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Loss of a Main Feedwater Pump Test at 100% Power Simulation using Korean Standard Nuclear Plant Analyzer (KSNPA)

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Abstract

The Loss of a Main Feedwater Pump test at 100% Power for YGN 4 was simulated in order to verify and validate the KSNPA. The comparison of the test data with the KSNPA prediction results showed reasonable agreement in the trends of the major plant parameters. All plant control systems including NSSS and T/G control systems are properly actuated and stabilized the plant conditions to a new steady state conditions in the KSNPA. From the comparison results, the KSNPA showed its capability to simulate the LOMFP event for the Korean Standard Nuclear Power Plant.

1. Introduction

The Korean Standard Nuclear Plant Analyzer (KSNPA) has been developed as a real time engineering desktop simulator to simulate the operating characteristics of the Korean Standard Nuclear Power Plant which is Ulchin Nuclear Power Plant Units 3 and 4 (UCN 3&4). The KSNPA is ported on the desktop engineering workstation and run on the basis of UNIX operation system and X-11 environment of the Graphical User Interface (GUI). The KSNPA can simulate the steady state operation, Performance Related Design Bases Events (PRDBEs), Safety Related Design Bases Events (SRDBEs) of the nuclear power plant[1]. The KSNPA shoud be verified and validated its prediction capabilities for various accidents or events by the comparison of its prediction results with the plant test data before it is used as a simulation tool.

Therefore, in this paper, the Power Ascension Test data of the Yonggwang Nuclear Power Plant Units 3 and 4 (YGN 3&4) are used as the plant test data in order to verify and validate the KSNPA, because the YGN 3&4 is the reference plant of the UCN 3&4. Among those tests, the Loss of a Main Feedwater Pump (LOMFP) test at 100% power for YGN 4, which is one of the major tests characterize the capability of the YGN 3&4, is selected. During this event, one of the two normally operating main feedwater pumps is tripped resulting in a 50% reduction in the feedwater flow. The Nuclear Steam Supply System (NSSS) control systems such as Steam Bypass Control System (SBCS), Reactor Power Cutback System (RPCS), Feedwater Control System (FWCS), Reactor Regulating System (RRS), Pressurizer Pressure and Level Control Systems (PPCS and PLCS), and Turbine/Generator (T/G) control system are designed to actuate automatically in order to prevent reactor trip due to high pressurizer pressure and stabilize the plant conditions at a new steady state.

The purpose of this paper is to verify and validate the KSNPA by comparing the measured test data with the results predicted by the KSNPA for the LOMFP at 100% power event.

2. Test Description

The main objectives of the LOMFP test at 100% power[2] are as follows:

(1) To demonstrate that the NSSS can accomodate a main feedwater pump trip at 100% power without initiating a Reactor Protection System (RPS) signal or an Engineered Safety Features Actuation System (ESFAS) signal as well as without opening any primary or secondary safety valves and tripping the turbine.

(2) To verify that the turbine setback and runback logic responds properly.

(3) To assess the performance of the NSSS control systems (SBCS, FWCS, RRS, PPCS, PLCS, and RPCS) and the Turbine Control System (TCS) following a main feedwater pump trip.

The test initial conditions are defined as the 100% power steady state conditions[2], and the measured major plant parameters at the time of test initiation are presented in Table 1. As shown in this table, all major initial conditions were within the acceptable range for performing the test, and all the NSSS and T/G control systems were in automatic mode of operation. The test was initiated by manually tripping the #1 Main Feedwater Pump (MFP 01P) while the #1 and #2 MFP were running.

3. Simulation Description

The initial conditions used for the simulation of the load rejection test are also defined as the full power steady state conditions and the performance warranty condition for YGN 4[3] as listed in the Table 1. Though the initial conditions used in the simulation are slightly different from the test initial conditions, the difference can be neglected in verifying the capability of the KSNPA. All NSSS and T/G control systems are set to be in automatic control mode.

4. Results

The test data and the KSNPA predictions for the major plant parameters are plotted in Figures 1 through 6. As shown in Figure 1, the MFP 01P was manually tripped when MFP #1 and #2 were running. Upon tripping the main feedwater pump, the total feedwater flow rate to the steam generator decreses immediately (See Figure 2). This rapid decrease of the feedwater flow rate results in a rapid decrease in the steam generator water level (See Figure 3). The FWCS increases the feedwater pump speed such that the unaffected pump can deliver the required feedwater flow and, then, restores the steam generator water levels to their setpoints. As compared in Figures 1 through 3, in general, the KSNPA predictions reasonably follow the trends of measured data. However, the differences in the main feedwater pump speed trend between about 150 seconds and 400 seconds (Figure 1), the feedwater flow trend between 200 seconds and 400 seconds (Figure 2), and the steam generator level after 120 seconds (Figure 3) are considered to be resulted from the feedwater fluid system modeling because the current KSNPA uses a simple feedwater system model which will be improved later.

As shown in Figure 4, the RPCS dropped the selected CEA group, which is the control bank #5 for this test, on LOSS OF FEEDWATER PUMP STATUS signal, and the RRS start to insert the CEA bank #4 into the core to match the reactor power to the turbine power. The CEA insertion also results in the RCS average temperature decrease (Figure 5). As compared in Figures 4 and 5, the RPCS of the KSNPA actuates properly on tripping one MFP, and KSNPA predictions reasonalby follow the trends of the measured data in general.

As shown in Figure 6, the measured generator power output initially decreased to about 70% by the turbine setback and followed by a further decrease to the final steady state value of 53% by the subsequent turbine runback signal. Although the initial decrease in the generator power output was less than the turbine setback target value of 60%, the steam flowrate to the turbine decreased to the target value. This difference in the generator output power and the turbine steam flowrate is determined to be caused by the existence of large steam reserviors in the Moisture Separator and Reheaters which are located between the high and low pressure turbines. Therefore, the turbine power predicted by the KSNPA, which is based on the steam flow rate to the turbine, agrees with the test data.

In general, reasonable agreement was observed between the KSNPA predictions and the measured data for the LOMFP test at 100% power even though the current KSNPA is a draft version at this stage and will be further upgraded its improved models and control systems later.

5. Conclusion

The Loss of a Main Feedwater Pump test at 100% Power for YGN 4 was successfully simulated using the KSNPA. The comparison of the test data with the KSNPA prediction results showed reasonable agreement in the trends of the plant major parameters. All plant control systems including NSSS and T/G control systems were properly actuated and stabilized the plant conditions to a new steady state conditions. Although there were some differences between the KSNPA predictions and the measured test data in the magnitude and response time, the KSNPA showed its capability to simulate the LOMFP event for the Korean Standard Nuclear Power Plant. Therefore, further tuning on the input data as well as simulation model improvement are deemed to be necessary for the KSNPA for better predictions.

References

(1) 정 원상 외 4인, "한국표준원전 NPA (Nuclear Plant Analyzer) 개발 현황," 한국원자력학회 '95 추계학술발표회, 서울, 1995.10.28.

(2) KEPCO, "Test Procedure for PAT Reactor Power Cutback System," 3S-I-752-01, Rev.0, 8/05/94.

(3) KAERI, "YGN 4 PAT Evaluation Report for Performance Warranty Test," YGN4-SA-PER027-95, Rev. 0, 2/29/95.

Table 1. Initial Conditions of Major Plant Parameters

Parameters	Test Values	Simulation Values
Neutron Flux Power	99%	100%
Turbine Power	92%	100%
Pressurizer Pressure	2240.0 psia	2250. psia
Pressurizer Level	51%	52.1%
RCS Average Temperature	591.5 °F	592.2 °F
RCS Reference Temperature	593.0 °F	592.8 °F
Steam Generatore Pressure	1090 psia	1108.5 psia
Steam Generator Level (NR)	44%	44%

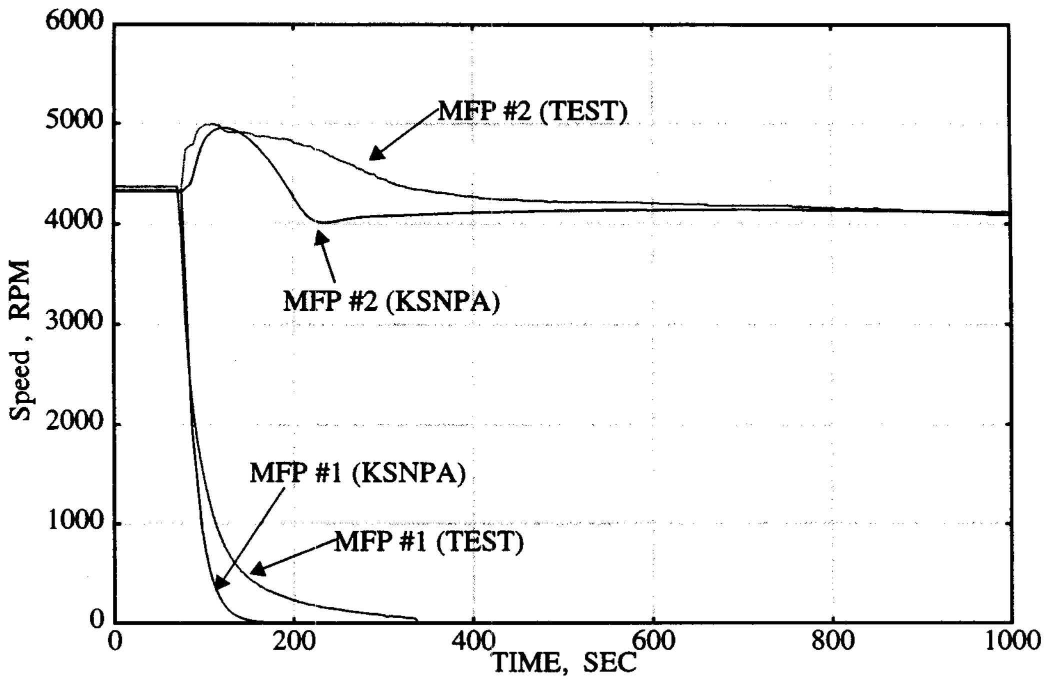

Figure 1. Main Feedwater Pump Speed for Loss of a Main Feedwater Pump

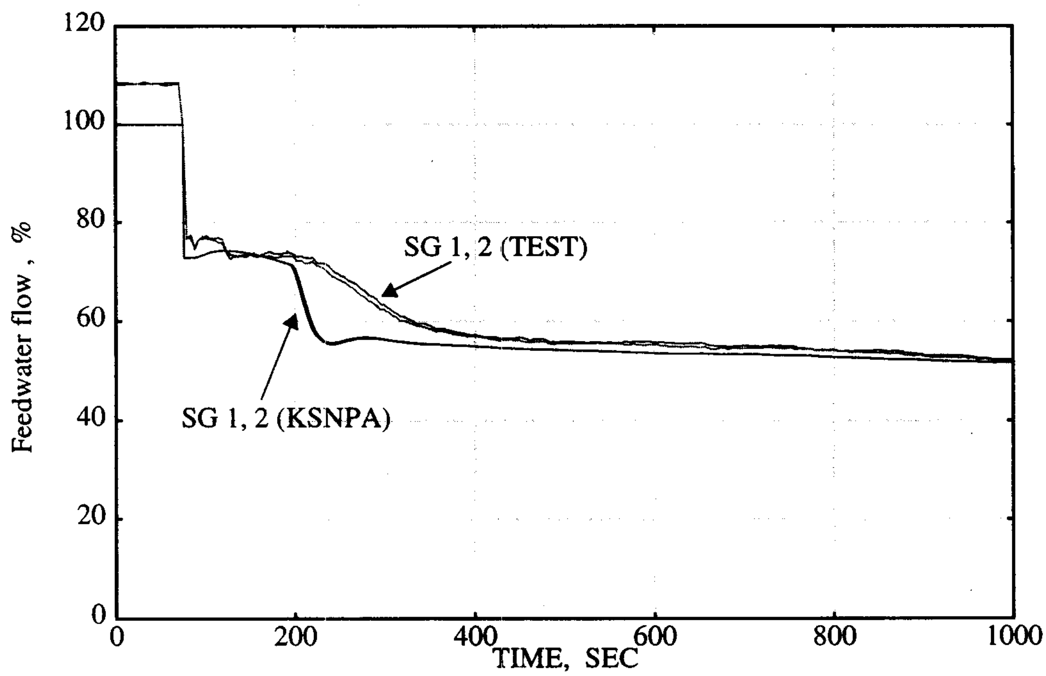

Figure 2. Feedwtater Flow Rate for Loss of a Main Feedeater Pump

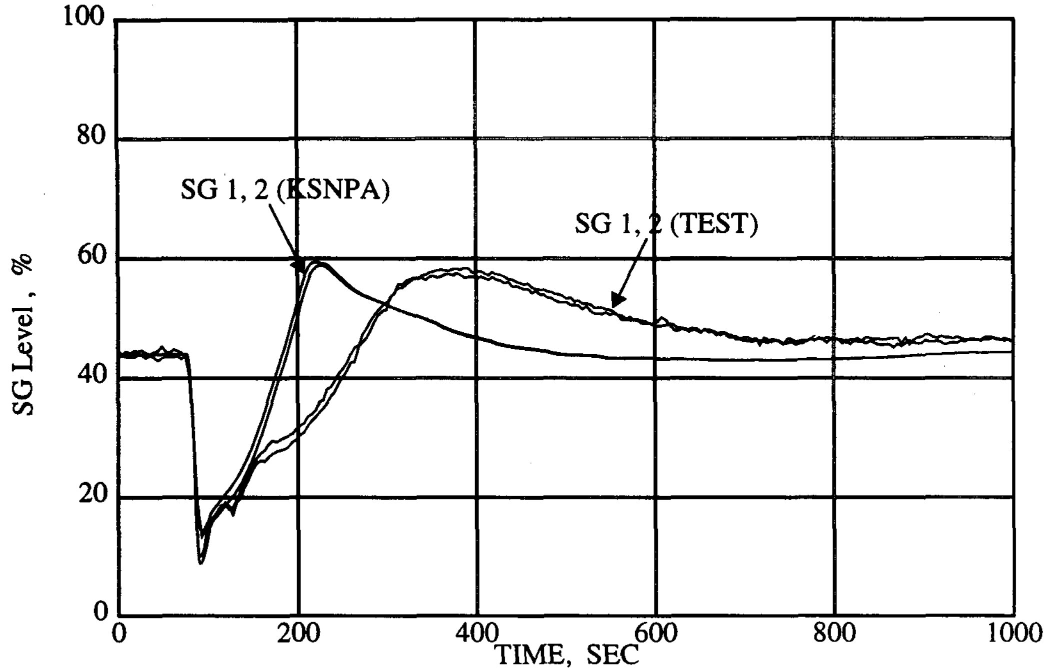

Figure 3. Steam Generator Levels for Loss of a Main Feedwater Pump

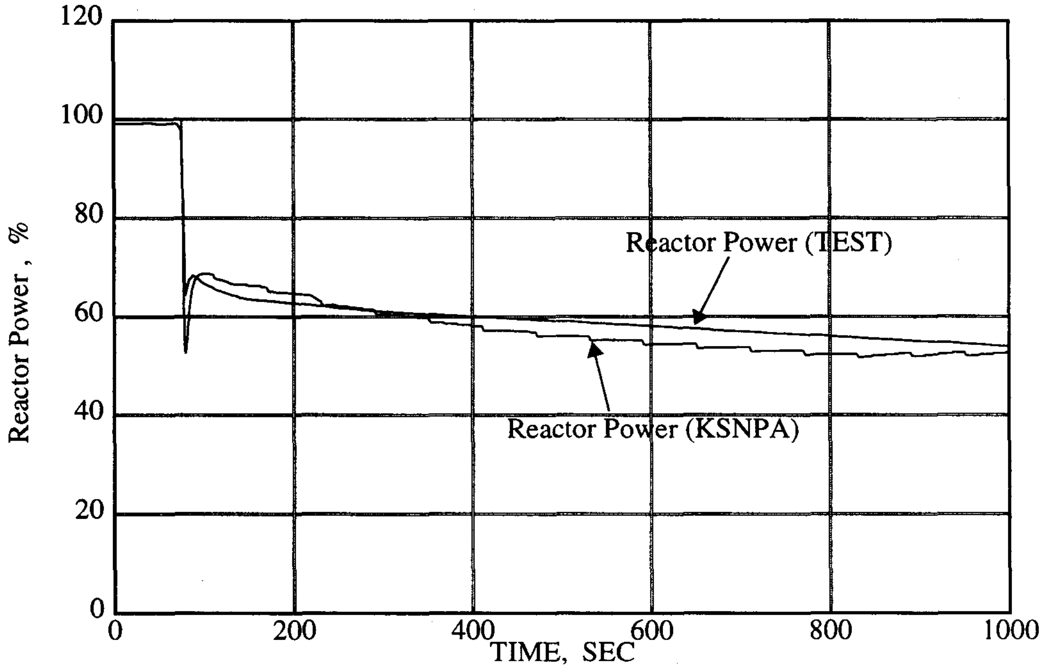

Figure 4. Reactor Power for Loss of a Main Feedwater Pump

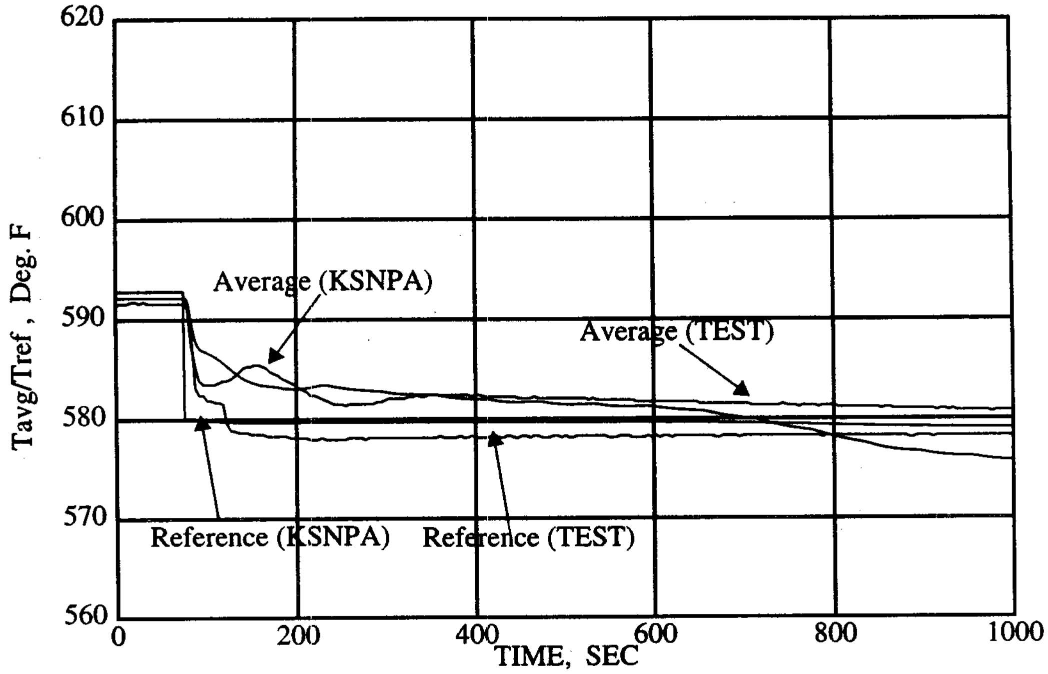

Figure 5. RCS Average and Reference Temperature for Loss of a Main Feedwater Pump

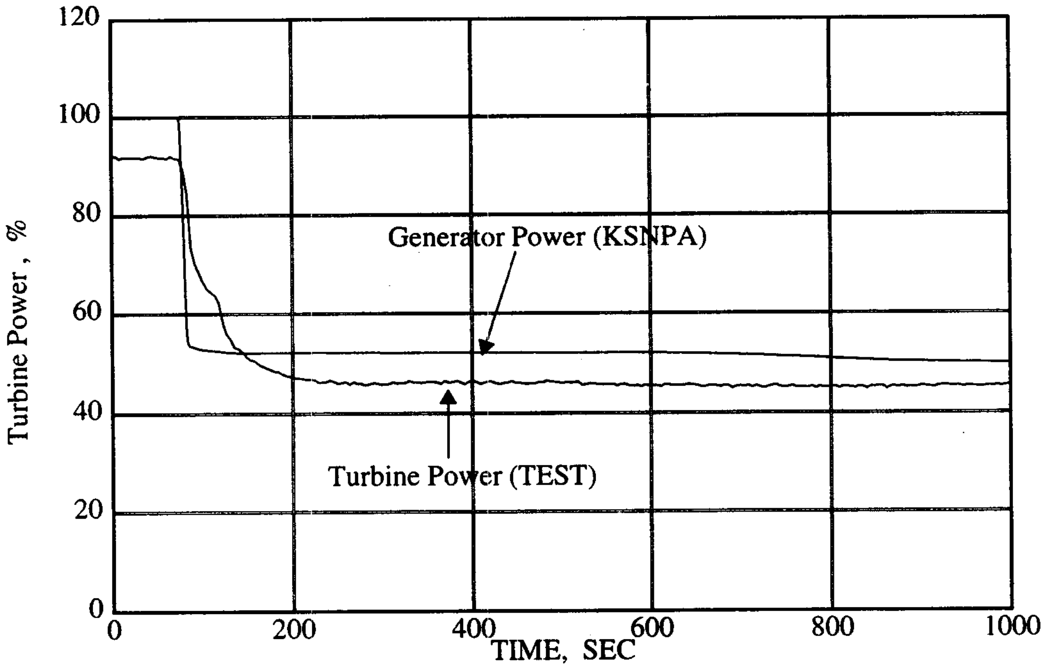

Figure 6. Turbine Power for Loss of a Main Feedwater Pump