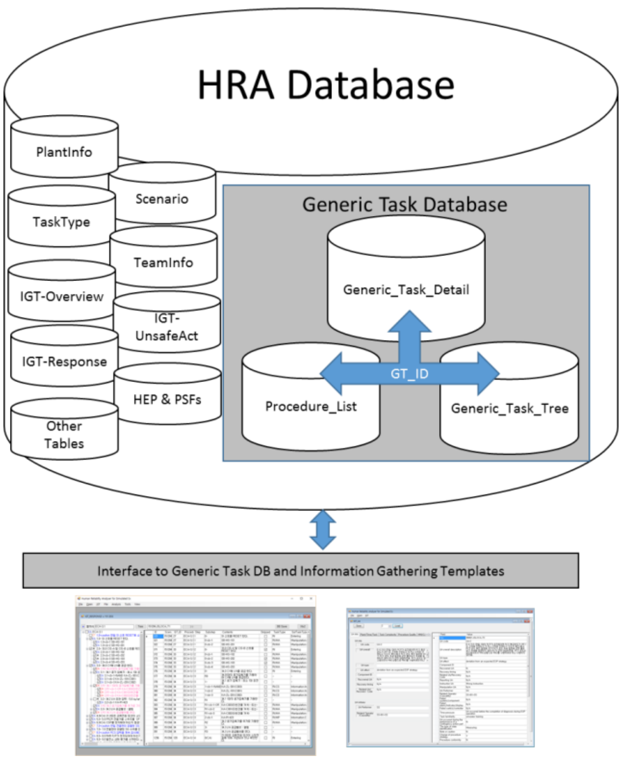

Figure 1. Generic Task DB Structure and Application

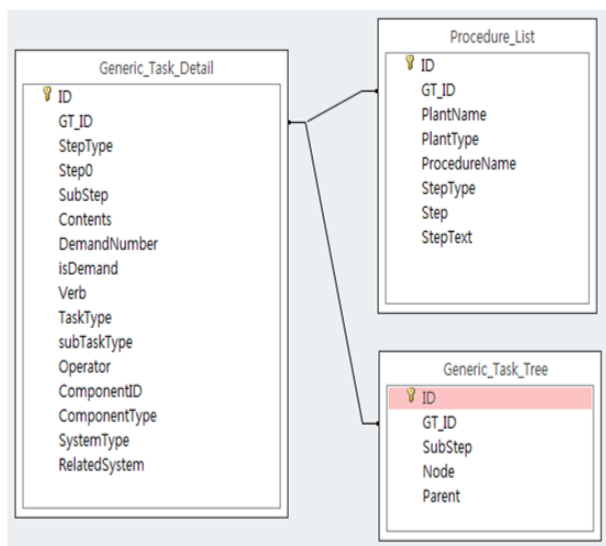

Figure 2. Entity-Relationship Diagram for Generic Task DB

Figure 1 and Figure 2 represent the structure of generic task data structure which is a quantification supporting part of HRA DB and ER (Entity-Relationship) diagram of the tables in the generic task database. The figure 1 shows the overall structure of the database and its application that linked to the external user interfaces for HRA analysis. Especially, the Fig.2 shows the ER diagram of essential tables of generic task database structure. As seen in the Fig.2, the 'Generic_Task_Details' table is connected to the 'Procedure_List' table and 'Generic_Task_Tree' table using the GT_ID (Generic Task Identifier) which is the unique identifier that has internal link to the detailed step task information exclusively.

To assume required task numbers for conducting emergency operations using a generic task database, whole instruction steps on emergency operating procedures (EOPs) were classified into detailed task goals and task instruction steps and inserted into the generic database through these all important tables and user interfaces. The following sections represent the detailed description of essential tables.

II.A. Design of Generic Task Detail

The 'Generic_Task_Detail' is a main table that contains standardized generic task information extracted from each instruction of operating procedures to estimate required total number of conductions performed by operators in emergency situations. The followings are essential fields and its properties of the table 'Generic_Task_Detail'. Table1 shows an example data entry of the table. As seen in Table1, each row has the task properties of the detailed instruction described in emergency operating procedures.

- GT_ID: Unique generic task identifier that has logical link to the detailed step task information
- Step: Task step number which has a same goal to be solved
- SubStep: Subtask step of specified step number. Each step (goal) can involve multiple sub steps
- Contents: This field represent an instruction content to be conducted by operating personnel
- DemandNumber: Required demand count to be performed by the operator
- TaskType: This field indicates cognitive activities of task type that include "Response planning and Instruction", "Information gathering and reporting - checking state", "Information gathering and reporting – measuring parameter", "Situation interpreting" and "Action".
- SubTaskType: Detailed subtask types of each task type.
- Operator: Related operator to the specified GT_ID and Step (SubStep)
- ComponentID: Related component or equipment identifier
- SystemType: Type of system
- RelatedSystem: Related system

GT_ID	Step	SubStep	Contents	Demand Number	TaskType	sub TaskType	Operator	ComponentID	Component Type	System Type
91	7	3-	Reset CV Spray Signal	-	-	-				
91	7	3-cb-1	SB-HS-104	1;1	RI;MA	ulation;Push	RO	SB-HS-104	Signal	ESFAS
91	7	3-cb-2	SB-HS-204	1;1	RI;MA	ulation;Push	RO	SB-HS-204	Signal	ESFAS
91	7	4-	Stop CSPump and Maintain Readystate	-	-	-				
91	7	4-cb-1	BK-HS-104	1;1	RI;MA	ulation;Push	RO	BK-HS-104	Pump	CSS
91	7	4-cb-2	BK-HS-204	1;1	RI;MA	ulation;Push	RO	BK-HS-204	Pump	CSS
91	7	5-	Close CV Spray Additive Tank Discharge Valv	-	-	-				
91	7	5-cb-1	BK-HS-108	1;1	RI;MA	ulation;Push	RO	BK-HS-108	Valve	CSS
91	7	5-cb-2	BK-HS-208	1;1	RI;MA	ulation;Push	RO	BK-HS-208	Valve	CSS
91	7	5-cb-3	BK-V-033 (Near Auxilary Building 100ft)	1;1	RI;MA	ulation;Push	RO		Valve	CSS
91	7	6-	Close CSP Discharge Valve	-	-	-				
91	7	6-cb-1	BK-HS-107	1;1	RI;MA	ulation;Push	RO	BK-HS-107	Valve	CSS
91	7	6-cb-2	BK-HS-207	1;1	RI;MA	ulation;Push	RO	BK-HS-207	Valve	CSS
92	8	0(CA)	Verify whether RHR P/P to be stopped	1	RI	Entering	SS			
92	8	1-	Check RCS Pressure	-	-	-				

Table 1. An Example of Generic_Task_Detail

II.B. Design of Procedure_List

The Procedure_List include the logical relations between each step of procedures and global unique index identifier (GT_ID) to the generic tasks. It enables an actual linking to the required generic_task_detail from the procedure list. As a connection table between Generic_Task_Detail and each task steps of emergency operating procedures, procedure_List has the properties of GT_ID, PlantName, PlantType, ProcedureName, StepType, Step and StepText. The followings are detailed field property of the Procedure_List and Table2 shows an example data entry of the table.

As shown in Table2, procedure 'E-1'of the 'Hanbit1 (Westinghouse reactor type)' plant unit has several task instruction steps to be conducted by operators during emergency situations. Each row of the table has a unit generic task identifier (GT_ID) to link to the detailed task instruction table ('Generic_Task_Detail'). For example, a step #7 of the procedure 'E-1' has a GT_ID 91 which is presented in table 1. Therefore, all instructions with a combination of GT_ID (97) and Step# (7) in table 1 should be conducted by responsible operator. In this situation, the required total number of task conduction can be calculated from the 'Demand Number', 'TaskType' and 'Subtasktype' field of the table 1, respectively.

- GT_ID: Unique generic task identifier that has logical link to the detailed step task information
- PlantName: Name of Plant
- PlantType: Plant type to be applied to data collection analysis. Usually, reactor type can be used as a designation of the plant type (e.g., WH, CANDU)
- ProcedureName: Name of the operating procedure to be applied to data analysis.
- Step: Step number of specified procedure
- StepType: Type of procedure step number. ‘N’ for normal state of procedure or ‘R’ for response not obtained state
- StepText: Step Label to be displayed on user interface

Table 2. An Example of Procedure_List

PlantName	PlantType	ProcedureName	StepType	Step	GT_ID
Hanbit1	WH	E-1	N	1	87
Hanbit1	WH	E-1	N	2	39
Hanbit1	WH	E-1	N	3	88
Hanbit1	WH	E-1	N	4	89
Hanbit1	WH	E-1	N	5	90
Hanbit1	WH	E-1	N	6	25
Hanbit1	WH	E-1	N	7	91
Hanbit1	WH	E-1	N	8	92
Hanbit1	WH	E-1	N	9	93
Hanbit1	WH	E-1	N	10	94

II.C. Design of Generic_Task_Tree

The Generic_Task_Tree has a logical hierarchy of step node of GT_ID. It includes GT_ID, substep, node and parent of each node. Figure 3 shows an example of the table data entry and a tree structure represented by a graphical user interface.

ID	GT_ID	SubStep	Node	Parent
1	1	0-	1_0-	<<TOP>>
2	1	0-cb-1	1_0-cb-1	1_0-
3	1	0-cb-2	1_0-cb-2	1_0-
4	1	0-cb-3	1_0-cb-3	1_0-
5	1	0-cb-4	1_0-cb-4	1_0-
6	1	R0-[1]	1R_R0-[1]	1_0-
7	1	R0-[1]-cb-1	1R_R0-[1]-cb-1	1R_R0-[1]
8	1	R0-[1]-cb-2	1R_R0-[1]-cb-2	1R_R0-[1]
9	1	R0-[2]	1R_R0-[2]	1_0-

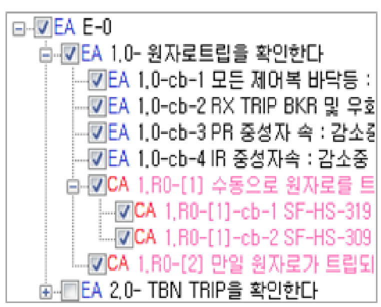

Figure 3. Generic_Task_Tree Hierarchy

III. HUMAN RELIABILITY ANALYSIS PROCESS ON SIMULATED ENVIRONMENT

Figure 4 represents the HRA process on simulated environment proposed on this study. The first step is a data collection from simulator experiments. The data collection should be carried out from results of simulator experiments for operators to conduct required tasks on the emergency situation. Audio-visual recordings, the trends of process parameters, operator's action log and other available sources can be gathered at the data collection. The second step is a crew response analysis. From available sources (e.g., Audio-visual recordings and operator's action logs), decide the operator's response to cope with emergency situations. Observed operator's response on required tasks can be made up through the flow of emergency operating procedures because they should perform required tasks described in the procedure. The third step is a screening human errors from unsafe act candidates. From the observed response, decide unsafe act candidates by choosing improper operator actions performed by operators. Unsafe acts (human induced errors) can be filtered from the candidates by expert judgements. Fourth step is a quantification process for human error probabilities. This step calculate human error probabilities dividing the total amount of tasks by the number of unsafe acts.

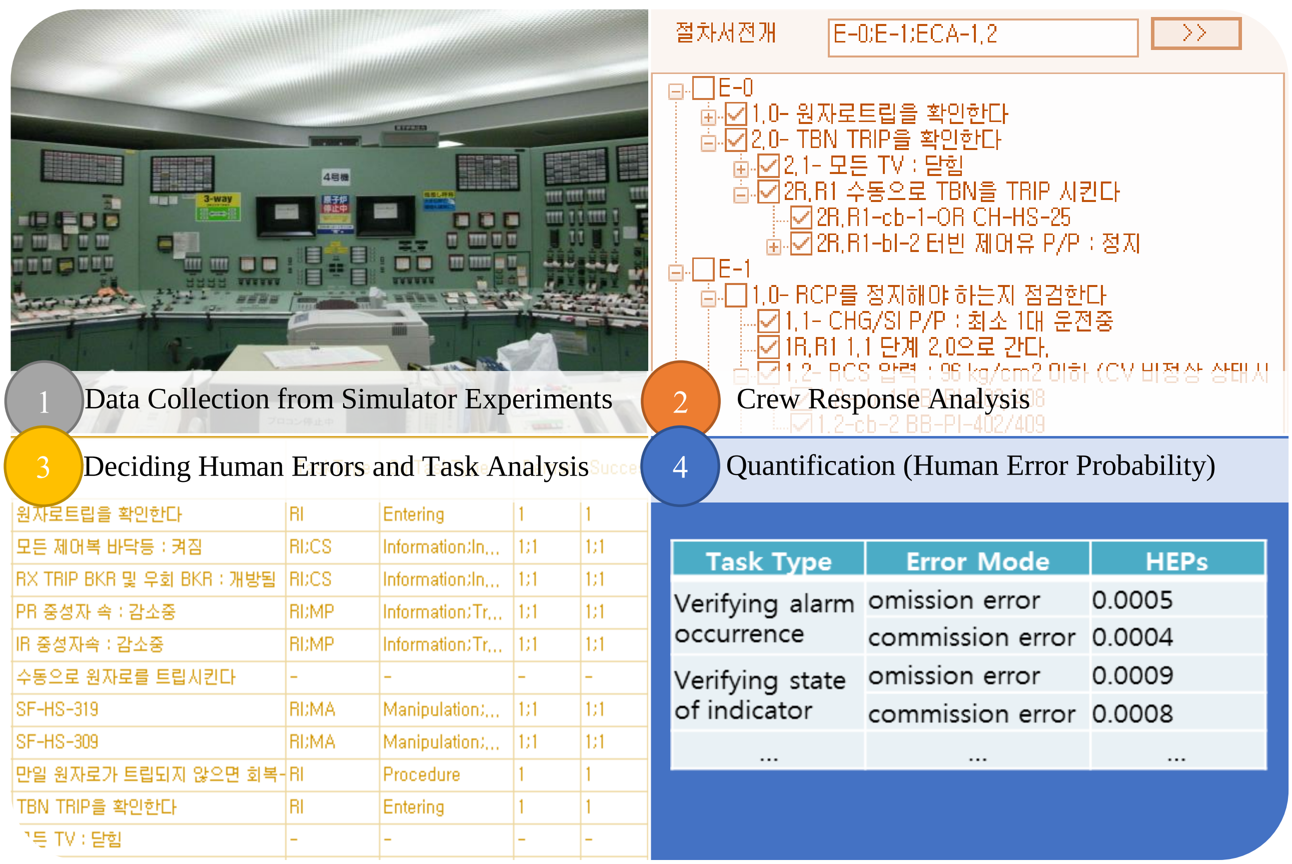

Figure 4. Human Reliability Analysis Process on Simulated Environment

To help the HRA analyst to effective counting for unsafe actions of operator's activity in an emergency situation, a graphical user interface based support system was developed. It extracts task properties from the generic task database and assists the HRA analyst to verify operator's actual tasks execution path during conduction of emergency operating procedure and to check the unsafe action from the lists of the executed tasks. Figure 5 shows an example of the user interface of the HRA analysis supporting system. Table 4 represents an example of HEPS estimated from simulation records for specific scenarios.

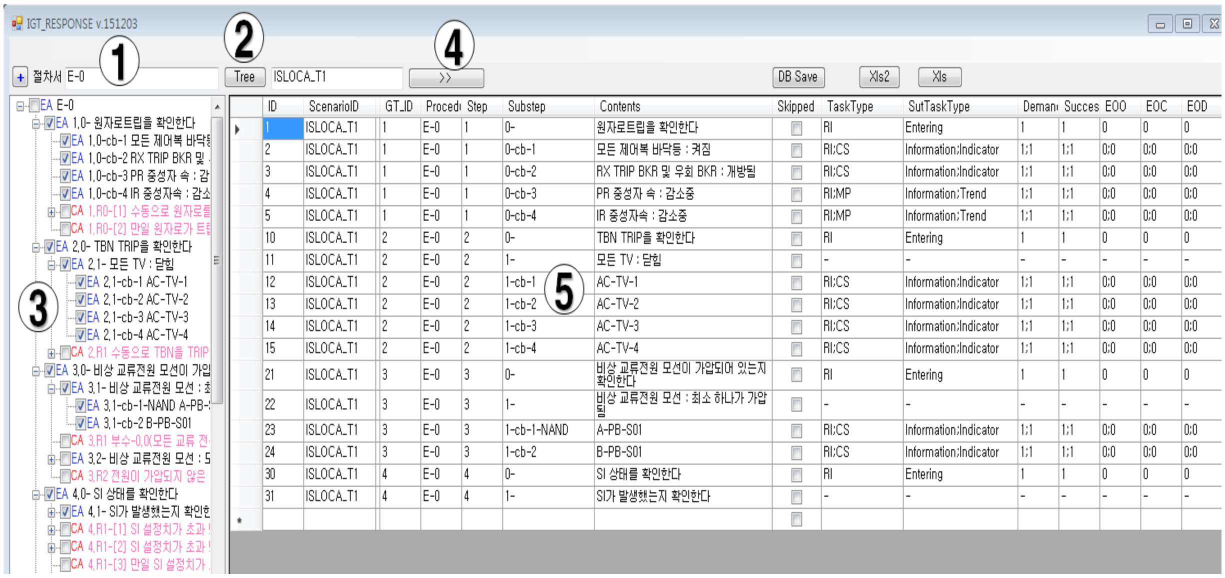

Figure 5. An example of Human Reliability Analysis using HRA analysis support system

Table 3. Example of HEPs

Task Type	Subtask Type	Opp.#	EOO#	EOC#	EOO_Pro.	EOC_Prob.
	Total	2433	2	0	8.220E-04	1.371E-04
	Verifying alarm occurrence	353	0	0	9.443E-04	9.443E-04
Information gathering and reporting – checking discrete state	Verifying state of indicator	1973	2	0	1.014E-03	1.691E-04
	Synthetically verifying information	107	0	0	3.115E-03	3.115E-03
	Total	1296	0	12	2.572E-04	9.259E-03
	Comparing for abnormality	372	0	0	8.961E-04	8.961E-04
	Comparing parameter	390	0	5	8.547E-04	1.282E-02
	Comparing in graph constraint	20	0	0	1.667E-02	1.667E-02
Information gathering and reporting – measuring parameter	Evaluating trend	392	0	6	8.503E-04	1.531E-02
	Reading simple value	122	0	1	2.732E-03	8.197E-03
	Total	13	0	6	2.564E-02	4.615E-01
	Diagnosing	13	0	6	2.564E-02	4.615E-01
	Identifying overall status	0	0	0	-	-
Situation interpreting	Predicting	0	0	0	-	-
	Total	4741	80	22	1.687E-02	4.720E-03
	Entering step in procedure	627	3	0	4.785E-03	-
	Directing information gathering	2813	8	4	2.844E-03	1.426E-03
	Directing manipulation	732	51	16	6.967E-02	2.349E-02
	Directing notification	316	9	1	2.848E-02	3.257E-03
Response planning and instruction	Transferring procedure	178	1	1	5.618E-03	5.650E-03
	Transferring step in procedure	75	8	0	1.067E-01	4.975E-03
	Total	737	12	2	1.628E-02	2.759E-03
	Manipulating dynamically	138	0	0	2.415E-03	2.415E-03
	Manipulating simple (discrete) control	574	12	2	2.091E-02	3.559E-03
Action - Manipulation	Manipulating simple (continuous) control	25	0	0	1.333E-02	1.333E-02
Action - notifying/requesting to MCR outside	-	305	3	1	9.836E-03	3.311E-03
Unauthorized control	-	0	0	11		

IV. CONCLUSIONS

This paper described the design of a generic task database to estimate the number of tasks conducted based on instructions of the operating procedures. Using an estimation method to obtain the total number of tasks conducted using direct counting is not easy for realizing and maintaining the data collection framework. To resolve this problem, this paper suggests an indirect method and a database structure that enables estimating the total number of tasks conducted based on instructions of the operating procedures of a nuclear power plant. As a result of this study, the essential table schema were designed for a generic task database that stores standardized generic tasks, procedure lists, task tree structures, and other supporting tables. To assume the required task numbers for conducting emergency operations, all instruction steps of the emergency operations were classified into detailed tasks and inserted into the generic database through these important tables and integrated HRA data analyzing user interfaces. The number of tasks conducted based on the operating procedures for an HEP estimation was enabled through the generic task database and framework. To verify the framework applicability, a case study for the simulated experiments was performed and analyzed using the graphic user interfaces developed in this study.

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