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A Framework to Measure Operator's Workload in Main Control Room of APR1400

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1. Introduction

In the MCR of an APR1400 (Advanced Power Reactor 1400) nuclear power plant, the high-tech MMIS (Man Machine Interface System) equipped with a computerized procedure system (CPS) and a high-tech alarm system is installed. Accordingly, though the work of operators has been changed a great deal, due to a lack of appropriate guidelines on the role allocation or communication method of operators, the problem of a lopsided workload for each operator has been raised [1][2]. Thus, it is necessary to enhance the operation capability by developing the guidelines on the role definition and communication of operators in the advanced MCR of NPPs. To resolve this problem, however, a method of measuring the workload according to work execution of operators is necessary, but the applicable method is not available at this time. The objective of this research is to develop an analytical framework to evaluate the workload according to the work execution of power plant operators.

2. Workload Evaluation

2.1 Framework for Evaluation of Workload

To determine the workload of operators in an advanced MCR, both the communicative behavior between operators and the operational behavior for the operation of MMIS-based control equipment should be considered in addition to measurements of the cognitive workload. Specifically, the workload of operators was judged after classifying it into the three factors of cognitive activity, communicative activity and operational activity. First, the cognitive task represents the cognitive activities of operators conducted for operation and situation handling of the power plants. For classification of the cognitive task, we used the task classification table proposed by Hollnagel [3]. The communicative task represents the communicative activities of operators conducted for the operation and situation handling of the plants, such as an information exchange between operators and instructions. The Extended Speech Act Coding Scheme was used for classification of the communicative task [4]. Finally, the operational task represents the behavior that operators take to conduct cognitive activities and was newly defined in this research depending on the necessity. Figure 1 shows the framework for 3 activity-based workload measurements used in this analysis.

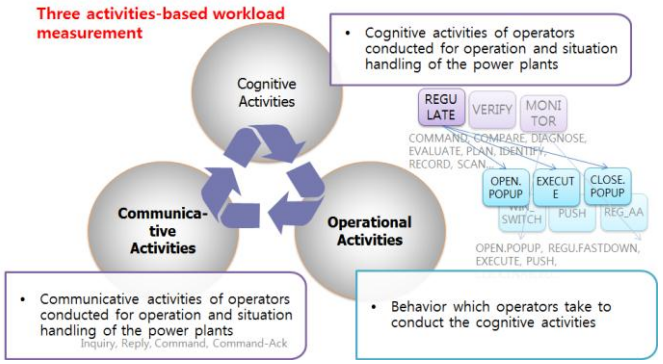

Figure 1. Workload Measurement Framework

2.2 Workload Evaluation Process

The data for an analysis of task load should be acquired to evaluate the workload. In general, the evaluation data are obtained by video-recording for the simulation experiments of operators. The acquired data are first classified into procedures and procedural numbers and the analysis is conducted. At the task analysis step for each procedural number, the kind of task is first selected from cognitive activities (diagnosis/decision-making), communicative activities, and operational activities. For each classified task, the relevant task behavior is judged and arranged, and the relevant tasks are then integrated to complete the workload evaluation. The workload evaluation results with the completed analysis show the execution results for the cognitive task, communicative task and operational task of each operator. When an adjustment is needed to balance the workload from the results analyzed in this way, the workload of each operator is adjusted and averaged to raise the task conduction efficiency and satisfaction of each operator. Figure 2 is a block diagram of the workload evaluation procedures of operators in an advanced MCR.

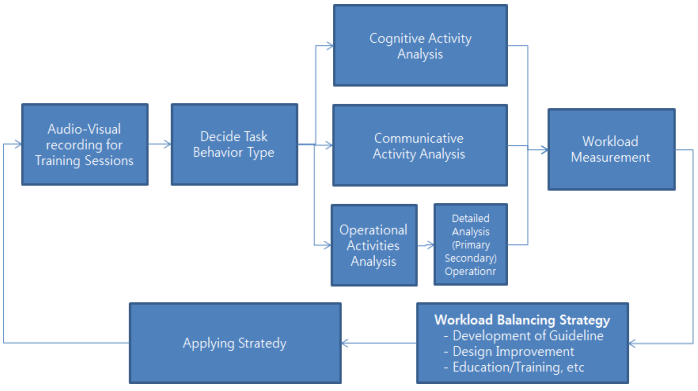

Figure 2. Workload Evaluation Process in Advanced MCR

2.3 Case of Workload Evaluation

If it is assumed that the emergency operation procedures (EOP) to be conducted by operators in the advanced MCR is the same as shown in Figure 3, the logic for execution of the workload evaluation may be composed of the following. First, after procedural steps 1 through 4 are completed, the case where the conditions of detailed step 4.1 is satisfied and the case where they are not satisfied may be investigated. When the conditions are satisfied, detailed step 4.1 is jumped to detailed step 4.3 to execute the procedures. If they are not satisfied, detailed step 4.2 is executed to control the pressure of the pressurizer and the procedure execution then moves over to the next step (detailed step 4.3)

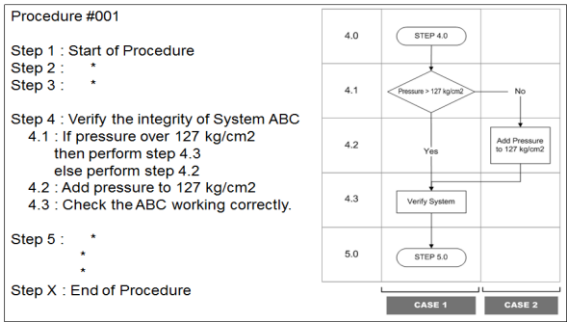

Figure 3. Emergency Operation Procedures (assumed)

If the pressure condition of the pressurizer for detailed step 4.1 is satisfied, the task activities conducted between Shift Supervisor (SS) and Reactor Operator (RO) consist of 7 steps as shown in Figure 4.

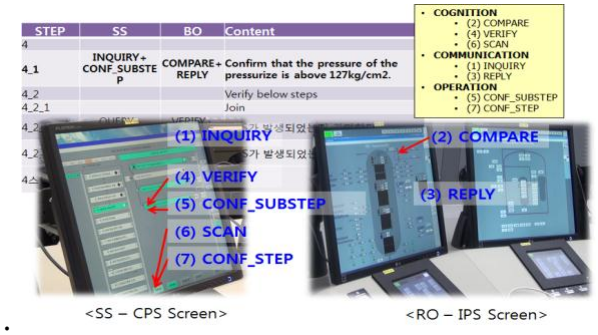

Figure 4. Case of Workload Analysis (Satisfied Conditions)

A detailed analysis for the execution of procedural step 4.1 between SS and RO, as shown in Figure 4, is given in Table 1. Step 4.1 starts with a question that SS asks RO about the pressure of the pressurizer (Task Id #1, INQUIRY), the RO compares the pressure values of the pressurizer from a relevant panel (Task Id #2, COMPARE), and when the condition is satisfied RO reports to SS that the pressure condition of the pressurizer is satisfied (Task Id #3, REPLY). At this time, SS confirms that the condition in the RO report is satisfied (Task Id #4, VERIFY), conducts the operation of computer login (Task Id #5, CONF_SUBSTEP), confirms whether step 4 of the entire procedures is satisfied (Task Id #6, SCAN), and then finishes the relevant step by conducting the operation to check that step 4 of the procedures is completed (Task Id #7, CONF_STEP). Table 1 shows the task analysis for the case where the conditions of detailed step 4.1 are satisfied. In this case, prior to the analysis, the task was classified into the kind and activity of the task for each relevant operator. As shown in the table, the results of the workload analysis for step 4 of the procedures indicate that step 4 consists of 3 cognitive tasks (two for SS, one for RO), 2 communicative tasks (one for SS, one for RO), and 2 operational tasks (two for SS).

Table 1. Case for Workload Analysis (Satisfied Conditions)

Task Id	Step	Type of Activity	Task Activity	Operator (SS)	Operator (RO)
1	4.1	Communication	INQUIRY	"Is the pressure of the pressurizer 127kg/cm2?"	
2	4.1	Cognition	COMPARE		Compare the pressure of the pressurizer.
3	4.1	Communication	REPLY		"The pressure of the pressurizer is above 127kg/cm2."
4	4.1	Cognition	VERIFY	Confirm that the pressure of the pressurize is above 127kg/cm2.	
5	4.1	Operation	CONF_SUBSTEP	Confirm steps and check satisfaction.	
6	4.3	Cognition	SCAN	Check if all the relevant steps are executed	
7	4	Operation	CONF_STEP	Check for move to the next step	
Number of Activities (Cognition: 3, Communication : 2, Operation : 2)					

3. Conclusions

A framework to measure the workload of crews in an advanced main control room has been suggested. In this research, we proposed a framework to measure and evaluate the workload of operators in an advanced MCR and the workload was measured through the simulator training experiment of the MCR of an APR1400. On the basis of these observations, it is necessary to reestablish the role and communication method of MCR operators suitable to the new operational environment and changed work and develops the appropriate operating guidelines.

ACKNOWLEDGEMENT

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