Study on Implementation Method of Safety System Communication Virtualization in MMIS Digital Twin

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1. Introduction

Korea Hydro & Nuclear Power (KHNP) is currently conducting an R&D project for a digital twin of the APR1400 nuclear power plant using virtualization technology.[1] The project aims to virtualize safety/non-safety system controllers in an emulation method and to use the same software and communication method as power plants.

However, in the virtual environment, only Ethernet communication is available, which means that the communication method used in the safety network cannot be utilized. Therefore, this paper proposes a method for virtualizing the safety system communication of the digital twin without modifying the software and structure of the safety controllers.

2. Implementation Method

2.1 Characteristics of Safety System Communication

The Man-Machine Interface System (MMIS) of the APR1400 consists of multiple controllers, and the safety grade controller of the power plant to which Korean digital MMIS is applied is built with a PLC platform called POSAFE-Q. POSAFE-Q uses the HR-SDN (High Reliability - Safety Data Network) and HR-SDL (High Reliability - Safety Data Link) communication protocols based on Profibus.

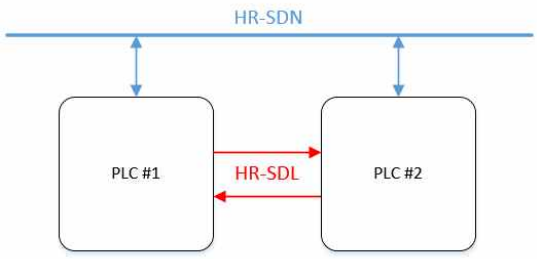

Fig. 1. Diagram of the communication between the safery-grade PLCs in the MMIS

Figure 1 shows a diagram of the communication between the safety-grade Controllers in the MMIS. As shown in Figure 1, PLC 1 and PLC 2 are connected in the form of Multi-Drop through a network such as HR-SDN and communicate through Peer-to-Peer communication using HR-SDL. However, in a virtual environment such as a digital twin, only Ethernet communication is available, so the software of the virtual PLCs (vPLCs) must be modified to enable communication between them. Therefore, a method is needed to ensure smooth communication in the digital twin system without modifying the software of the vPLCs.

2.2 Communication Protocol Conversion Unit

The structure of a virtual machine in the digital twin system is shown in Figure 2. Each virtual machine consists of a hierarchical structure of Guest OS, Emulation SW, and vPLC. The vPLC operates within the Emulation SW. To use the SDN/SDL communication method, which are the same as those used in the actual plant, a communication protocol conversion unit was added between the Emulation SW and the Guest OS.

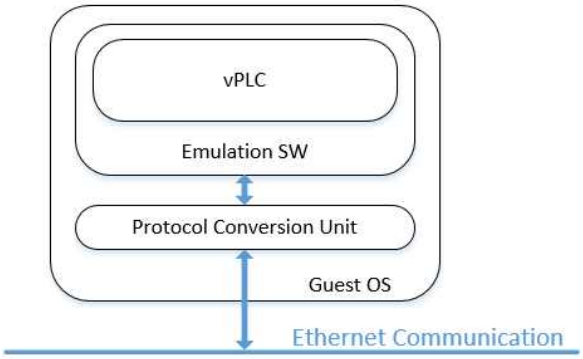

Fig. 2. Structure of Virtual Machine in the digital twin

The communication protocol conversion unit performs a function of making data of different communication methods compatible. In other words, the communication protocol conversion unit encapsulates SDN/SDL data going out from vPLC into Ethernet packets, and de-encapsulates Ethernet packets coming into vPLC from outside into SDN/SDL packets.

Fig. 3. The packet structure of the communication protocol conversion unit

Figure 3 shows the packet structure of the communication protocol conversion unit. The packet is divided into four parts: address area and header, SDN/SDL data, and CRC. The address area records the system name of the sending vPLC, cabinet number,

vPLC number, slot number, channel number, etc. The header records the communication cable name, communication type, and communication data size. SDN/SDL data is loaded into the data area without any processing. Finally, CRC is added to verify the integrity of the communication data. Note that SDN/SDL communication data has a structure that includes packet headers and data used in physical SDN/SDL communication, so it can be used without changing the software of the existing PLC.

2.3 Master Node

SDN/SDL communication is a serial communication method in which the communication path is determined by cables. Both SDL and SDN, which originated from PLC, are designed to deliver data to all connected PLCs via broadcast over the cable.

In other words, the communication in the safety system replaces the switch role in Ethernet communication with cabling. Therefore, when SDN/SDL is virtualized in a digital twin system, additional software is required to perform the role of network cabling. We have implemented this function through the master node.

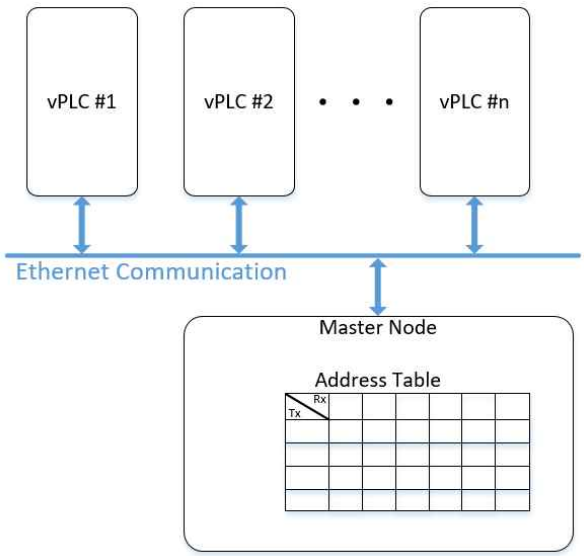

Fig. 4. Diagram of safety system communication virtualization in digital twin

The master node has the address table of all vPLCs that make up the safety system. SDN/SDL data from vPLCs is sent to the master node, and the master node sends communication data to the vPLC corresponding to the destination address based on the source and destination address information of the packet.

The address table of the safety system can be set in a 1:1 as well as a 1:N structure, so that SDN/SDL data in a 1:N structure can be transmitted and received without omission.

3. Conclusions

In this paper, we proposed a method to virtualize the communication of the safety system in the MMIS digital twin project without modifying the shape and software of the safety system controller. The method involves adding a communication protocol conversion unit between the vPLC and guest operating system to allow the vPLC to communicate using the SDN/SDL communication protocol used in the actual power plant.

The proposed method can virtualize the communication of the safety system without changing the existing software of the safety system, ensuring the reliability of the power plant simulation in the digital twin. Future work can focus on the implementation and evaluation of the proposed method in the MMIS digital twin project.

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.