Development of Virtual PLC for the Korean APR 1400 NPP Digital Twin

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1. Introduction

The Virtualization Technology that converts a central processing unit (CPU) operations as a hardware to that of as a software has been used in several industry fields such as a semiconductor manufacturing, vehicle driving control platform development, military defense and aircraft control facility development[1].

The KHNP Central Research Institute (CRI) has been working on the R&D project of development of Korean APR1400 NPP digital twin to enhance a life-cycle engineering for a NPP since 2020. The purpose of this R&D is to increase the utilization rate of a APR 1400 NPP by using a domestic virtual MMIS digital twin which can be utilized for several purposes through a plant life cycle.

When we make use of the MMIS digital twin, it will be possible to contribute to improving design quality and shortening the start-up period through preliminary functional verification and testing in the design/manufacturing/start-up phase. In addition, it is possible to prevent anticipating errors in advance by performing pre-verification through twin when improving the functions of existing facilities in the operation phase. It can also be used for an operator training.

MMIS virtualization is divided in to developing core elements such as a virtual PLC/ DCS/network/, and implementing MMIS system by combining these elements [1]. In this paper, the virtualization of POSAFE-Q PLC is focused on and described only. First of all, after the concept of virtual PLC is introduced, the scope and functions of the virtual PLC that performed in this study is described. Then, the design structure of the virtual PLC is briefly explained, and the functional test results that performed on the virtualized processor module is introduced.

2. Concept of Virtual PLC

PLC virtualization makes it is possible to perform the same functions as hardware by implementing it in software. In order to perform the same function, the kernel or application programs that are loaded and operated in the PLC must operate identically. Therefore, it is the most important to virtualize the process functions of PLC.

The POSAFE-Q PLC virtualization platform can be used as a basic component of a digital twin by executing the software binary running on the hardware PLC in the same virtual environment.

In addition, the POSAFE-Q PLC virtualization platform provides a user with a visual interface of the virtual machine (VM) to intuitively operate it, and gives the internal state information of the PLC to effectively utilize the VM.
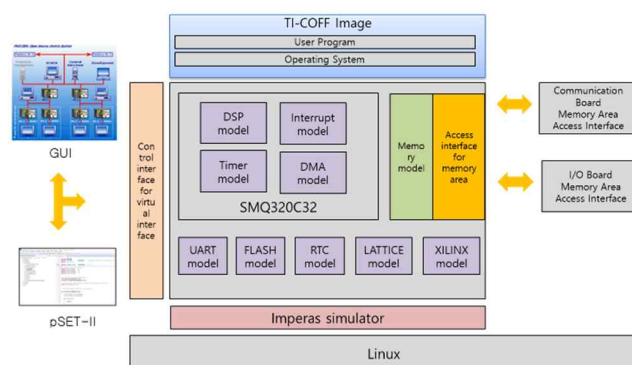

Fig. 1. Virtualization structure of POSAFE-Q PLC process module

The developed virtual control module is operated in a general computer environment. However, in this study, it was selected to arrange the control module in a VM rather than a general computer environment for the result with high independence of hardware.

3. Scope and functions of Virtual PLC

3.1 Scope of Virtual PLC

Virtual PLC is basically implemented in a full virtualization way for a process module, and the other modules such as I/O, communication, and analog modules provide an interface that can input and output simple data. For the interworking between the pSET-II which is an external program and virtual PLC, virtual PLC also provides the function of loading a user program in the same way as the existing POSAFE-Q PLC. The virtualization of PLC modules is conducted for the installed modules of SHN unit 1 and 2, SKN unit 5 and 6

3.2 The function of Virtual PLC

The required functions of virtual PLC are as follow:

- CPU virtualization of PLC process module
- Memory virtualization of PLC process module

- UART function virtualization of PLC process module
- CPLD function virtualization of PLC process module
- The other function virtualization for the binary execution

Furthermore, virtual PLC should provide a visualized user interface to use virtual platform effectively. Therefore, it should offer a user to which module the user is using and each module's operating status visually. Details are as follow:

- Interface for the installation of module
- Current status of module installation
- Status of the installed module
- Interface for checking a specific memory value of a process module

4. Structure Design and Process Module Test of Virtual PLC

4.1 Structure Design of Virtual PLC

Imperas program as a software virtualization development tool is used to make a virtual PLC. Based on Imperas virtualization platform, it can provide virtual modules(process module, communication module, I/O module) and API, etc. Accordingly, the basic structure of virtualization platform can be designed as the following figure.
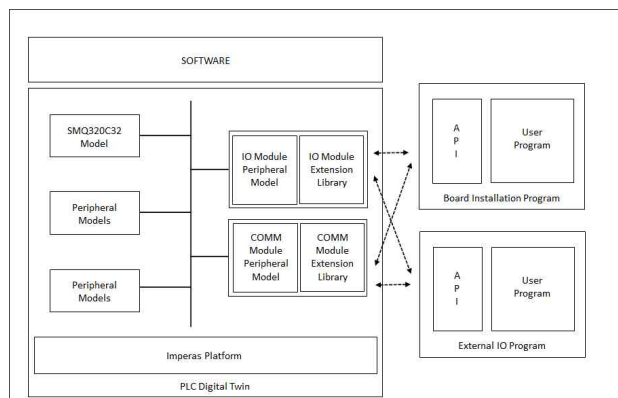

Fig. 2. Interface structure of virtual PLC

Analog and digital input/output board, and communication board can be divided into the same elements as peripheral devices by accessing and controlling the memory area in the processor. Since the input/output board and communication board are simulated, they are designed in the form of I/O module peripheral device and communication module peripheral device respectively.

Simulation of I/O module and communication module peripheral devices should be analyzed to send and receive data with a process module properly, and

designed for data exchange with the CPU board in the same way as the data format provided by the module.

4.2 Functional Test of Virtual Process Module

Fig. 3. Code composer debugging with JTAG

Code Composer is an integrated development environment (IDE) tool which is provided by Texas Instrument Inc. to develop TMS320 series processors. Code composer can be controlled by connecting with the target processor through JTAG.

For a processor module, more than 500 test cases were performed, and it was confirmed that the results were all satisfactory.

5. Conclusion

This paper shows the concept, scope, and function of PLC virtualization. In order to operate equally with the same function of the real PLC effectively, virtualized PLC are designed with a full virtualization of processor module and functional virtualizations of the other modules, and implemented as using the same application software and user program which are used in the real PLC. Structure design of virtual PLC is also set up and the virtual processor module's operation is confirmed by a comparative test.

We also conduct the DCS virtualization similar to PLC virtualization, and have been building a safety and non-safety system by using virtual PLC and DCS platform with a full scope simulator. This simulator is being developed for the virtual MMIS exclusively. It is expected that we can show the entire function and performance of virtual MMIS system with a connection of the developing simulator.

REFERENCE

[1] S.J. Lee, Development of digital twin of APR1400 MMIS based on virtualization techniques, Conference on Information and Control Systems, October 2021.