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A framework for the testing & validation of the I&C system based on a simulator

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1. Introduction

The I&C system for a nuclear power plant should be developed as a prototype or mock-up from the concept phase of the development process, and the function and performance of the computer system also have to be tested and validated. If possible, the developed prototype or mock-up could receive the signals of a normal or abnormal operation status of a nuclear power plant and generate the proper requirement output signal. Using these processes, it can be verified that the status of a plant is changed to the design state or the state needed by the plant operator. Thus, the testing and validation for the operation and performance of the developed I&C system are a critical process. For the exact testing and validation of the developed I&C system, not only static variable data but also dynamic variable data that can be modified inside the plant core during plant operation should be utilized as direct input data. This paper describes a conformity framework that can conduct the testing and validation, and in particular describes the validation facility based on a simulator in detail. A simulator can receive the internal core status, and a real-time validation can then be performed using internal data simultaneously.

2. Testing and Validation Facility for I&C systems

The facility follows several processes for testing and validating the control system of the I&C system, which is called a Hardware in the Loop Simulation (HILS).

a) Connect with the simulator, in/out device and target hardware
b) Support the input data requested by the target system
c) Calculate the logic with input data in the target system
d) Send the calculated data to a simulator through the in/out device
e) Store the received data in the space of a simulator
f) Recalculate the logic with state-of-the-art data in a simulator

A traditional testing and validation facility based on a simulator is shown in Figure1. A hard-wired interface and Ethernet interface are supported for the in/out operation of the existing simulator.

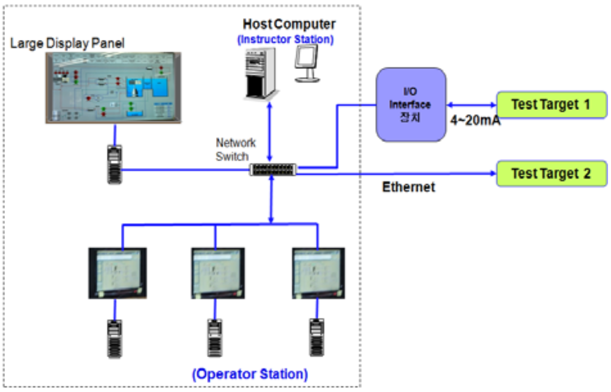

Figure1. Hardware architecture of traditional simulation-based validation facility

3. Simulation-based platform for validation

This paper describes a platform that can be used to conduct a conformity evaluation after establishing the simulation-based validation facility for the I&C system of a nuclear power plant. This platform consists of a tool environment and the testing program. The former can conduct automation test-validation based on a simulator, and the latter can monitor several variables and generate the input data for testing.

3.1. A conformity evaluation platform based on a simulator for the I&C system

3.1.1. Testing and validation method automation

To conduct the testing and validation for the software implemented inside and I&C system, the software development, testing, and validation requirements should be defined in software documents, and we should verify whether the defined functions are operated correctly or not. These traditional processes are an important procedure to perform the testing and validation of the I&C system, and the functions of system can then be guaranteed through these processes. A simulation-based conformity evaluation platform is an environment that can automate the testing and validation actions. If the testing requirements are defined according to the international standards or stakeholder documents, and these are supported as input data for an automation program in an IO simulator, the IO simulator can generate the static signals and can test the function of the target system. Figure2 shows the automaton platform for validation of the I&C system.

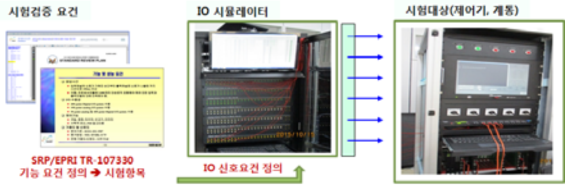

Figure2. Automation platform for validation of the I&C system

3.1.2. Testing automation based on a plant simulator

A testing automation facility based on a plant simulator can analyze the real-time operation of a plant simulation, generate the analyzed signal, inject the signal into target system and verify the normal operation of the I&C systems. A traditional testing & validation method defines the static test requirements and extracts the input data from the defined requirement using IO signal generation devices. On the contrary, a simulation-based test method can generate the real calculated input data from a simulator and send the signals to a test device directly. A simulation-based test method can receive the signal represented in a normal or abnormal state, and can imitate the real operation environment of the plant system; thus, the quality and reliability of the evaluation can be improved. If using these testing facilities and testing platforms, the real-time testing and evaluation ability for a future I&C system will also be improved. Figure3 shows a validation platform based on a simulator.

Figure3. Simulator-based validation platform

3.2. Monitoring and testing programs for simulator variables

A developed system is required to adapt to a real field during an acceptance testing process. The acceptance test needs a simulator that can imitate the entire plant system. It is also necessary to prepare a facility to simply perform an evaluation for the I&C system prior to preparing the entire plant simulator. We previously tried to judge whether the software of the I&C system would be operated exactly when the static data are supported to test the function of the I&C system. However, static data are not real data generated in a real nuclear power plant. Thus, there are some limitations to make a variety of input scenarios. To overcome the restrictions, if the input data generated in a simulator might be input inside of the I&C system and an evaluation might be performed, a tester can change the dynamic status of the power plant and verify the correctness of the function. The testing quality will be more improved when using dynamic input data according to the plant core status than using static input data. To send the inner variable of a simulator to the I&C system in real time, some programs are required. The program can monitor the simulation variables, extract the needed input data and conduct the testing action automatically. In this work, a communication program that can send/receive the interface signals of the I&C system to the CNS (Compact Nuclear Simulator) system has been developed according to this necessity.

3.2.1. UDP communication program for a simulator

The model related to the reactor core analysis code and the NSSS (Nuclear Steam Supply System) model are operated and simulated inside of the CNS system. The CNS also stores the analog/digital values used in the I&C system. The communication program as shown in Figure4 tries to send the stored data to the different equipment using the UDP communication protocol. The stored data are also changed into physical signals using the LabView Tool. This program has a protocol for sending/receiving some data using the LabView tool, a function for analyzing the binary values, and a function to sort out the data for the graphical interfaces.

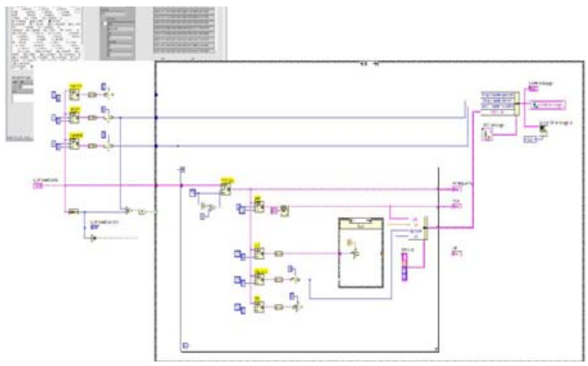

Figure4. UDP communication program

3.2.2. Signal monitoring and generating program for the interface with a simulator

The CNS simulator has a code to simulate the inner status of the reactor. It generates the status variables of a plant core in real time and stores the real data after converting to digital values. This program displays the stored data on a computer monitor in real time and makes the real analog/digital signal using the LabView tool practically. The LabView program to make these signals has features that can control the PXI hardware devices.

This program can be operated into the LabView tool installed on the IO simulator made of the PXI hardware. The method used to confirm the communication with the IO simulator is to check the received data upon monitoring the display. We can review the normal operation if an analog/digital output signals are generated when the channel signal is selected by the program. If the IO values used in the target system are assigned in each channel, the signals generated in the CNS simulator in real time will be utilized as the input data of the target system devices. Using this methodology, the target testing is possible. Figure5 shows the signal monitoring and generating program.

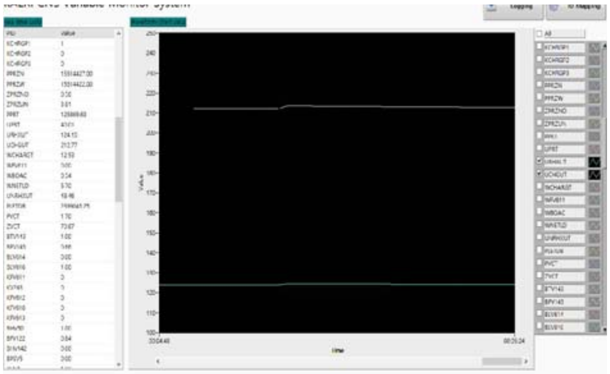

Figure5. Signal monitoring and generating program

4. Conclusion

A simulation-based conformity evaluation platform is an environment that can automate the testing and validation actions. A traditional testing and validation method defines the static test requirements and extracts the input data from the defined requirement using IO signal generation devices. On the contrary, a simulation-based test method can generate the real calculated input data from a simulator and send the signals to the test devices directly. In this paper, we developed a framework that can conduct a conformity evaluation based on a simulator and implement the communication and monitoring program. If this evaluation platform is utilized during the development process, the I&C system will be tested with the calculated data in the core of the reactor. We can evaluate the performance of the I&C system in detail using this method.

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