Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Development of NSSS Control System Performance Verification Tool

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1. Introduction

Thanks to many control systems and control components, the nuclear power plant can be operated safely and efficiently under the transient condition as well as the steady state condition. If a fault or an error exists in control systems, the nuclear power plant should experience the unwanted and unexpected transient condition. Therefore, the performance of these control systems and control components should be completely verified through power ascension tests of startup period.

However, there are many needs to replace control components or to modify control logic or to change its setpoint. It is important to verify the performance of changed control system without redoing power ascension tests in order to perform these changes.

Up to now, a simulation method with computer codes which has been used for design of nuclear power plants was commonly used to verify its performance. But, if hardware characteristics of control system are changed or the software in control system has an unexpected fault or error, this simulation method is not effective to verify the performance of changed control system.

Many tests related to V&V (Verification and Validation) are performed in the factory as well as in the plant to eliminate these errors which might be generated in hardware manufacturing or software coding.

It reveals that these field tests and the simulation method are insufficient to guaranty the performance of changed control system. Two unexpected transients occurred in YGN 5&6 startup period are good examples to show this fact. One occurred at 50% reactor power and caused reactor trip. The other occurred during 70% loss of main feedwater pump test and caused the excess turbine runback.

2. Background

2.1 Simulation Method

The computer code should be tuned with plant transient data before evaluating the performance of changed control system. The PRDBE (Performance Related Design Bases) which includes the all of power ascension tests have been off-line simulated with and without changed control logic. The performance of changed control logic is verified if two results of the above are same or the result with changed control system shows better responses.

2.2 Field Tests for V&V

A hardware manufacturer designs the control system according to relevant design specification. An error may be included during hardware fabrication or software coding. Then, control system was tested many times in the factory as well as in the plant to filter this error. However, it is difficult to find the error from these tests which only check the static responses.

3. Method and Results

It is necessity to develop new methodology and tool to guaranty the performance of control system.

3.1 Computer Code

Several computer codes can be used to simulate nuclear power plants. The KISPAC computer code has been used for the purpose of performance analyses for the OPR1000 nuclear power plant. The CENTS code has been used for those of Westinghouse type nuclear power plants. This code is also embedded in the NPA (the Nuclear Plant Analyzer) which was developed between 1998 and 2001. This workstation based NPA was chosen for the computer code of NSSS control system performance verification tool for the efficiency.

3.2 PC Based NPA

The workstation based NPA was converted to personal computer based NPA. In this process, most efforts were concentrated on making component control module, memory editing module, external plotting module, and simulation control module. The GUI (Graphic User Interface) related works were relatively neglected because of limiting resources.

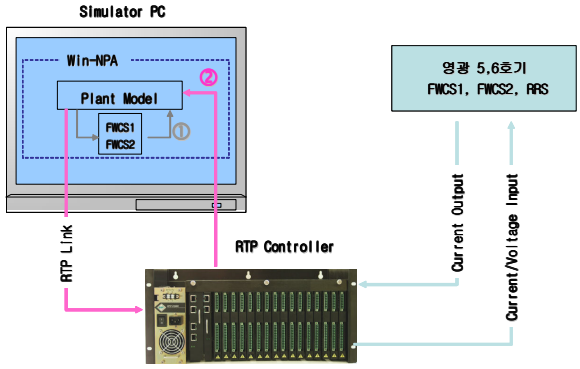

Figure 1. Outline of NSSS control system performance verification tool

2.3 Test the Tool

The tool was used in the YGN 5&6 nuclear power plant. The research was performed about FWCS (Feedwater Control System) control logic for PI controller output to track LPFDL (Low Power Flow Demand Limit) signal at low power. This control logic change was performed at first after startup period and there is no experience of changing program of PLC based control system, the operator eagerly want to know that control logic change will not cause any problem both steady and transient conditions of nuclear power plants.

First, performance verification tool was on-line connected with NSSS control system using A/D (Analog to Digital) converter. Figure 2 shows the connection between FWCS and performance verification tool using A/D converter. Second, the steady state condition was accomplished using operator modules in MCR (Main Control Room). Third, the performance verification tool simulates the PRDBE (Performance Related Design Basis Event) like load rejection and loss of a main feedwater pump before changing the control logic. Finally, the same procedure was performed again after changing control logic. The two results were compared and evaluated the effects of control logic changes. The result was shown in figure 3.

The transient responses for loss of main feedwater pump event were similar to each other after and before control logic changes. Then, control logic changes will not affect the performance of control system and the plant will be operated without deteriorating the control system performance.

Figure 2. Connection between NSSS control system and performance verification tool using A/D converter

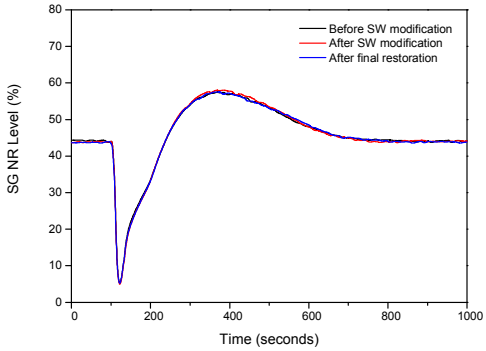

Figure 3. Simulation results for YGN 5&6 control logic changes

4. Conclusion

The new tool is developed to verify the performance of the NSSS control system when the following elements are modified: Control logic, Setpoint, Control component. This tool was successfully used in verifying the performance after control logic change in YGN 5&6. The YGN 3&4 plant plans to change their control system hardware. This tool also will be used to verify performance of changed hardware. The registration of software has been finished and is applied for patent in the name of figure 4. The continued R&D will upgrade the user interface as well as expand the scope to verification of safety system.

Figure 4. Logo for NSSS control system performance verification tool

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