Study on the Design of Structure and Automation of iCPS for i-SMR

Chanho Sung*, Kyungmin Kim, Jungho Kim
KHNP Central Research Institute, 70 1312-gill, Yuseung-daero, Yuseung-gu, Daejeon, Korea
**Corresponding author: chsung95@khnp.co.kr*

Keywords: i-SMR, iCPS, Structure, Automation

1. Introduction

Currently, the standard design of i-SMR (innovative Small Modular Reactor) is in progress from 2024. iCPS which is the computerized procedure system for i-SMR, is also in its design and developing status.

Computer-based procedures have been applied to nuclear power plants from the 2000s worldwide. KHNP developed the CPS (Computerized Procedure System) in the early 2000s and has been applying it to APR1400 type nuclear power plants such as SUN1&2, SHN1&2, and SUN3&4 since 2016.

iCPS needs to be strengthen for operating automation because i-SMR has 4 reactor modules and 3~4 operators in 1 integrated control room [1]. That is, the i-SMR can be said to have a higher workload and complexity in the integrated control room compared to the APR1400 nuclear power plant's MCR which has 1 reactor and 5 operators in 1 control room. Therefore, the existing CPS needs design change for being applied to i-SMR.

This paper describes the structure and the characteristics of automation function design of iCPS.

2. iCPS Structure

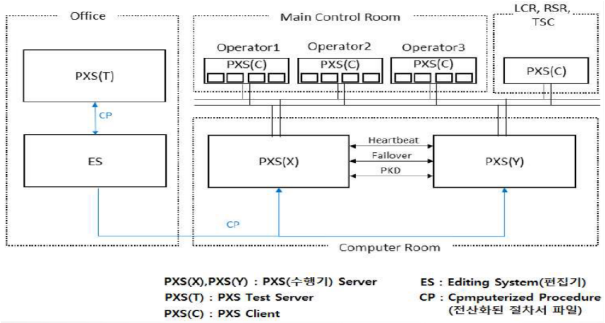

Fig. 1. iCPS Structure

iCPS will be built on LCR (Local Control Room), RSR (Remote Shutdown Room), and TSC (Technical Support Center) of i-SMR and will consist of server redundancy and network redundancy. The preparation of procedures, including detailed procedures, is done through the procedure editor, and the prepared procedural electronic files are installed and operated on the iCPS server.

iCPS consists of the Procedure eXecution System (PXS) and the procedure Editing System (ES). PXS server is dualized and is responsible for managing the procedures of the 4 reactor modules and linking them to the i-SMR information system. PXS client provides a user interface that enables the actual execution of the procedure by providing the operators with procedure execution screens.

CP (Computerized Procedure) is an electronical file used in iCPS, and CP created through ES is mounted on the PXS server. The redundant PXS servers (X, Y) share all the information in real time, and when one server fails, it is automatically turned over to the other server.

PXS(T) is a server that can test the operation of procedures before installing CP in the actual power plant. Figure 1 represents the overall structure of iCPS, including the configuration of the server and the client.

The procedural structure used in iCPS has a four-step hierarchical structure as shown in Figure 2. That is procedure, gross step, step, and instruction. This structure is the same as the CPS of APR1400. However, this structure may change according to changes in the detailed design, automation level design, and procedure operation method of i-SMR in the future.

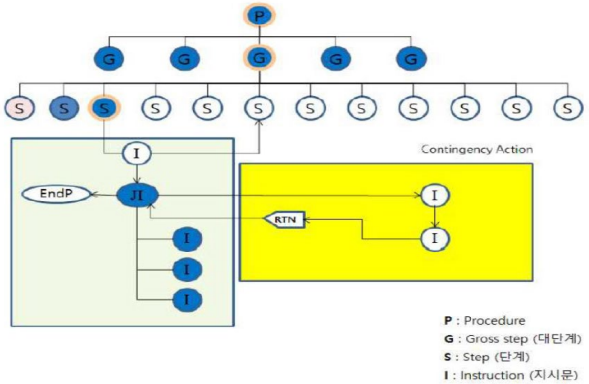

Fig. 2. 4-step Hierarchical Structure of Procedures for i-CPS

3. iCPS Automation

Since i-SMR operates 4 reactor modules with a small number of operators in a single integrated control room,

it is essential to strengthen operation automation to reduce operator's workload and improve operability. In order to strengthen such operation automation, the design of automating the execution of procedures is in progress.

3.1 iCPS Automation Performance Range

iCPS is designed to support manual and automatic operation in relation to the execution of the procedure. The operator can perform one of the two modes, and can change the operating mode as necessary even if the procedure is being operated.

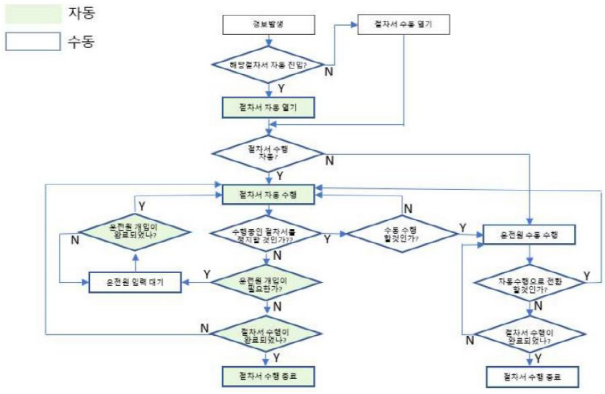

Fig. 3. iCPS Procedural Performance Strategy considering Automation [2]

Figure 3 shows the strategy for procedural performance in iCPS, reflecting manual/automatic operation and operator intervention. The automatic operating ranges of the procedures considered in iCPS is as follows.

- Instruction Level Automatic Execution / Step Level Automatic Execution

In the automatic execution of the instruction level, the instructions are automatically performed at the current step, but the progress to the next step is not automatically performed. The progress to the next step is carried out manually by the operator's decision.

In the automatic execution of the step level, the progress to the next step is automatically performed when all instructions are performed at the current step. That is, Step level automation enables instruction level automation and move to the next step automatically. After all steps are finished in the current procedure, the operator decides completion of the procedure manually.

- Equipment automatic operation and stop

For simple control functions, such as operation and stopping of plant equipment required during the procedure, iCPS enable to control the equipment by automatically transmitting an operation or stop signal to i-SMR information system.

In addition to the automations mentioned above, automatic entrance of EOP (Emergency Operation Procedure) and ARP (Alarm Response Procedure) is also considered.

3.2 Real-Time Display of the Automation Progress

Depending on the design requirements and HFE requirements, the procedure information in progress of the automation should be provided in real time so that the operator can recognize it. iCPS provides the status information of automation performance in 3 sections in real time. The 3 sections are the over view pane, the step detail pane and the step control pane. In the over view pane, special symbol marker and symbol blinking is displayed for steps that are in the progress of performing automation. In the step detail pane, instructions undergoing automation show the same symbol and blinking as in the over view pane. In the step control pane, the button for starting automation shows that automatic execution is in progress through color cording and blinking.

4. Conclusions

The standard design and the development of iCPS are in progress at the same time to comply with the entire i-SMR design project plan. This paper represents the structure and automation design of iCPS. Strengthening automation of iCPS is essential to reduce operator's workload and improve operability for i-SMR. Once iCPS is developed, the usability test will be carried out by mounting it to i-SMR simulator.

REFERENCES

[1] KHNP, Plant Design Description for i-SMR, 2023
[2] KHNP, Interim Report, Development of Simulator and CPS for i-SMR, 2024