# Development of Control Verification Simulator for Plant Control System

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## 1. Introduction

If there is a problem with control equipment of nuclear power plant, disconnect the control system from the field device and check the off-line control equipment. However, the control equipment is designed to operate the communication and control logic sequentially while the field devices are connected. Therefore, if you check off-line, you will not be able to check all the functions.[1]

To solve this problem, we developed a simulator that can check all the functions even when the control equipment is off-line. This simulator was developed for of control equipment of plant control system

In this paper, we introduce the control loop of the plant control system and the developed simulator.

## 2. Analysis of control loop

The plant control system controls and monitors safety and non-safety related filed equipment. The plant control system controls more than 1,300 devices including pumps, heaters, valves, motors, fans, dampers and electrical system breakers.

The plant control system can be roughly divided into digital control loop and analog control loop. The plant control system mostly control the device with digital signals, some of which have analog control.

### *2.1. Digital control loop*

Figure 1 shows the control loop of the isolation valve in the component cooling water system. We can check the control logic of isolation valve in Control Logic Diagram (CLD) of plant control system. Based on the CLD, the connection status of the field devices and input/output signals are summarized as shown in figure 1.

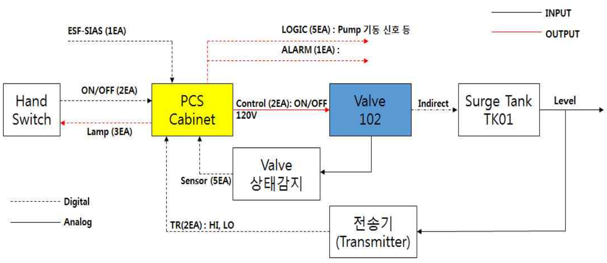


Fig. 1. Block diagram of digital control loop

Table I: IN/OUT Signal of digital control loop

| | | Signal Type |
|---|---|---|
| Input | | Hand Switch |
| | | Transmitter |
| | | Control Device Status Monitoring |
| | | Other Loop Card |
| | | External Facilities |
| Output | | Alarm |
| | | Device Control |
| | | Hand Switch Ramp |
| | | Various status commands |

Most of the digital control loops can be summarized as in Fig. 1 and table 1.

### *2.2. Analog control loop*

Figure 2 shows the control loop of the Blowdown Flash Tank Level in the steam generator blowdown system. We can check the control logic of isolation valve in Control Logic Diagram (CLD) of plant control system. Based on the CLD, the connection status of the field devices and input/output signals are summarized as shown in Fig. 2.

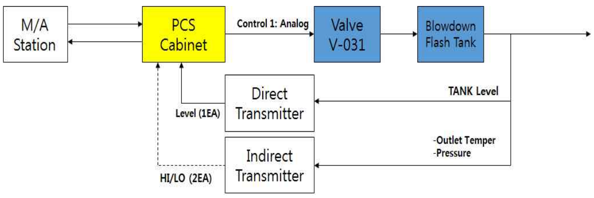


Fig. 2. Block diagram of analog control loop

## 3. Simulator software

The power plant equipment connected to the control facility is implemented by software. A Field device controlled by digital signals can be implemented simply by an ON/OFF switch. However, a field device controlled by analog signals need to be aware of the model expression of the device so that it can be implemented in software.[2]

### *2.1. Transfer function model test*

The control model of the power plant can be divided into eight types as shown in Fig. 3. The eight transfer function models in Fig. 3 are implemented by software.

| Description | Laplace Equation |
|---|---|
| Dead time with gain | $K_p e^{-\theta s}$ |
| First order with dead time and gain | $\frac{K_p e^{-\theta s}}{1+\tau s}$ |
| Second order with dead time and gain | $\frac{K_p e^{-\theta s}}{(1+\tau_1 s)(1+\tau_2 s)}$ |
| Second order over-damped with dead time (Imaginary roots) and gain | $\frac{K_p e^{-\theta s}}{(1+P_1 s)(1+P_2 s^2)}$ |
| Integrator with dead time | $\frac{e^{-\theta s}}{\tau s}$ |
| Integrator with first order and dead time | $\frac{e^{-\theta s}}{\tau_1 s+\tau_2 s^2}$ |
| Inverse response process or shrink-swell: Integrator with first order, lead time, and dead time | $\frac{(1+\tau_l s)e^{-\theta s}}{\tau_2 s+\tau_3 s^2}$ |
| Double integrator with dead time | $\frac{e^{-\theta s}}{\tau s^2}$ |

Fig. 3. Function of control model

The user can select one of 8 models and change the model parameters. As shown in Fig. 4, the response of the model produced by the user can be confirmed in the simulator.

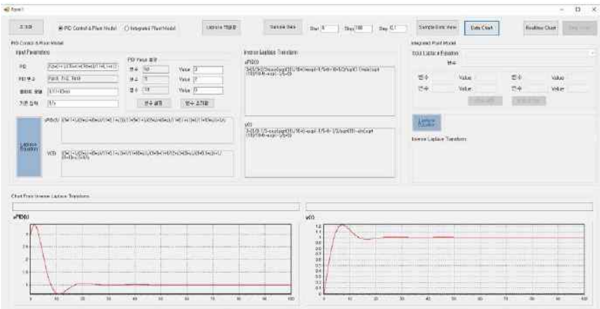

Fig. 4. Simulation of control model

*2.2. Serio test mode*

The scenario test mode is a mode that can automatically check the operation of the device. The user enters the operation or maintenance procedures in the excel sheet.
The excel input form is predetermined by the input and output signal of the device. The simulation program loads the stored excel sheets and sequentially checks the output value.

In the middle of Fig. 5, the output value is shown in the graph. Test results can be saved and the results can be output in the form of a report.

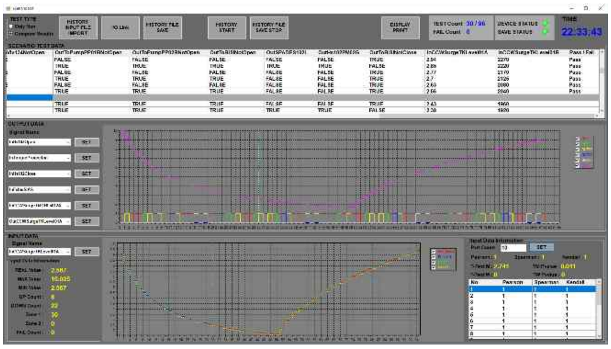

Fig. 5. Serio test mode

*2.3. Manual test mode*

The manual test mode is a mode that can manually check the operation of the device. In this mode, the user can change the input signal individually.

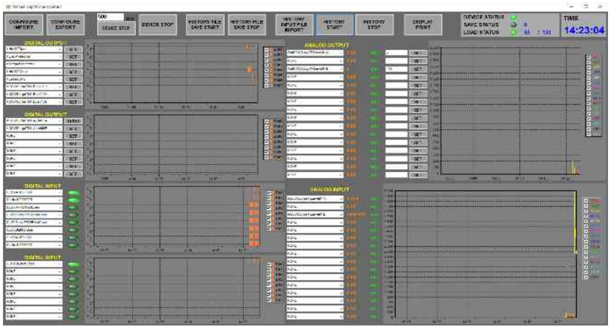

Fig. 6. Manual test mode

## 4. Conclusions

The test will be conducted on the plant control equipment using the simulator. The simulator will be supplemented based on the test results. The developed simulator will be used to verify the reliability of long-term operation of the manufactured equipment.[3]

## REFERENCES

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[3] H.S.Ryu, M.S.Kim, J.M Kim, K.D. Lee, Development of Long-term Reliability Evaluation Method for Digital Equipment, KIEE Sumer Conference 2018.