Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Analysis of Turbine Load Rejection for APR1400 using SPACE

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1. Introduction

Turbine Load Rejection event is one of the Performance Related Design Basis Event (PRDBE) that can be stabilized using plant control systems without any safety system actuation. The initiation of the event is turbine load rejection from 100% to 5% in 0.019 seconds. Then, big mismatch between the reactor and turbine power initiates an automatic response of many Nuclear Steam Supply System (NSSS) control systems to reach a new stabilized operating condition.

The NSSS control systems of APR1400 is composed of the Power Control System (PCS) and the Process-Component Control System (P-CCS). The PCS includes Reactor Regulating System (RRS), Reactor Power Cutback System (RPCS) and Digital Rod Control System (DRCS). The P-CCS includes the Pressurizer Pressure Control System (PPCS), the Pressurizer Level Control System (PLCS), the Feedwater Control System (FWCS) and the Steam Bypass Control System (SBCS).

The SBCS is designed to cover 55% of maximum steam flow to the turbine when the turbine is not available. Turbine load rejection results in the increase of secondary pressure due to sudden blocking of steam flow to turbine. Then the Reactor Coolant System (RCS) cooling through steam generators is decreased rapidly and the RCS temperature will be increased. To prevent the Main Steam Safety Valve (MSSV) opening, the SBCS uses the turbine bypass valves to allow steam release to the condenser. On the other hand, turbine load rejection initiates the RPCS actuation to reduce the required capacity of turbine bypass valves. The RPCS drops selected group of control rods to decrease the reactor power rapidly to 75%. After the actuation of RPCS, the reactor power is controlled and stabilized to a constant value by the RRS and SBCS.

Turbine load rejection analysis using a newly developed computer code, Safety and Performance Analysis Code (SPACE), is done to evaluate the applicability of SPACE code to the plant performance analysis.

2. Analysis Methodology

2.1 Plant Modeling and Initial Conditions

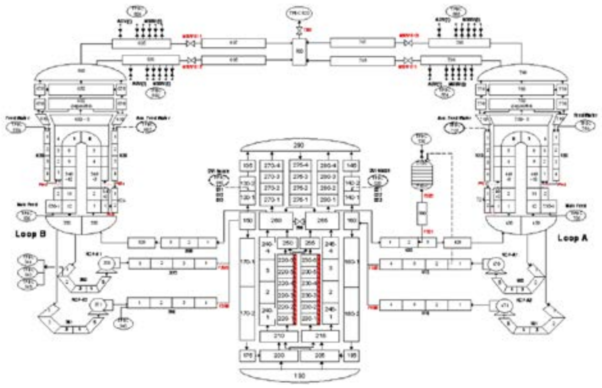

Fig 1. SPACE Nodalization of APR1400

APR1400 plant is two-loop 3983 MWt pressurized water reactor. Fig 1 shows the SPACE nodalization of APR1400. Turbine bypass valves are connected to the common header (C800) as boundary conditions. Table 1 provides the initial plant conditions used in this analysis.

Unlike usual safety analyses such as LOCA and Non-LOCA analyses, this analysis is performed modelling all the control systems (RRS, RPCS, PPCS, PLCS, FWCS and SBCS) in APR1400 for simulating the actual plant behavior without conservative assumption.

Table 1. Initial Conditions for Turbine Load Rejection Analysis

Parameter	Design Value	SPACE
Core Power, MWt	3983	3983
Pressurizer pressure, MPa(a)	15.51	15.51
RCS flow rate, kg/s	20,991	20,991
RCS average temperature, K	580.4	580.2
Secondary pressure, MPa(a)	6.89	6.87
Pressurizer level, %	50	50
Steam Generator level, % NR	50	50

3. Analysis Results

Fig. 2 shows reactor power. The reactor power reduces to 75% rapidly due to RPCS actuation. After the RPCS actuation, the reactor power is stabilized to a constant value below the Automatic Motion Inhibit (AMI) setpoint 55% by RRS. And remained power can be controlled by SBCS.

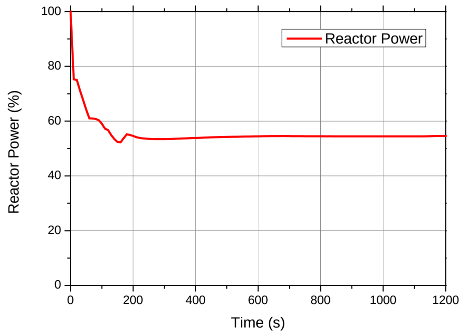

Fig 2. Reactor Power

Fig. 3 shows the turbine power after the event. The turbine power is dropped from 100% power to 5% power in 0.019 seconds. It causes power differences between primary side and secondary side. So it initiates RPCS and SBCS actuations. It is manually inserted by user.

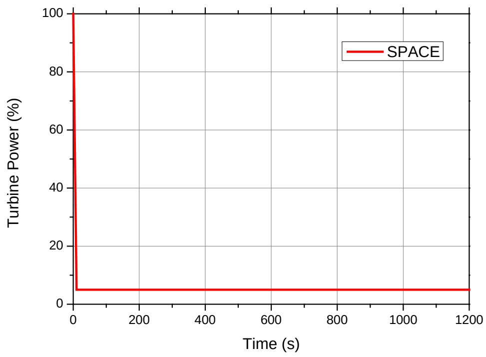

Fig 3. Turbine Power

Fig. 4 shows the steam generator water level. The steam generator water level is controlled by the FWCS and the stabilization of water level requires a longer time than reactor power.

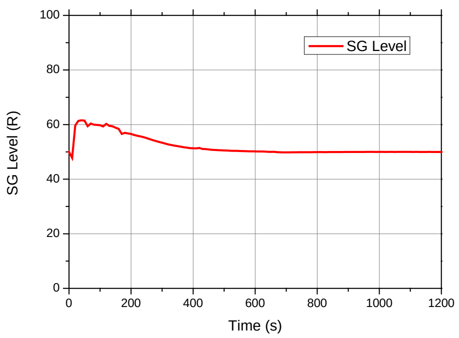

Fig 4. SG Level (NR)

Fig. 6 shows the pressurizer water level. The pressurizer level increases initially due to the increase of RCS temperature. However, the pressurizer water level is stabilized earlier than other parameters by the PLCS.

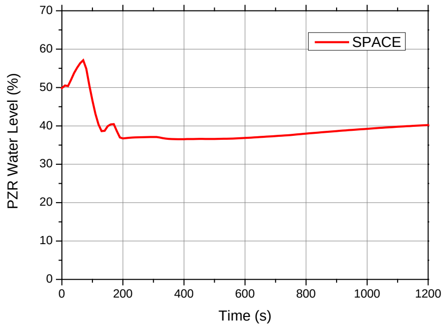

Fig 5. PZR Water Level

4. Conclusions

Turbine load rejection is a typical event to test NSSS control systems since it requires the automatic response of all major NSSS control systems. It is shown that the NSSS control systems of APR1400 have the capability to stabilize the plant without any safety system actuation for turbine load rejection event.

This analysis results show that SPACE code has the capability to analyze the turbine load rejection event. However, further validation is necessary for other PRDBEs such as Two Main Feedwater Pumps Trip, Turbine Load Step Change and Turbine Load Ramp Down (5%/min) to verify the capability of SPACE for the full range of performance analyses.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Research & Development of the Korea Institute of Energy Technology and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry and Energy.

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