Design Experience for Realtime Simulator of SMART(System integrated Modular Advanced Reactor)

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1. Introduction

As part of its mid- to long-term plan for nuclear power, the Korea Atomic Energy Research Institute (KAERI) has developed an integrated code, MARS, which integrates and modernizes the optimal analysis code RELAP5 and the multidimensional core thermal-hydraulic analysis code COBRA-TF. Currently, the MARS-KS version is used as the regulatory verification code for KINS. Training simulators based on optimal analysis codes developed so far have been developed for specific commercial nuclear power plants and are highly dependent on imported technologies, making it difficult to apply them to SMART, which is scheduled to be built with domestically developed technology. Therefore, it is necessary to develop a simulator that can simulate the design and operating characteristics of an integral reactor such as SMART. In this paper, the design experience for the simulator platform development is described.

2. Building a simulator platform

A. Control Console Design Principles

Main control room control console serves as a workspace where a team of operator can safely operate and maintain SMART in all operating modes, including abnormal and emergency operations, except in the event of a fire evacuation. The HFE requirements applied to the design of this main control room space are as follows :

○ Accessibility to HSI equipment and facilities

The equipment layout in the control room workspace is arranged to minimize the operator's movement. In addition, the equipment placed on the control panel is arranged to minimize the operator's movements.

○ Application of the latest anthropometric data of Koreans

The latest Korean anthropometric data is applied to determine the key design variable values of the control panel shape, and visibility is taken into consideration.

○ Facility layout considering collaboration

the SMART control room, equipment including control panels is arranged to improve team performance by considering collaboration among operators.

All control consoles were designed to accommodate the body positions of Korean adult men (25 to 50 years old) and adult women (25 to 50 years old) that fall between the 5 %tile and 95%tile of the national standard body position data of the “6th Korean Human Dimension Direct Measurement Survey Report” by the Korea Agency for Technology and Standards. The equipment installed in each control console was designed to comply with the ergonomic design standards and the shape & configuration design of the Main Monitoring and Control Workstation(MMCW), the Safe shutdown Monitoring and Control Workstation (SMCW), and the Auxiliary Monitoring and Control Workstation (AMCW) was performed(see Fig. 1&2)

B. Simulator platform shape & configuration design

To build the simulator platform hardware, the Main Monitoring and Control Workstation(MMCW), the Safe shutdown Monitoring and Control Workstation (SMCW), and the Auxiliary Monitoring and Control Workstation (AMCW) and Large Display Panel were designed based on NUREG-0700, "Human-System Interface Design Review Guidelines. "

The SMART main control room includes the Main Monitoring and Control Workstation(MMCW), the Safe shutdown Monitoring and Control Workstation (SMCW), the Auxiliary Monitoring and Control Workstation (AMCW), and Large Display. The each control console in the main control room is used by the Reactor Operator (RO), Assistant Operator (AO), and Senior Reactor Operator (SRO) to monitor and operate SMART.

The equipment installed in the reactor operation area and turbine operation area of the main control panel are designed identically, so if one function is lost, continuous monitoring and operation can be performed using the equipment on the opposite side until the function is restored.

The operator can perform all abnormal and emergency operations using the SMCW panel. Therefore, the SMCW panel can be used as a substitute even when the main control panel's functions are completely lost. When the reactor operator's duties suddenly increase, such as reactor startup and shutdown operations, abnormal and emergency operation modes, an assistant operator with a reactor operator's license is assigned to the safety shutdown control panel to assist the reactor operator.

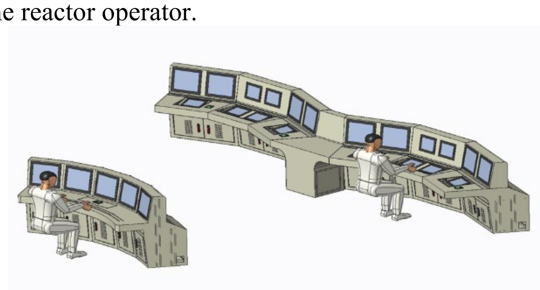

Fig. 1. Main Monitoring and Control workstation(MMCW) Console Layout

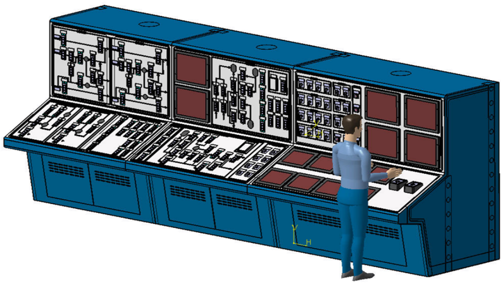

Fig. 2. Safety Shutdown Monitoring & Control Workstation (SMCW) Console Layout

C. Simulator platform hardware design

The MMCW for the Reactor Operator (RO) contains the following devices :

○Information processing system(IPS) display and input device
○Alarm and indication system(AIS) display
○Safety grade soft controller
○Non-safety grade soft controller

The Supervisory Reactor Operator (SRO) console includes the following devices :

○IPS display and input device
○AIS display
○Severe accident Display

The SMCW includes the following devices :

○operator module for Reactor protection system / core protection system
○Safety grade soft controller
○Post-accident monitoring and inadequate core cooling monitoring system display
○IPS display and input device
○AIS display
○Reactor trip manual switches
○System level manual ESF actuation Switches
○Diverse reactor trip manual switch
○System level diverse manual ESF actuation switches
○ Minimum inventory switches

D. Instructor Workgroup Software Design

The Instructor Station software must be able to control the overall execution status of the simulation using the responses of each simulator engine for SMART simulation. Each simulation engine must accept simulation operation-related commands according to the Instructor Station operation mode (Run, Freeze). When the operation mode is Run, each simulation engine must accept the operation mode freeze (Freeze) and Malfunction deletion commands as input. When the Instructor Station operation mode is Freeze, each simulation engine must accept the operation mode execution commands: initial condition selection command, initial condition creation command, initial condition deletion command, execution speed selection command, arbitrary return (Backtrack) execution request command, arbitrary return cycle setting command, malfunction operation command, and termination command.

3. Conclusion

This study demonstrates the successful development of the SMART simulator platform, highlighting the critical integration of human engineering principles and cutting-edge technology. The primary components of the simulator, including the control consoles and hardware, have been designed to ensure safe and efficient operation. The Instructor Station software provides versatile control capabilities across various simulation modes, effectively supporting operator training and enhancing operational proficiency.

Each simulation engine responds dynamically to the commands from the Instructor Station, accurately reflecting system states in real-time. In Run mode, the engines handle real-time operational commands, while in Freeze mode, they facilitate setting initial conditions and reverting to specific states. This capability significantly enhances operators' ability to respond to various scenarios.

The insights and methodologies from this simulation platform development will serve as a valuable reference for the future design and operation of advanced nuclear systems like SMART.

Acknowledgements

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References

[1] ANSI/ANS-3.5, Nuclear power plants simulator for use in operating training and examination, 1998

[2] USNRC Regulatory Guide 1.149, Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, 2001

[3] USNRC NUREG-0700, Human-System Interface Design Review Guidelines, 2002