Application of the Performance Validation Tool to NSSS Control System Replacement

Suk Whun Sohn, In Ho Song, See Chae Jeong, Jong Joo Sohn
NSSS Engineering Department, KOPEC, 150, Dukjin-Dong, Yusung-Gu, Daejeon, KOREA, swson@kopec.co.kr

1. Introduction

Hardware of control systems in nuclear power plants are usually upgraded two or three times during the design lifetime. When the hardware needs to be replaced, its performance should be evaluated and validated in order to ensure that the hardware has been properly manufactured and installed in accordance with design specifications. Several nuclear power plants have experienced transients including a reactor trip when their hardware of control system has been changed. The transients occur from minor hardware errors caused by incomplete validation. Therefore, the decision to replace troublesome hardware with new one may not be easy due to the reason above.

Typically, factory acceptance test (FAT) and pre-operational test are performed in case of control system replacement. FAT is done by manufacturers before installation. The pre-operational test is performed by plant operators after new hardware installation. Nevertheless, these tests are not enough to validate the performance of hardware in control systems which have complicate logics and functional modules such as PI controller, high pass filter, lead/lag filter, and lag filter. For newly constructed nuclear power plants, dynamic performance of hardware is validated additionally through the integrated tests during power ascension test (PAT) after performing FAT and pre-operational test. It is difficult to perform the PAT for validating a dynamic performance of hardware at commercially operating plants because of economic and safety concerns. In this paper, new tool and a method for the dynamic performance validation of hardware in these plants are introduced, which are developed to reduce the operators from the burden replacing NSSS control systems using window based nuclear performance analyzer (Win-NPA) [1 and 2].

2. Background

2.1 Introduction of Win-NPA

The Win-NPA is an interactive, high fidelity, real-time engineering simulator for nuclear power plants. The Win-NPA consists of the process model simulating the plant behavior, graphical user interface (GUI), and simulation executive for enhanced user interface. Its simulation capability covers a wide range of nuclear power plant operations including normal, abnormal, and accident conditions.

2.2 FWCS Hardware Replacement

Hardware of feedwater control system (FWCS) installed in YGN 3&4 is single loop system with several control cards which exchange their signal each other sequentially. Therefore, the whole control would fail if one of these control cards has any trouble. Once a control card failure mentioned above has occurred, they decided to change their hardware. In order to validate the performance of new FWCS hardware, the Win-NPA was utilized. The FWCS was modeled in detail based on design specifications within Win-NPA. The validation method was also set up with the tool.

3. Method and Results

3.1 Method

The Figure 1 shows the validation process of the changed hardware. The validation of the hardware was divided into two main parts. The first process is for dynamic performance test to confirm that the hardware is properly designed and manufactured. The second process is for performance evaluation test to evaluate the performance of the hardware.

The Win-NPA was directly connected with hardware via signal interface module as shown in Figure 3. The control system input signals such as steam generator water level, feedwater flow, and steam flow were generated in Win-NPA and transferred the hardware via the interface module. The output signals from the hardware like main feedwater pump speed and economizer valve position demand were sent to Win-NPA instead of real main feedwater pump or valves.

The Win-NPA played a role of plant with this configuration. The following seven (7) tests were simulated. These tests were considerately selected among startup tests in order to validate the control performance of the FWCS.

- Load Rejection to House Load
- Loss of Main Feedwater Pump
- Reactor Trip
- Turbine Power 10% Step Decrease (100 to 90%)
- Turbine Power 5%/min Ramp Decrease (100 to 30%)
- Valve Transfer (Increasing Direction)
- Valve Transfer (Decreasing Direction)

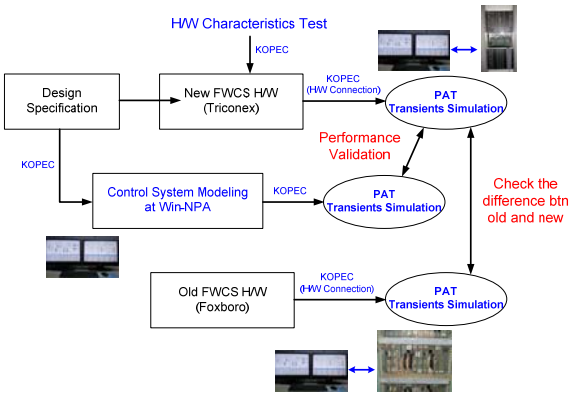

Figure 1. Performance validation process of changed hardware

3.2 Results of Dynamic Performance Test

The dynamic performance test was performed by comparing between the simulation results of seven individual tests by Win-NPA only and by Win-NPA with new hardware connection. The Figure 2 shows the simulation results of load rejection to house load event which is the most significant transient among startup tests. The graphs show that the two results are almost identical each other. Based on these results, it was proven that the new hardware is correctly manufactured as required in the design specifications.

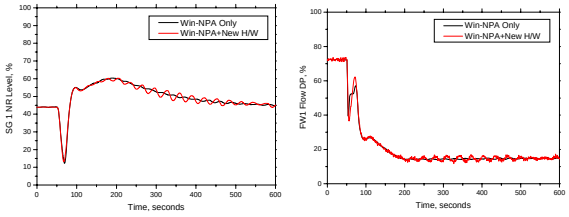

Figure 2. Simulation results of Load Rejection to House Load Event (with and without hardware connection)

3.3 Results of Performance Evaluation Test

In connection of old hardware with the Win-NPA, the same transients were simulated again. These simulation results as mentioned in 3.2 were compared with the results performed with new hardware mentioned above. The comparison results are shown in Figure 4. As shown in this figure, there was little difference between old and new hardware.

3.4 Further Application

The performance validation tool will be used in order to insure the validity of maintenance activity which is always performed during overhaul period. This tool will be connected with control system including its control valves. Both sides of control valve should be isolated with isolation valves. Before and after maintenance, Transients will be simulated and their results will be compared to validate whether maintenance activity is proper or not.

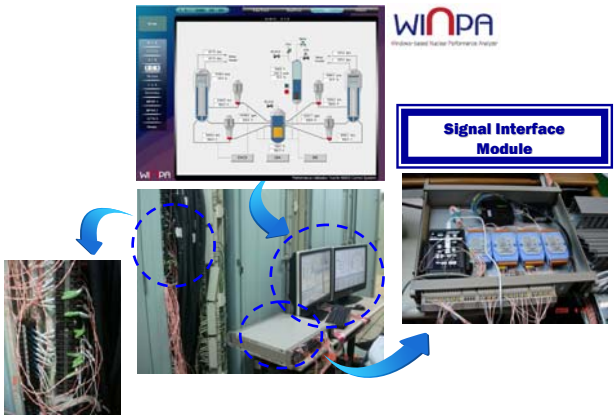

Figure 3. Performance validation tool package for NSSS control system

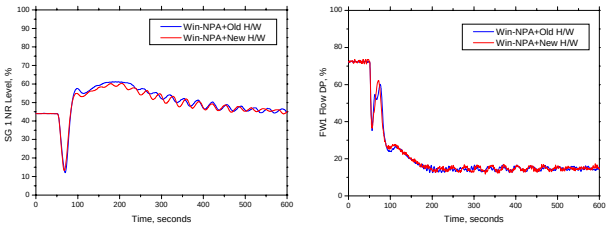

Figure 4. Simulation results of Load Rejection to House Load Event (with new and old hardware)

4. Conclusion

Through the performance validation tests, the YGN 4 plant is successfully reached its power to full power level without any disturbance or transient. The developed performance validation tool and method are suggested as a good solution. When the component or system in nuclear power plant is replaced and the validation of the performance before and after installation is required.

REFERENCES

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