Human-Centered Design & Concept of Operations (ConOps) for SMART MCR

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1. Introduction

SMART (System integrated Modular Advanced ReacTor) main control room (MCR) is designed considering human factors engineering principles. These principles are adopted and considered across all design stages.

This paper describes the main objective of the HFE program which is the Human-centered design as well as the concept of operation (ConOps) for SMART MCR.

2. Methods and Results

2.1 Human-centered design concept

The main objective of the HFE (Human Factors Engineering) program is to accomplish the 'human-centered' HFE design, which includes the following: (See Figure 1)

- Personnel tasks can be accomplished within time and performance criteria
- The HSIs, procedures, staffing/qualifications, training, and management and organizational arrangements support high personnel situation awareness
- The design support personnel in maintaining vigilance over plant operations and provide acceptable workload levels, i.e., minimize periods of under- and over-load
- The HSIs minimize personnel error and support error detection and recovery capability.

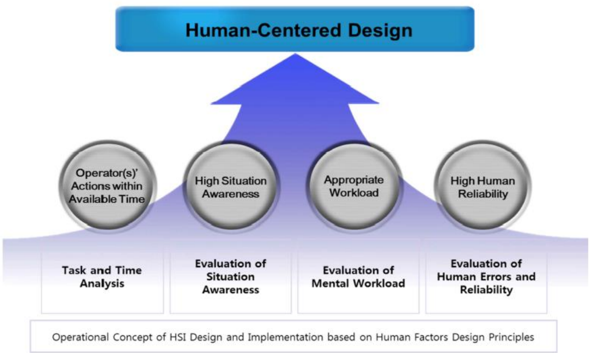

Figure 2: Human-centered design concept for the SMART MCR

For HFE to have the greatest impact, it should be fully integrated into the overall plant engineering process. This will help ensure timely and complete interaction with other engineering activities. Experience has shown that when HFE activities are performed independently from other engineering activities, their effectiveness is lessened.

To meet applicable current regulatory and industry requirements, MMIS includes the design features in consideration of the post-accident concerns from TMI and Fukushima accidents. Functions are allocated to human and system resources and are separated into tasks. The subsequent analysis of personnel tasks identifies the alarms, displays, controls and task support needs required for performing the task. Tasks are arranged into jobs and assigned to staff positions. Each position is evaluated to verify the workload is acceptable. The alarms, displays, controls and task support needs are design inputs for developing the human system interfaces (HSIs), procedures, and training program. The human factors verification and validation are performed considering broad-based span includes normal and emergency operations, maintenance, tests, inspections, and surveillance work.

2.2 Concept of Operations (ConOps)

The ConOps describes the way the system works from the operator's perspective and includes the user description and summarizes the needs, goals, and characteristics of the system's user community, which includes operation maintenance, and support personnel.

The HSI design process is sequentially implemented by concept design, basic design, and detailed design

At the conceptual design, the operational concept is established through operating experience review (OER), functional requirements analysis (FRA) and function allocation (FA), task analysis (TA), and staffing and qualification(S&Q). The operational concept includes the relation among operators and plant automation, the relation among operators, and the high-level description for operators' tasks using HSI.

At the basic design, related requirements are analyzed and selected, and the basic HSls are developed and tested or evaluated, then HSI design guidance (style guides) is developed for the detailed design.

At the detailed design, the detailed displays are developed based on the HSI design guidance and the basic HSI elements.

The result of this activity is the detailed design of the HSIs and procedures. The results are then used as input to verification and validation activities. They are also used in training program development to train personnel for the accomplishment of their tasks.

2.2.1 General ConOps for SMART MCR

SMART MMIS design has the ultimate design goal of maximizing the efficiency and safety by systematically reflecting the advanced digital technology and the latest ergonomic principles. The SMART MCR Operators obtain and share all operational information through the network, efficiently monitor the increased automatize and passive systems and operate the plant efficiently and safely with minimum control intervention.

In the SMART MCR, the operator's tasks are divided into primary tasks and secondary tasks. The primary tasks include monitoring plant parameters, performing procedures, responding to alarms, and controlling plant components. The secondary tasks include interface management tasks performed to assist in the primary tasks and all the activities to maintain the normal state of the plant.

The primary tasks of the SMART MCR operator are divided into monitoring and detection, situation awareness and assessment, response planning, and response implementation as shown in Figure 1.

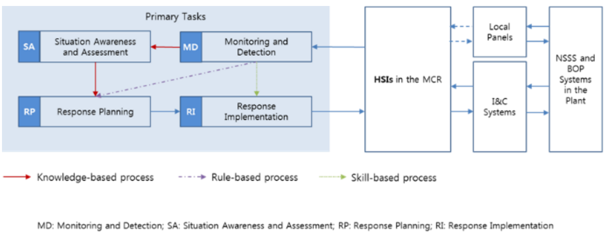

Figure 2. Primary tasks of the SMART MCR operator

As shown in Figure 2, the operator identifies the state of the plant through the monitoring and detection tasks, plans for future response, and conducts the planed actions based on knowledge. However, if there are already established rules such as procedures, the response plan will be set up and executed immediately without judgment based on rules. In addition, there are cases where immediate actions are executed directly after monitoring and detections based on skills.

Monitoring and detection

The monitoring and detection tasks include the act of extracting plant information. The monitoring task is an act of confirming whether the plant is in normal operation. The operator checks variables displayed on his/her workstation or control panel, monitors the variables displayed on the information displays, listens the voice information of other operators, and checks the operation status of the equipment or components by sending other operators to the site. The detection task is an act of perceiving any change in the state of the plant, for example, when a specific component cannot be operated normally.

The SMART MCR provides the operator with easily overlooked monitoring information by using an alarm and indication system and information processing system.

Situation Awareness and Assessment

The situation awareness task is an operator action that monitors and perceives the status of the current plant and anticipates the status of the plant after the present. The situation assessment task is based on the situation awareness to determine whether the present plant status is acceptable or abnormal to be. The situation assessment of the operator is related to the situational physics model of the plant and the mental model of the operator. The mental model of the operator depends on the knowledge of the operator and the current states of the plant.

The SMART MCR supports HSIs that can continuously and correctly update the current situation model to assess the operator's correct situation. In addition, the operators need formal education and training requirements and a certain level of operating experience to build the correct mental model.

Response planning

The response planning task is a process of determining the action process necessary to deal with the current problem situation, and the process of confirming the operation goal using the situation model. Operational goals vary, for example, by identifying appropriate procedures, checking the status of back-up systems, and diagnosing problems. To achieve the operational goals, the operator builds alternative response plans, evaluates the plans, and chooses the most appropriate alternative using his/her situation model.

The SMART MCR provides HSIs that are as simple and intuitive to select response plans as possible, and also it supports the operator's response planning tasks by providing all possible situation models in detailed procedures.

Response Implementation

The response implementation task includes the act of performing the plan established through the response plan, selecting the controller, inputting the control points, and monitoring the feedback of the system. The operators are more likely to commit human errors such as mode errors during execution. In particular, in the case of digital-based advanced control schemes, a new type of mode error may occur.

The SMART MCR provides interfaces that minimize the operator errors that can occur during the execution process, and they focus on preventing new types of human error by considering the characteristics of digital based interface.

2.2.2 Levels of ConOps for the SMART MCR

The ConOps for the SMART MCR deals with concepts of using all interfaces from system level to components and equipment level as shown in Figure 3.

Control room level

The ConOps of the control room level is related with remote shutdown room (RSR), technical support center (TSC), operating support center (OSC), and emergency operating facility (EOF).

Workstation level

The ConOps of the workstation level deals with all types of workstations and other auxiliary facilities such as communication devices, printers, meeting tables, etc.

Components and equipment level

The ConOps of the components and equipment level addresses how to use all components and equipment in the each workstation.

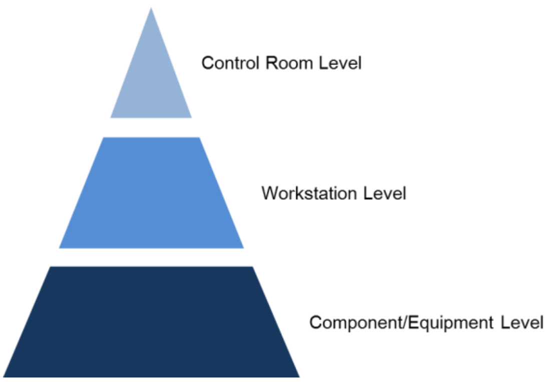

Figure 3. Levels of ConOps for the SMART MCR

2.2.3 ConOps for the SMART MCR

The SMART MCR is a computer-based advanced control room, which involves static operation using individual workstations as compared to conventional analog control rooms that can lead to communication problems between operators. Therefore, in the SMART MCR, the shape of the main monitoring and control workstation (MMCW) is triangular to improve communication among operators as shown in Figure 4.

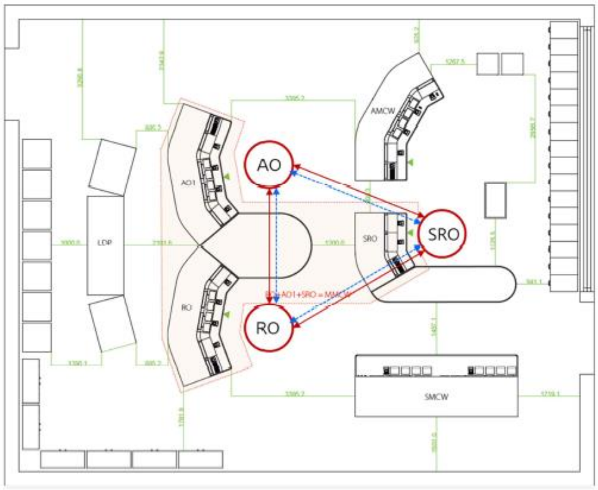

Figure 4. Triangular shape of the MMCW in the SMART MCR

The primary concept of operations of the SMART MCR to be reflected in the HSIs design is characterized by computer-based advanced control and it has the following conceptual features.

Centralization of Information

Centralization of information is a concept that intensively provides information through personal workstations so that the operator can obtain all the information necessary for plant operation without any spatial and temporal constraints and control actions. The SMART MCR provides safety-related monitoring information including post-accident monitoring information, plant status information, and interfaces for control actions by a single workstation. Therefore, the operator can obtain all necessary information from the operators monitoring and control workstation without spatial movement. Also the operator can recognize and diagnose the plant situation, share and communicate the plant status when necessary, control the plant, and confirm the feedback information of the controllers on each workstation.

Automation of information

The automation of information minimizes unnecessary attentions in the process of the operator's information processing and automatically processes the primary information to minimize the cognitive error caused by the complex cognitive process so that the operator could be provided the processing information.

Shared Information

The provision of shared information is a concept that provides the same information to the operators at the same time and provides information that can share the situation awareness among the operators. The SMART MCR provides comprehensive operating information on the operation status of equipment and systems that are important for safety and operation, on the LDP, so that the operator can grasp the operation situation and the plant status in a lump. The operators can quickly and synthetically share the whole plant operating situation, and each operator gets the details, if needed, from his or her workstation.

3. Conclusions

This paper has explained the Human-centered design and the concept of operation (ConOps) of SMART MCR.

In the SMART MCR, operators can search all plant process information through their own workstations. Also they share their perceived current situation information among them using the LDP as a group-view display then they identify certain systems information for cooperation between operators, determine whether they are satisfied with the operation procedures, and communicate for requests. The SRO also makes final decisions in coordination with the operators in instruction, report, awareness, diagnoses, and assessment of the plant condition.

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