Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 9-10, 2024

Study on Performance Test of Master Node in MMIS Digital Twin

Min-seok Kim [a*], Hosun Ryu [a]
[a]*KHNP, Central Research Institute, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, 34101, South Korea*
[*]*Corresponding author: minseok2@khnp.co.kr*

***Keywords :** MMIS, Digital Twin, Master Node, Network, Virtual Network, Virtual I/O

1. Introduction

Korea Hydro & Nuclear Power(KHNP) is developing a digital twin of Korean APR1400 MMIS using virtualization technology. [1]

The Korean MMIS digital twin research project's goal is to build all systems of a real power plant with the same functions and equivalent performance in a virtual environment. Therefore, the MMIS structure and software of the real power plant are implemented as they are. However, the I/O connection of the controller, which is routed by physical connection, needed an alternative to be implemented in a virtual environment, and this project developed an I/O Master Node as a method for I/O connection. The I/O Master Node is in charge of all I/O data connections and is responsible for transmitting and receiving I/O values between Virtual PLC (vPLC), Virtual DCS (vDCS), Full Scope Simulator (FSS), and Smart Engineering (SE). In addition, since the HR-SDN/HR-SDL communication used in the safety system is not an Ethernet method supported in a virtual environment, the SN (Safety Network) Master Node converts the communication and is responsible for transmission and reception. [2] The relationship between the Master Node and each component can be expressed as Figure 1.

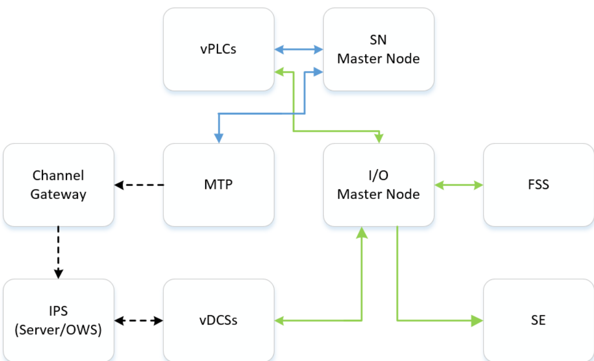

Fig. 1. Configuration diagram of Master Node and each controller.

In this paper, we will describe the results of performance measurements and testing to determine whether the Master Node can effectively coordinate hundreds of virtual controllers in advance of constructing the MMIS digital twin.

2. Methods and Results

This section describes how to test the performance of a Master Node. We describe the validation method and test results for SN Master Node and I/O Master Node. Furthermore, it sets up the RCOPS(Reactor COre Protection System) system configuration and confirms the successful transmission and reception of SN Master Node and I/O Master Node.

2.1 SN Master Node

In the SN Master Node performance test, the quantity of vPLC was calculated to be approximately twice the quantity of PLC in the real power plant. 31 vPLCs, which is the maximum number that can be configured in an SDN network, were configured into one set, and 10 such sets were configured. Each vPLC was configured with 2 SDL Tx, 5 SDL Rx, and 2 SDN ports. An illustration of the vPLC configuration is shown in Figure 2.

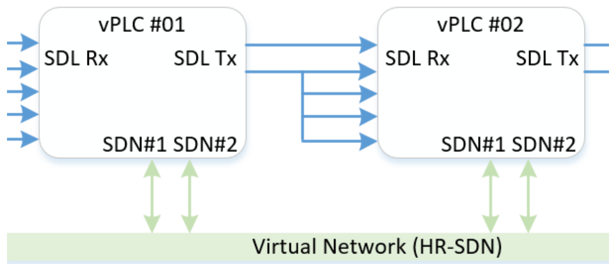

Fig. 2. vPLC configuration diagram for SN Master Node testing.

SDL data transmitted from vPLC#01 goes into vPLC#02, and SDL data transmitted from vPLC#02 goes into vPLC#03. SDL data transmitted from vPLC#31 goes into vPLC#01. In other words, vPLCs formed an SDL communication network with a circular structure. The SDN test method was structured in such a way that SDN data sent from vPLC#01 was transmitted to all vPLCs except vPLC#01.

As a result of the test, all vPLCs communicated with SDL and SDN in a cycle of 30ms, and CPU, memory, and network utilization were stable. To achieve these results, we improved multi-threading, communication buffer, communication cycle, and network isolation.

2.2 I/O Master Node

The I/O Master Node was tested with 310 vPLCs and 288 vDCSs (the maximum configurable number of DCSs). Each vPLC and vDCS was configured with the following I/O card configurations

Table I: I/O Card Configuration

	Configuration	Quantity
vPLC	AO(NDA8-2Q, 8ch)	2
	AI(NAD8-3Q, 8ch)	2
	DO(NQ-D23Q, 32ch)	1
	DI(NI-D23Q, 32ch)	1
vDCS	DO(DOM01A, 16ch)	8
	DI(DIM48A, 32ch)	8

In the configuration shown in Table 1, communication with the I/O of all vPLCs and vDCSs was performed, and all I/O channels were copied to the terminal block in the Master Node. These operations were performed periodically, and CPU, memory, and network usage were measured during this process.

Table II: I/O Master Node Performance Test Result

Measurement Items	vPLC+vDCS I/O Communication	Note
Transmission Interval	17.3 ms	
	15 ms (Input)	
	50 ms (Output)	Agent Settings

As a result of the test, it was confirmed that vPLC I/O could communicate within a maximum of 17.3ms, and vDCS I/O could communicate at 15ms/50ms.

2.3 RCOPS System Validation

Based on the performance tests of the SN and I/O Master Nodes, we conducted RCOPS system validation tests to confirm whether the Master Nodes and virtual controllers were successfully connected through the actual system configuration. The RCOPS system consists of 20 vPLCs and 8 safety system PCs, and is mounted on a blade server as shown in Figure 3.

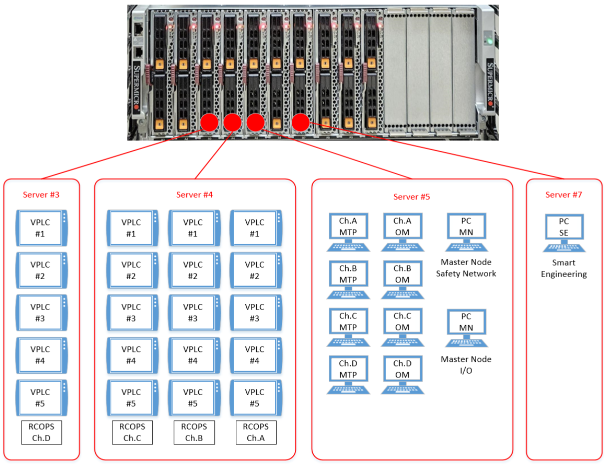

Fig. 3. Configuration diagram for RCOPS system validation testing.

The same software as the real power plant was installed on the vPLCs and safety system PCs, and as a result of checking the network status of the system on the MTP screen, it was confirmed that it was operating without interruption.

3. Conclusions

In this paper, SN and I/O Master Node were introduced as a method to link the I/O of the controller, which is routed by physical connection, and HR-SDN/HR-SDL communication of the safety system in a virtual environment. Since the Master Node is responsible for communication of all I/O and safety systems in the digital twin system, performance testing to check the performance of the Master Node is important. Through performance testing of the SN and I/O master node, we confirmed that the I/O communication of the controller and the communication of the safety system operate without problems even in a virtual environment. Based on these test results, the master node proved that it can provide I/O connection and HR-SDL/HR-SDN communication without problems in a virtual environment.

REFERENCES

[1] Sungjin Lee, Won Woong Ko, “Basic Concepts of APR1400 MMIS Digital Twin using Virtualization Technology”, Transactions of the Korean Nuclear Society Spring Meeting, 2020.

[2] Min-seok Kim, Hosun Ryu, "Study on Implementation Method of Safety System Communication Virtualization in MMIS Digital Twin", Transactions of the Korean Nuclear Society Spring Meeting, 2023.