Evaluation of Steam Generator Level behavior for Determination of Turbine Runback rate on COPs trip for Yonggwang 1&2 Power Uprating Units

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1. Introduction

4.5% power uprate project has been progressing for the first time in Yonggwang 1&2(YGN1&2). Reviews for design change due to the power uprate were accomplished [1]. Steam generator level behavior was one of the most important parameters because it could be cause of reactor trip or turbine trip. As the results of the reviews, YGN1&2 had to reassess it for change of turbine runback rate when turbine runback occurs due to the condensate operating pumps (COP) trip. This study has been carried out for evaluating the steam generator level behavior for determination of turbine runback rate on COPs trip for Yonggwang 1&2 Power Uprating Units.

The steam generator water level evaluation program for YGN1&2 (SLEP-Y1) has been developed for it. The program includes models for the steam generator water level response. SLEP-Y1 is programmed with advanced continuous system simulation language (ACSL). The language has been used to simulate physical systems as a commercial tool used to evaluate system designs [2]..

2. System Modeling

The model includes NSSS components and control systems to evaluate steam generator level behavior. For modeling of the primary system, simple point-kinetics is used for the reactor. And a transport delay time model is used for determining the temperature of the hot and cold legs. A first order lag on the actual RCS average temperature represents the hot and cold leg temperatures, and the RCS pumps are not modeled. Then in the primary system the pressure change and heat transfer due to the pumps are not calculated.

The steam generator model can effectively be separated several sections. The sections consist of the primary side tubes, secondary side tube bundle area, riser, upper downcomer, lower downcomer and steam dome as shown in Fig.1.

The regions have separate mass and energy balances in order to determine exit properties. An overall steam generator momentum is then balanced to calculate the change in the various section flow rates. The "Tube Bundle Boiling" region calculates a boiling height for a phase change location; this boiling height will change depending upon operating parameters. In the upper downcomer, mixing between the feedwater and the recirculation flow is assumed to occur only below the feedring.

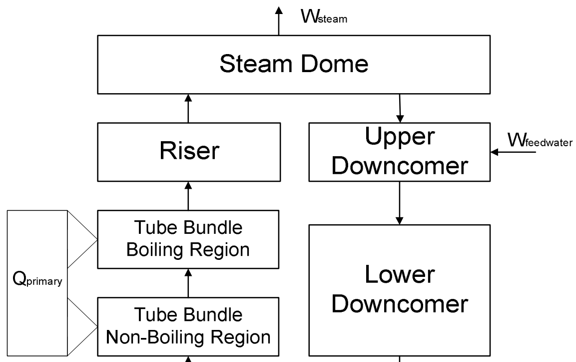


Fig.1 Steam generator modeling

The heat transfer from primary to secondary system is determined with heat transfer coefficients, which is expressed as a function of the logarithmic mean temperature difference.

The control system was modeled based on the Westinghouse plants equipped with Model F steam generators. The control systems include the reactor control, steam generator level control, feedwater pump speed control and steam dump control. The detailed value and set-point of each of the control systems logic, input, and variables were achieved from Yonggwang 1&2 control systems for updating [2].

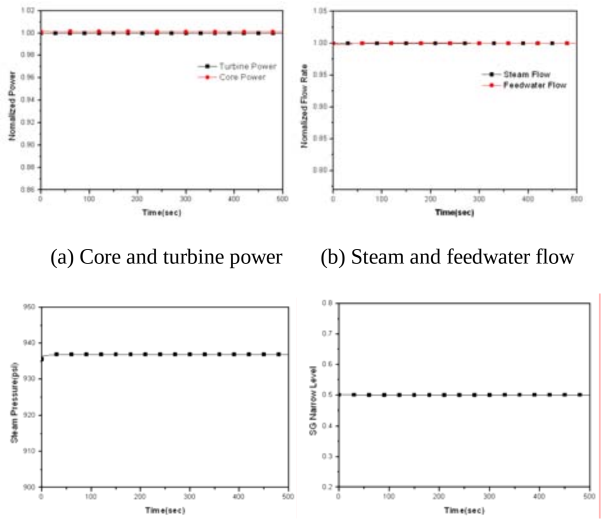
3. Analysis Method and Results

In order to verify the initial conditions after power uprate, steady state analysis was conducted. Table 1 and Fig.2 show the comparison results between the analysis and nominal data at 100% full power operation for YGN1&2. As a result, they are consistent with the results within 0.15% relative errors. Therefore it was found that initial conditions were set up appropriately.

YGN1&2 has 4 COPs, where 3 pumps are operating and one is standby at full power operation. If more than 2 pumps are unavailable, the turbine runback begins and the power decreases to 90% power. The present rate is set to 50%/min [3]. However, according to the design change the steam generator level behavior was estimated for the following two cases in this study.

Table 1 Steady state calculation

Description	Nominal data	Analysis results	Error
NSSS Thermal Power, MWt	2.91E+03	2.92E+03	0.15%
Steam Flow, lb/hr	1.30E+07	1.29E+07	-0.07%
SG Steam Pressure, psia	9.37E+02	9.37E+02	-0.01%
Feedwater Flow, lb/hr	1.30E+07	1.29E+07	-0.07%
Feedwater Temp., °F	4.46E+02	4.46E+02	0.00%
SG Level (NR), %	5.00E+01	5.00E+01	0.00%



(a) Core and turbine power (b) Steam and feedwater flow

(c) Steam pressure (d) Steam generator water level

Fig.2 Results for steady state calculation

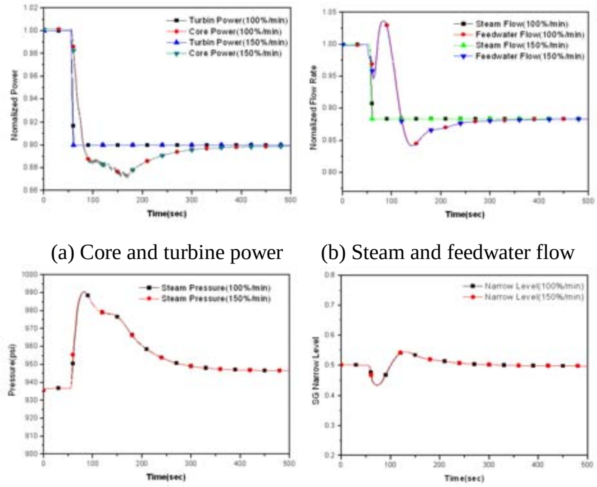
- Case 1. Turbine runback to 90% power with 100%/min runback rate
- Case 2. Turbine runback to 90% power with 150%/min runback rate

When COP is unavailable, it could have an effect on the feedwater pressure and temperature. So we assumed that the pressure decrease as much as the condensate flow decrease and that the temperature depend on the turbine power. The turbine runback transient started at 50 seconds and the transient finished at 500 seconds.

Table 2 and Fig.3 show the turbine runback analysis results. At the final state, most of parameters were stable. The power decreased gradually into 90%. Especially the steam generator levels for the both cases were within the safety range from lo-lo level (17%) to hi-hi level (78%) trip set-points[3] as shown in Fig. 2. It means that the steam generator levels could be controlled well during turbine runback by COPs trip whether the rate is 100%/min or 150%/min.

Table 2 Results for turbine runback due to COPs

Description	Case 1. 100%/min turbine runback	Case 2. 100%/min turbine runback	Remark
Normalized NSSS Thermal Power, %	89.89	89.89	final state
SG Steam Pressure, psia	948.38	948.38	final state
SG Level (NR), %	49.69	49.69	final state
	54.38	54.4	max
	43.82	43.74	min



(a) Core and turbine power (b) Steam and feedwater flow

(c) Steam pressure (d) Steam generator water level

Fig.3 Responses for turbine runback due to COPs trip

4. Conclusion

The simulation program SLEP-Y1 has been developed to evaluate steam generator level behavior for YGN1&2 uprating units. The steam generator level behavior during turbine runback by COPs trip was evaluated with the SLEP-Y1. The results showed that the steam generator levels could be controlled well for the both cases of 100%/min and 150%/min turbine runback rates. The SLEP-Y1 will be useful for evaluation of other transient and sensitivity studies as other design changes in YGN1&2

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