Role Allocations and Communications of Operators during Emergency Operation in Advanced Main Control Rooms

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1. Introduction

The advanced main control room (MCR) in GEN Ⅲ+ nuclear power plants has been designed by adapting modern digital I&C techniques and an advanced man machine interface system (MMIS). Large Display Panels (LDPs) and computer based workstations are installed in the MCR. A Computerized Procedure System (CPS) and Computerized Operation Support System (COSS) with high degrees of automation are supplied to operators. Therefore, it is necessary to set up new operation concepts in advanced MCRs that are different from those applied in conventional MCRs regarding role allocations and communications of operators [1]. The following presents a discussion of the main differences between advanced MCRs and conventional MCRs from the viewpoint of role allocations and communications. Efficient models are then proposed on the basis of a task analysis on a series of emergency operation steps.

2. Methods and Results

2.1 Traditional Role Allocation in MCR during Emergency Operation

It is assumed that the operators in a MCR total 4 persons: one Shift Supervisor (SS), one Reactor Operator (RO), and one Turbine Operator (TO) with one independent Safety Technical Advisor (STA). In conventional MCRs, as the SS is generally located behind the positions of the RO and TO, and as such it is almost impossible for the SS to monitor and detect operation parameters and alarms independently. On the contrary, as the SS alone has access to the Emergency Operation Procedure (EOP) during emergency operation, the RO and TO can implement the necessary operation actions through only verbal instructions by the SS. The traditional role allocations in conventional MCRs during emergency operation are presented in the following table 1 [2].

Table 1: Traditional role allocations in conventional MCRs during emergency operation

Position	Main Role and Responsibility
SS	-Select EOP -Pick up plant status from RO/TO -Instruct operation actions to RO/TO
RO/TO	-Monitor plant status and report to SS -Implement actions by SS's order
STA	-Survey critical safety parameters
	-Request change of procedure if needed

2.2 Operational Benefits in accordance with Changes of Environment in Advanced MCRs

The operational benefits in accordance with changes of the MCR environment from conventional MCRs to advanced MCRs are as follows [3]: (1) The SS can ascertain the plant status and operation parameters directly from his or her workstations without the RO or TO's assistance. Hence, the SS can perform concurrent checking for the RO and TO's operation actions. (2) The RO and TO can read the same computerized procedure on their own workstations. AS such, they can implement the necessary operation actions quickly without waiting for the SS's verbal instructions. (3) Regarding implementation of important actions by the RO and TO, if the SS's approval has not been obtained, it is possible to restrict such actions by using the control logic in the computerized procedure system. Therefore, important and critical actions can be performed only when the SS permits them.

2.3 Emergency Operation Model in Advanced MCRs

In order to develop an efficient model for operators' role allocations and communications on the basis of the operational benefits in accordance with changes of the environment in advanced MCRs, a task analysis was performed for the Reactor Coolant Pump (RCP) protection operation in emergency operation scenarios. The content for the operation actions was as follows: "In case the pressure of the reactor coolant system (RCS) is below 121kg/cm2 and safety injection (SI) has been actuated, if the subcooling margin (⊿Tsat) of the RCS is below 15°C, stop all the RCPs immediately".

When the above RCP protection operation is performed in conventional MCRs, the operators' role allocations and communications can be summarized as given in table 2.

Table 2: RCP protection operations in conventional MCRs

		Task Analysis	Communi-cations
1	SS	-Order pressure check	RO/ Verbal
2	RO	-Report RCS pressure	SS/ Verbal
3	SS	-Order SI check	RO/ Verbal
4	RO	-Confirm & report SI	SS/ Verbal
5	SS	-Order ⊿Tsat check	RO/ Verbal
6	RO	-Report ⊿Tsat	SS/ Verbal

7	SS	-Order all RCPs stop	RO/ Verbal
8	RO	-Stop all RCPs	SS/ Verbal

When the above operation actions are performed in advanced MCRs equipped with CPS and Computer Based Communication (CBC) devices, the anticipated operators' role allocations and communications can be summarized as presented in table 3 below.

Table 3: RCP protection operations in advanced MCRs

		Task Analysis	Communications
1	RO	-Check pressure	SS/ CBC(manual)
2	RO	-Confirm SI	SS/ CBC(manual)
3	RO	-Check ⊿Tsat	SS/ CBC(manual)
4	RO	-Request approval of all RCPs stop	SS/ Verbal
5	SS	-Approve to stop	RO/CBC(manual)
6	RO	-Stop all RCPs	SS/ CBC(manual)

In the table above, the CBC (manual) is designated as a type of sending messages to target a person's CPS or monitor or LDP by manual action of another operator, e.g. a mouth click on a specific part of each operation step in his or her own CPS. On the contrary, the CBC (auto) can refer to the type of sending messages to target persons only by automation of the concerned system without the operators' intention or manual actions.

The strengths of the emergency operation model in advanced MCRs as proposed above are as follows: (1) The work load of the SS can be substantially lessened and double checking of the RO or TO operation actions can be performed more easily by the SS, who should control all situations of the MCR without restricting his or her attention to a limited area. (2) The speed of performing the EOP can be significantly increased, because the RO and TO can independently implement the operation steps assigned to them. (3) Important actions such as stopping all RCPs and changing the ongoing procedure can be performed only when approval is gained. Therefore, the operation actions in critical situations can be performed more surely and carefully. (4) It is possible for operators to communicate with each other more clearly and securely even in noisy MCRs due to alarms during emergency operation by using the computer based communication method as well as the verbal communication method.

2.4 Communication Method Model in Advanced MCRs

The communication methods in advanced MCRs can be divided into the verbal method and the computer based method. They should be selected properly according to the patterns of operations on the characteristics such as importance, urgency, and frequency [4]. The computer based communication methods can be divided into two categories, the automatic message sending type without any operators' intervention and the manual message sending type by operators' intentions and actions. The appropriate communication method model derived from a task analysis of emergency operation actions is summarized in table 4.

Table 4: Communication method model in advanced MCRs

Computer based method		Verbal method
Automatic	Manual	
-Caution -Warning -Very important steps -Mismatch (operator decision/ plant status) -Procedure enter/change/ terminate	-Performing of ordinary operation steps (execute/ re-execute/ terminate/ hold)	-Actions of special or important or exceptional operation steps - Procedure enter/change/ terminate etc.

3. Conclusions

Advanced MCRs have been designed to enable 1~2 fewer operators to work in them than in conventional MCRs, by adapting an advanced MMIS, including LDPs, workstations, CPS and COSS, etc. It is thus necessary to adapt to these environmental changes and to set up new operation concepts, especially concerning role allocation and communication methods for MCR crew members.

In this regard, emergency operation actions can feasibly be performed more efficiently in advanced MCRs than in conventional MCRs by adapting new allocations of operators' roles and the communication method model described above

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