Operational Strategy of CBPs for load balancing of Operators in Advanced Main Control Room

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1. Introduction

With the using of a computer-based control room in an APR1400 (Advanced Pressurized Reactor-1400), the operators' behaviors in the main control room had changed. The major functions that the advanced MCR should have are said to be a computer-based procedure (CBP) system, advanced alarm system, group-view display, soft control, and a computerized operator support system/advanced communication system [1]. However, though the working environment of operators has been changed a great deal, digitalized interfaces can also change the cognitive tasks or activities of operators. First, a shift supervisor (SS) can confirm/check the conduction of the procedures and the execution of actions of board operators (BOs) while confirming directly the operation variables without relying on the BOs. Second, all operators added to their work the use of a new CBP and Soft Controls, increasing their procedural workload. Third, direct information acquisition changed the communication methods and contents between operators.

Kim indicated that the new features of digitalized control rooms may require new operational tasks and changes of communication methods, which have not yet been observed in conventional main control rooms [2]. For example, the control room of an APR1400, which is a computer-based control room, requires SS to follow a CBP by manipulating every instruction on screen and BOs to operate the control variables by using soft controls. Hence, new operational control strategies of CBPs are necessary for load balancing of operator's task load in APR1400.

In this paper, we compared the workloads of operators in an APR1400 who work with two different usages of the CBP. They are SS oriented usage and SS-BO collaborative usage.

2. Workload Evaluation

2.1 COCOA

The workloads of the operators were compared by the COCOA (cognitive, communicative, and operative activity) framework [3]. The COCOA framework, a task-loading approach of workload evaluation, calculates the operator's workloads based on a task analysis. Figure 1 shows the COCOA framework for three activities based workload measurement used in this analysis. The COCOA consists of cognitive, communicative and operational activities to measure three dimensional task load of operators conducted for the operation and situation handling of the power plants.

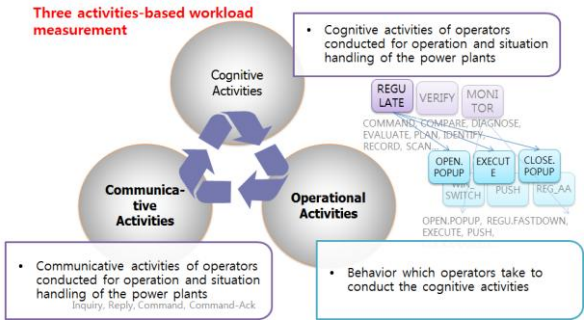

Figure 1. COCOA Workload Measurement Framework

2.2 Operational Strategies

In order to compare the efficiency of load balancing effect of operators, we suggested SS-BO collaborative mode based on SS oriented CBP usage. The first usage is a SS oriented mode, which is similar to the method used when operators in conventional plants usually follow an emergency operating procedure. The second usage is SS-BO collaborative mode that SS assigned the control authority of sub steps of each step into corresponding BO to conduct the CBP by checking and clicking each detailed sub steps. Only SS performs control authority assignments to BOs and simply reviews the behaviors of the BO during the sub steps.

Table 1. Comparison of two usages

Usage	Role of SS (CBP control)	Role of BO (CBP control)
SS Oriented	SS progresses all sentences of CBP.	BOs monitor CBP screens and follow the SS's instruction.
SS-BO Collaborative	SS assigns CBP to related BO to conduct sub steps. After the BO finish all instructions on the sub steps, the SS verifies the CBP.	After the SS's assignment, the BO performs the detailed instructions written in the given sub steps.

2.3 Experiments

In this study, the numbers of activities that operators conducted during the experiments were counted. First, which activities can be used was identified from the required procedures. Who conducted the activities were then analyzed by audio-video records. To calculate the

numbers of operational activities, all operative behaviors of crews were also tracked using the video records.

Experiments in a full-scope simulator were conducted under the following conditions.

- Independent variable: CBP usage
- Dependent variable: workload analyzed by COCOA method
- Participants: reserved operators of APR1400
  - ■ Three teams in experiments for SS oriented usage
  - ■ Five teams in experiments for BO-SS-collaborative usage
- Scenario:
  - ■ LOCA : SPTA + DP + LOCA
  - ■ SGTR : SPTA + DP + SGTR
    - SPTA: Standard Post Trip Action
    - DP: Diagnosis Procedure

The quantity of operators' activities for each CBP usage was compared with the activities of other usage.

3. Results

The activity frequencies of operators during both LOCA and SGTR are shown in figures 2 and 3. The annotated terms, SD (significantly different) and NSD (not significantly different), indicate that the quantities of two bars that the terms indicate are statistically different or not.

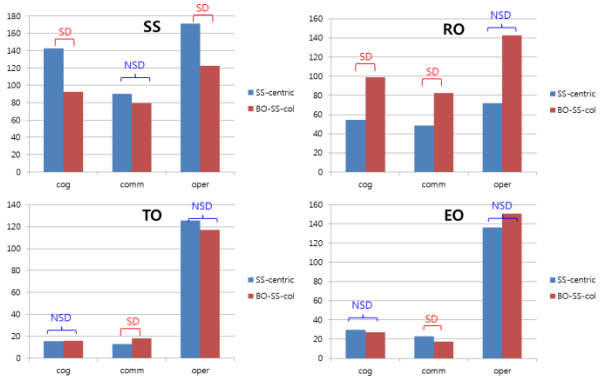

Figure 2. Difference between activity frequencies of CBP usages during LOCA scenario

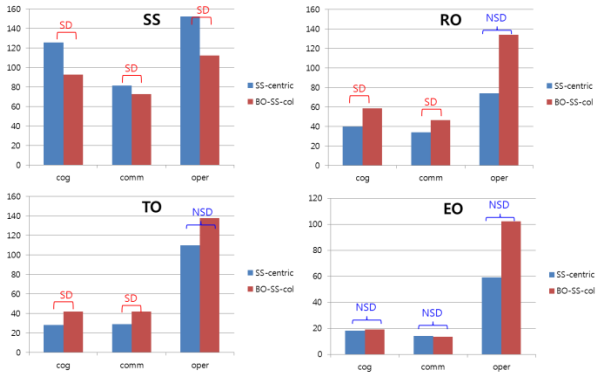

Figure 3. Difference between activity frequencies of CBP usages during SGTR scenario

The results of workload analysis indicate that the overall (cognitive, communicative and operational activities) tasks of the SS (Shift Supervisor) are far more than those of other operators in SS-oriented usage. That is caused by operating activities for controlling CBP as well as performing cognitive activities. Compared to SS-oriented usage, the task load of the SS was decreased in the SS-BO collaborative usage. By contrast, BO's activities tend to increase in the usage of SS-BO collaborative mode than the SS-Oriented mode. It is obvious that additional activities for conducting CBP were transferred from the SS to BOs.

4. Conclusions

In this research, we evaluated the workloads of operators in an advanced main control room by the COCOA method. Two types of CBP usages were defined and the effects of these usages on the workloads were investigated. The obtained results showed that the workloads between operators in a control room can be balanced according to the CBP usages by assigning control authority to the operators.

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REFERENCES

[1] O'Hara, J., Brown, W.S., Lewis, P.M., Persensky, J.J., Human-System Interface Design Review Guidelines, NUREG-0700 Rev.2, U.S.NRC, Washington. DC., 2002

[2] Kim, S., Kim, Y., Jung, W., Operator's Cognitive, Communicative and Operative Activities based Workload Measurement of Advanced Main Control Room, Annals of Nuclear Energy, Under Review, 2013.

[3] Kim, S., Kim, Y., Jung, W., A Framework to Measure Operator's Workload in Main Control Room of APR1400, In: KNS 2013 Spring Meeting , 2013.