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Development of APR1400 Simulator for Domestic MMIS Digital Twin

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1. Introduction

KHNP CRI is developing a domestic MMIS digital twin that can be used for multiple purposes during the construction-commissioning-operation life cycle of the APR1400 type power plant with the goal of achieving the world's highest utilization rate [1].

The domestic MMIS digital twin uses virtualization technology to implement the actual MMIS of Shin-Hanul #1, 2 and Shin-Kori#5, 6 as virtual MMIS. And the software and firmware used in the actual MMIS are developed so that they are loaded and run in the virtual MMIS as they are without change [2].

The power plant field device model (simulator) to be linked with the virtualized MMIS utilizes the previously developed operator Full-scope simulator (FSS). The FSS is a simulator that simulates the entire range of a power plant for the purpose of operator training and was developed as 3KM. It is being developed by removing the MMIS part (control logic, IPS, etc.) implemented in FSS and changing it to a desktop form so that devices such as transmitters and valves are linked to virtualized MMIS.

The virtualized MMIS and the FSS are connected by Ethernet and periodically communicate with the virtualized MMIS to send and receive transmitter signals and control signals. In order to link the virtual MMIS and FSS signals, it creates a Master Node (MN) in the virtualized MMIS and communicates with the FSS, manages the transmit/receive signals and delivers the signals to each virtualized MMIS. Therefore, the 3KM control logic (drawing) was changed to link the APR1400 FSS for Shin-Hanul #1, 2 and Shin-Kori #5, 6 with the domestic MMIS digital twin, and the APR1400 desktop simulator with the MN linkage function of the digital twin and additional functions is being developed.

2. Change the APR1400 FSS

The virtualization scope of the domestic MMIS includes most of the safety systems, non-safety systems and information processing systems as shown in Figure 1, but turbine control and some third-party systems are excluded. Therefore, when converting the APR1400 FSS, in the case of a control logic not implemented in the virtualized MMIS, the control logic implemented in the FSS is used as it is.

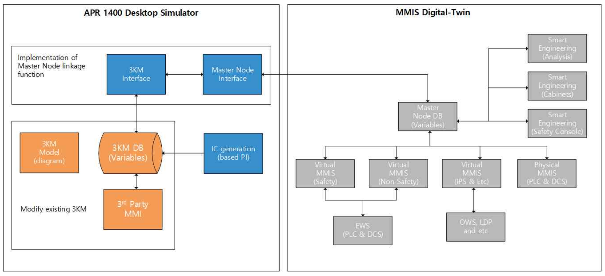

Fig. 1. ARP1400 FSS based function implementation block

After identifying the safety/non-safety system control logic drawings implemented in APR1400 FSS, the identified 3KM control logic drawings are compared with the power plant design drawings and MMIS production drawings, and the input/output variable list and variable input/output direction used in each drawing are derived do. The variable relation derived above is implemented in DB form.

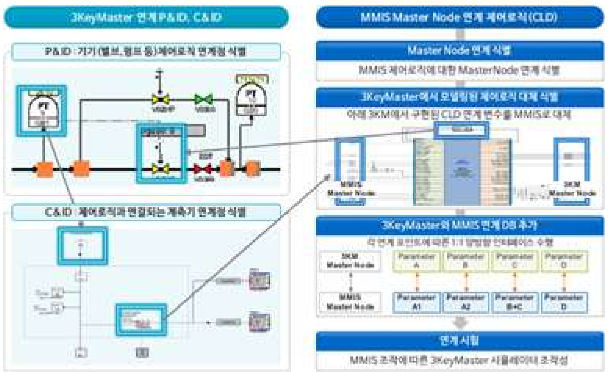

Fig. 2. Modify of 3KM Logic

As shown in Figure 2, in APR1400 FSS, the control logic part is removed and the transmitter and device control signals are modified to interlock with the MN.

In addition, the drawing (model) that receives and processes information from physical components such as Safety Console, MTP/ITP, ESCM, and OWS of APR1400 FSS is identified.

3. Linkage function with Master Node

APR1400 Desktop Simulator for domestic MMIS digital twin is connected to MN of virtualized MMIS by Ethernet as shown in Figure 1. For this, MN Interface is developed as a new function in FSS. In addition, 3KM Interface, which is linked to 3KM, a simulation solution used in Shin-Hanul #1, 2 and Shin-Kori #5,6 FSS, will also be developed as a new function.

3.1 Communication Method

For connection with the MN, it will be decided by considering the advantages and disadvantages of the shared memory method and the communication method using sockets.

1) Shared memory method

The shared memory method is a method of reading, writing, and exchanging information in the shared area by setting the shared memory in the MN and the FSS. This is a method in which a process that shares a portion of memory with multiple processes requests the kernel to allocate/remove shared memory to allocate/remove memory space to the process and avoid overhead such as copying to shared memory using pointers.

2) Socket method

It is implemented by socket communication between the server and the client system, extracts the information to be transmitted from the MN from 3KM, sends and receives data in a data structure format, and then sends the information received from the MN to 3KM. The server sends the value of the data structure to the client, and the client modifies the value that needs to be updated and sends the value of the data structure to the server.

3.2 Link DB

It is identified using the information of the Field Terminal List (FTL) and composed as shown in the table below.

○ 3KM/MN Interface

- Construct shared memory reflecting the relational DB of input/output variables
- Connect 3KM/MN variable to shared memory
- The value sent from the MN/3KM is reflected in the shared memory
- Reads the variable value with the 3KM/MN -> MN/3KM direction from the shared memory and sends it to the MN3KM Interface periodically

4. Create a PI-based IC

It is compare the current power plant status with the IC list registered in 3KM of FSS to check whether there is the closest IC. At this time, the range of the detailed state variable of the power plant to be compared with the proximity condition is defined. If there is no closest IC, the next priority is selected and 3KM is driven, and the control variable is adjusted and the 3KM state is stabilized so that the detailed state variables are close.

By accessing the PI server operated by the power plant, information on points registered in the server can be extracted, and the current value of the point, the event occurrence time, the value of a specific time, etc. can be inquired.

Fig. 3. Linkage with PI Server

It retrieves the point information using the FSS-PI mapping information, checks whether it is a registered point, and retrieves the corresponding tag information. In addition, it is possible to find an IC that is close to the current value of the power plant, and if you want to find an IC that is close to the point in time of a specific condition, the PI system gets a list of event times where the value of the point occurred and compares it with the APR1400 FSS value.

The effective range (5%) is set through the FSS process variable and the value obtained from the PI system, and the corresponding comparison is displayed on the screen so that the user can check whether they match.

5. Conclusions

In this paper, we describe a method of modifying the existing APR1400 FSS so that the virtualized MMIS and the existing APR1400 FSS are linked to simulate the entire power plant.

By using the simulator using the virtual controller, it is expected that various problems that have not been verified in the existing simulator can be verified. In addition, the use of the MMIS digital twin simulator is expected to be of great help in the construction period and operation of new nuclear power plants.

REFERENCES

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