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Human Error Analysis for Operation Executions in Advanced Main Control Rooms

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1. Introduction

As digital and computer technologies have been adapted in nuclear power plants (NPPs), there have been many changes in the design of main control rooms (MCRs) [1, 2]. In advanced MCRs, the operation environment has considerably changed compared with that of conventional MCRs. Operators in advanced MCRs can search for the necessary information by navigating computerized displays and control devices using the mouse or tough panels at their positions. While the predominant means for providing control input is via hard-wired, spatially dedicated devices that have fixed functions in conventional MCRs, the operator may interact with the plant via "soft" controls in advanced MCRs which are designed by computer-based technologies [2]. Due to these different interfaces, human errors should be refined in the human reliability analysis (HRA) for advanced MCRs.

2. Characteristics of Soft Controls

The actions for the plant operation are performed by soft controls in advanced MCRs. These are control devices having connections with control and display systems that are mediated by software rather than direct physical connections. Consequently, their functions may be variable and context dependent rather than statically defined. For example, a particular control action may produce different results based on the mode of the soft control. Also, devices may be located virtually rather than spatially dedicated. That is, personnel may be able to access a particular soft control from multiple places within a display system [3]. There are various kinds of input devices for the soft controls; tough screen, light pen, mouse, trackball, joystick, and so on.

NUREG/CR-6635 explains general characteristics and definitions of human errors which can be occurred in soft controls [3]:

- Multiple locations for access – A soft control for a particular variable can have many locations in an advanced MCR.
- Serial access - Advanced MCR components usually contain more displays and controls than can be viewed at one time via the display devices.
- Present and available- Soft controls may be designed to be continuously present, or to be retrieved from a display system when needed.
- Physical decoupling of input and display interfaces - With soft controls the location of control action may not be closely coupled with the presentation of feedback; the operator may take a control action in one place and read the setting elsewhere.
- Interface management control - In advanced MCRs, operators typically navigate displays and carry out retrieval actions to access them.
- Multiple modes - A soft control may perform a range of them each representing a different mode of a soft control device.
- Software-defined functions - Because operators' actions are interpreted by software, many operations may be initiated via a single action using a soft control.
- Interface flexibility - Computer-based technology can allow the user interface of soft controls to be adapted to changing needs or conditions of use.

3. Human Error Modes of Soft Controls

In this work, human errors which could be occurred during the operations using soft controls are analyzed. For simplicity, diagnosis process and other additional actions for operations such as searching reference information are not considered.

Several human error modes are the same as those of conventional MCRs. However, some human error modes should be considered more importantly and additional error modes may be needed because of special features of soft controls in advanced MCRs.

While the main reason of mistakes is not MCR design but misjudgments of operators, the design difference between conventional MCR and advanced one could be main reason to cause slips of operators. Therefore, the human error analysis in this work is focused on the slip.

Since soft controls are performed on the screens, the space for controllers is limited. That means, several soft controls share the same screen, so that confusions of operators could be caused. In conventional MCRs, device controllers are widely spread and located in different positions. However, in advanced MCRs, operators need to navigate the screen and to select the target device. These operation processes can cause wrong selection of screen or device. The intentions of operators may be related to primary tasks, such as providing control inputs to plant systems, or secondary tasks, such as manipulating the user interface to access information or controls or to change control modes. Interface management tasks are referred to as secondary tasks because they are concerned with controlling the interface rather than the plant.

Slips involving primary tasks may result in the execution of inappropriate control actions. Slips involving secondary tasks are likely to cause delays in accessing controls and displays, or to disorient the operator within the display system. While conventional MCRs do not have secondary tasks, the secondary tasks of soft control take relatively large portion. Therefore, not only slips for primary tasks but also that for secondary tasks should be analyzed in soft controls.

Generally, sequential tasks should be performed in advanced MCRs in order to perform an operation. The plant information of advanced MCRs is provided to operators by computer screens as hierarchical forms due to the spatial limits. Therefore, operators should perform secondary tasks to find appropriate screens or devices by screen navigations and selections before they perform the primary task to control a device. When operators are required to control a device using soft controls, they have to do three sequential actions in advanced MCRs. First, they have to navigate the screens in order to find the appropriate screen having the target device. Then, the device should be selected by a mouse click or other selection methods on the screen. And finally, they control the device in the control windows. This process can be different according to the interface of soft controls.

The operations using soft controls are performed such process, and possible human errors during the process could be classified into 6 types as follows:

- Operation omission: an operator has a potential to omit a necessary operation when he/she selects an operation to be performed in operating procedures. Also, after navigating screens and selecting a right control device, the operation could not be performed due to an inappropriate manipulation of soft controls.
- Wrong object: when an operator selects the target device, he/she could select a wrong device because of confusion between similar control devices. In this case, if the operator recognizes the wrong selection, then the operation could be recovered.
- Wrong operation: even though an operator performed appropriate navigations of screens and right selection of the target device, an operator can perform a wrong operation.
- Mode confusion: if a control window includes multi-mode, an operator performed a right operation on the wrong mode.
- Incomplete operation: when an operator executes an operation after appropriate navigations of screens and right selection of the target device, the operation could not be executed sufficiently.
- Delayed operation: due to the wrong selections of screens or devices and recovery of them, an operation could not be performed on right time. Additional time for reselection of screens or devices could be one of the reasons of such delayed operation.

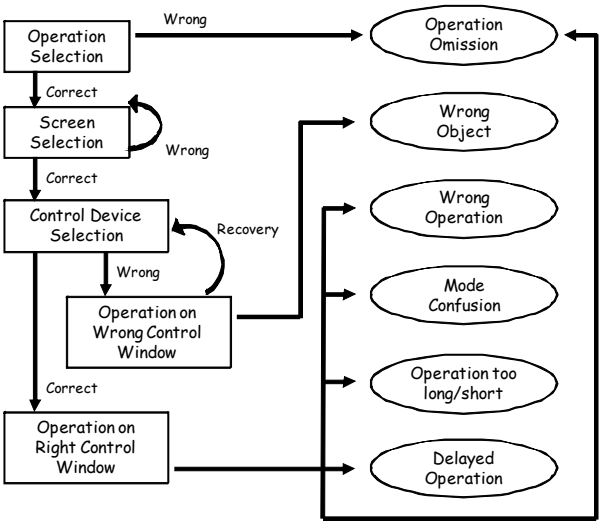

Fig. 1. Human Error Modes in Soft Controls

4. Conclusion

In this work, human errors which could occur during operation executions using soft control were analyzed. Soft controls of advanced MCRs have totally different features from conventional controls, so that they may have different human error modes. When operators are required to control a device using soft controls, they have to do four sequential actions in advanced MCRs: operation selection, screen selection, control device selection, and operation execution. This work classified the human errors in soft controls as six types. Since one of the features of computerized MCRs is interface flexibility, the analysis of human errors can be used for designing more reliable interfaces and for reducing human errors by appropriate training.

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