Performance Analysis Code Application for Ulchin 1&2 NPP Transients

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1. Introduction

A performance analysis code is developed to evaluate transients of the Ulchin Nuclear Power Plant Units 1 and 2 (UCN 1&2). The UCN 1&2, Framatome-type 3-loop plant, has been operated since 1988. However, there are few performance analysis codes to predict the system behavior following to the plant transients. For better plant operation, performance analysis tools are necessary to increase the plant performance. Therefore, CENTS code is used for performance analysis to evaluate control system setpoints, and improve plant operation. CENTS code was developed by CE and used for simulation of CE-type plants, CENTS has been used in the past for best-estimate analyses of Westinghouse designed 3-loop plant and NRC approved it [1].

2. Model Description

In this section, some of the techniques used to model the RCS, Steam Generator, Feedwater System and Control System are described. CENTS models most of the NSSS and related systems. CENTS is an interactive, faster than real time computer codes for simulation of the NSSS and related systems. It calculates the behavior of a PWR for normal and abnormal conditions including accidents. It is a flexible tool for PWR analysis which gives the user complete control over the simulation through the user-friendly input and output options.

2.1 RCS and Steam Generator Model

UCN 1&2 design features similar to the Westinghouse designed 3-loop plant, realistic control system model with feedwater system model, and best estimated inputs were prepared based on the Kori 3& 4 design. Figure 1 is the RCS modeling for the UCN 1&2.

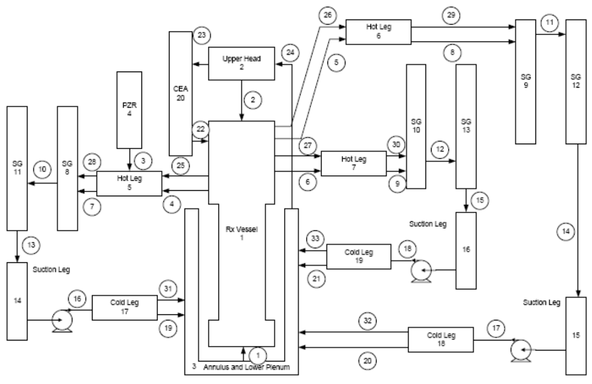

Figure 1. CENTS RCS nodalization

Two phase fluid is introduced in nodes and mass, energy, and momentum equations are solved to get the pressures, temperatures, and flowrates. Interfaces with RCS system such as charging and letdown, pressurizer safety and relief valves, safety injection, etc. are also modeled. After CENTS code was verified and validated for the Westinghouse-type 3-loop plant, the code was updated with new features. However, previous modeling is still effective and main system modeling can be used for the performance analysis.

Three nodes are used for the secondary side of each steam generator – a downcomer, an evaporator region, and a steam dome. This system representation allows accurate modeling of the recirculation phenomena and the downcomer and evaporator water levels. Mass and energy balances are made for each node. The flow between the downcomer and the evaporator, and the main steam flow are calculated using momentum balances. The pressure and remaining state properties are calculated from the mass and energy in each node

2.2 Feedwater System Model

Detailed feedwater system model is developed for the purpose of performance analysis for the UCN 1&2. Feedwater systems from condensate to SG nozzle and auxiliary feedwater system are modeled as shown in Figure 2.

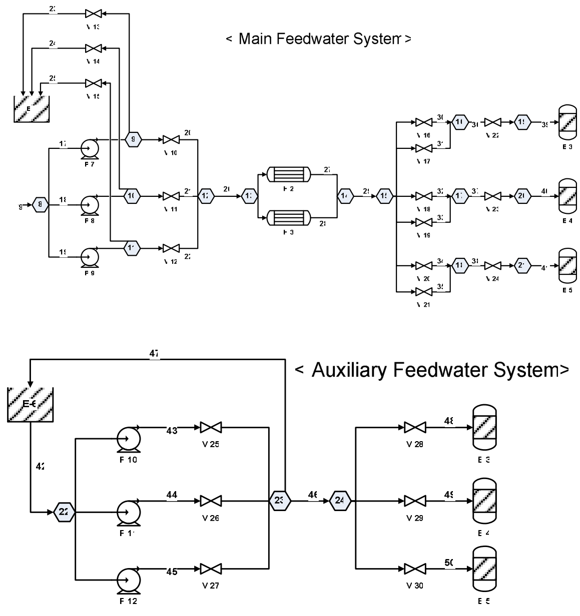

Figure 2. CENTS feedwater system nodalization

Steady state mass and momentum equations for the nodes and flowpath are solved to obtain pressures and flowrates. A secondary heat balance is introduced to determine the feedwater enthalpy. Heat addition by heaters is a function of turbine power.

2.3 Control System Model

CENTS has generic modules for control system modeling. System based model is prepared as input database. The CENTS user may change the values of input variables (setpoints, manual control signals and certain hardware performance characteristics) supplied in the database during the transient simulation.

The control system and the protection system including permissive signal are modeled. The modeled control systems are Rod Control System, Pressurizer Level and Pressure Control System, Steam Dump Control System, SG Level Control System, and Feedwater Pump Speed Control Systems. Sensor response times are modeled and valve response times are also modeled if needed.

3. Simulation of Performance Related Events

Typically, the ability to maintain a steady state is the first test applied to a plant simulation code. Steady state and several typical performance related events are simulated with CENTS code. Table 1 shows the comparison of the major steady state parameters at full power between the results from CENTS code and plant operating conditions of UCN 1&2.

Table 1. Comparison of parameters at full power condition

Parameters	Plant Condition	CENTS Code
T-avg (°F)	582.6	582.9
Pressurizer Pressure (psia)	2250	2250
PZR Level (%)	66.1	66.3
SG Pressure (psia)	836.9	836.1
SG Level (%)	44	44
Feedwater Temperature (°F)	427.1	426.2

To verify the code simulation, the plant transient data sets would be the applicable records. However, real plant transient data sets are not enough to cover all transient evaluation, so several transients are simulated to obtain reasonable analysis results. Among the various simulations for performance related events for code verification, a full load rejection transient occurred in UCN 1&2 is used for this evaluation. Figure 3 shows the comparison of reactor power as calculated by CENTS to measured plant response of full load rejection transient. The CENTS simulation results are reasonably acceptable with the plant data. In spite of the similar behavior, CENTS results for SG narrow range level show different trend to the plant data due to the lacks of data set. Figure 4 shows the SG narrow range level during the plant transient.

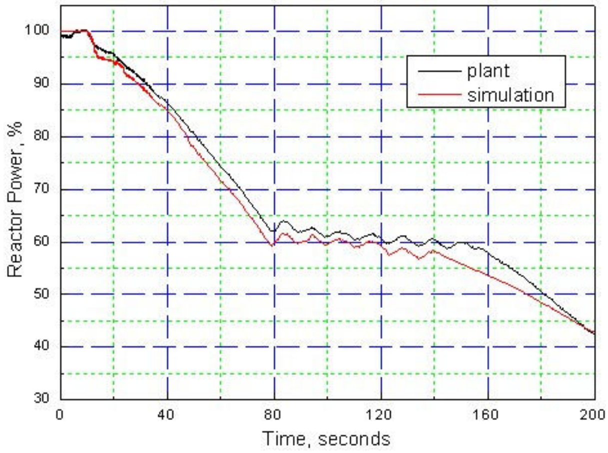

Figure 3. CENTS simulation result with plant transient

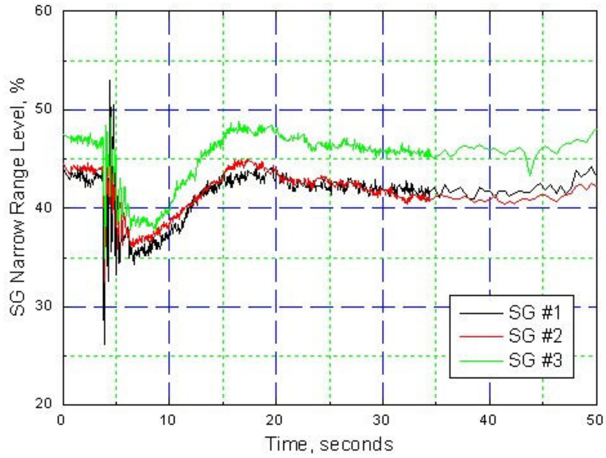

Figure 4. SG level from full load rejection in UCN 1&2

4. Conclusion

CENTS code is developed for performance analysis for UCN 1&2. For the code simulation, feedwater system and control system are modeled in detail, and several performance related events as well as one plant malfunction are simulated. The results of those simulations are reasonably acceptable. With more code verification efforts, CENTS code will be used for performance analysis such as control system setpoints evaluation to improve plant operation.

REFERENCES

[1] NRC Letter, Robert C. Jones (NRC) to S.A. Toelle (ABB CE), Febrary 24, 1995, TAC M85911

[2] I. H. Song, et al., "Performance Analysis of Westinghouse 3-Loop Plants with CENTS Code," Transactions of the Korean Nuclear Society Autumn Meeting, Busan, Korea, October 27-28, 2005.