Steam Generator Rebalancing Exercise

OBJECTIVES

- Illustrate considerations important for rebalancing the steady-state behavior of TRACE U-Tube SG models

OVERVIEW OF STEPS

1. Run the stand-alone steam generator system model
2. Rebalance the steam generator system model to achieve new targets

STEP 1. RUN THE STAND-ALONE STEAM GENERATOR SYSTEM MODEL

Methods used in this exercise are generally applicable to rebalancing the steady-state behavior of BWR reactor vessels (exchanging power delivered from SG tubes to power delivered to the core fuel rods and considering added jet pump momentum)

1. Open the SG-1.med file located in the Day3/Afternoon/SteamGeneratorModeling/SteamGeneratorExercise folder
   a. Model is a typical U-Tube steam generator used in many PWRs.
   b. Steam generator primary side
      1. Tubes – PIPE 305
      2. Inlet (hot leg) flow and temperature from FILL 1
      3. Outlet (cold leg) pressure from BREAK 11

c. Heat structures representing tubes are attached to PIPE 305 (inside) and the SG boiler PIPE 375 (outside)

d. Steam Generator Secondary side

1. Downcomer – PIPE 370
2. Separator, dryer, steam dome – TEE 380
3. Turbine header pressure boundary – BREAK 555
4. Steam line – PIPE 31
5. MSIV – VALVE 532
6. Steam line header – PIPE 545
7. Turbine stop/control valve – VALVE 550

e. Note that there is a "Controls" tab containing controllers for the turbine control valve and the downcomer level

1. Valve 550 (turbine control) is adjusted to achieve the desired primary system average loop temperature
2. Main feedwater flow rate (FILL 21) is modified to obtain desired downcomer level
3. Connection flow areas at top and bottom of boiler region are adjusted to achieve desired recirculation flow ratio and secondary mass

f. Additional signals and control blocks provide

1. Steam generator power
2. Recirculation ratio
3. Secondary system mass

The animation model SGAnim.med that displays key TRACE outputs for this exercise is available in the SteamGeneratorModeling folder to facilitate extraction of the data from multiple TRACE runs

2. Run the base model (SG-1)
   a. If desired, set the job name by clicking on the TRACE block in the Job Stream view window and modifying the "Name" block in the Properties Window
   b. If desired, set the step name by clicking on the "Execute" button in the Job Stream view window and modifying the "Name" block in the Properties Window
   c. Lock the view and submit the model for execution by clicking on the "Execute" button in the Job Stream View Window.
   d. Click the "OK" in the "Submit Stream" dialog window to submit the job.
3. The animation SGAnim.med file should open and connect automatically, but if it does not, open the SGAnim.med file in the model editor and do the following:
   a. In the Navigator Window within the animation, select Data Sources → Master
   b. Expand the "Source Run URL" in the Properties Window
   c. Locate and highlight the job name you selected previously (defaults will be "Single_Step" and "Base_Job") and click "OK"
   d. Connect to the data file - 
   e. Click on the "Play" icon in the toolbar to animate the TRACE calculation
      1. Note that the TRACE-calculated and desired target parameter values are shown during the animation
4. Record the TRACE-calculated parameter values in the SG-1 column in the Table below for comparison with the Target values and the updated values from the runs that follow

5. We will proceed to the next step after a short discussion on what we have observed. While some of you may be able to complete this process without the extra discussion, please wait to proceed so that everyone can benefit from our collective experience. When it seems like most people have completed the first step, we will move on.

Run ▶ **Parameter (TRACE Data Channel) ▼**	**SG-1**	**SG-2**	**SG-3**	**SG-4**	**Target Value**
Primary System					
Hot Leg Temperature, K (fill 1, tln-1A01)					591.4
Cold Leg Pressure, MPa (break 11, pn-11A01)					15.5
Cold Leg Temperature, K (pipe 305, tln-305A18)					558.5
Average Loop Temperature, K (control block 202)					575.0
Hot Leg Mass Flow Rate, kg/s (fill 1, fxmass-1)					4400
SG Power, MW (control block 304)					761.7
Secondary System					
Feedwater Temperature, K (fill 21, tln-21A01)					500.6
Steam Dome Pressure, MPa (tee 380, pn-380A13)					5.7
Steam Flow Rate, kg/s (valve 550, rmvm-550A09)					424.2
Downcomer Level, m (control block 101)					10.0
Recirculation Ratio, - (control block 322)					3.0
Secondary System Mass, kg (control block 401)					26000

Run ▶ Parameter (TRACE Data Channel) ▼	SG-5	SG-6	SG-7	SG-8	Target Value
Primary System					
Hot Leg Temperature, K (fill 1, tln-1A01)					591.4
Cold Leg Pressure, MPa (break 11, pn-11A01)					15.5
Cold Leg Temperature, K (pipe 305, tln-305A18)					558.5
Average Loop Temperature, K (control block 202)					575.0
Hot Leg Mass Flow Rate, kg/s (fill 1, fxmass-1)					4400
SG Power, MW (control block 304)					761.7
Secondary System					
Feedwater Temperature, K (fill 21, tln-21A01)					500.6
Steam Dome Pressure, MPa (tee 380, pn-380A13)					5.7
Steam Flow Rate, kg/s (valve 550, rmvm-550A09)					424.2
Downcomer Level, m (control block 101)					10.0
Recirculation Ratio, - (control block 322)					3.0
Secondary System Mass, kg (control block 401)					26000

STEP 2. REBALANCE THE STEAM GENERATOR SYSTEM MODEL TO ACHIEVE NEW TARGETS

1. Rebalancing Run SG-2:

a. Save your SNAP file as SG-2.med

1. "File → Save As" and rename the file to SG-2.med

b. Make the following changes:

1. FILL 1 – Mass flow rate 4,400 kg/s
2. FILL 1 – Liquid temperature 591.4 K

3. BREAK 555 – Pressure to 5.39 MPa
4. Control Block 203 – 575.0 K (Input for Constant 1)
5. FILL 21 – Liquid temperature to 500.6 K

c. Re-run the model and record the results in the SG-2 column of the table

d. Save the model to preserve changes

e. Pause for a discussion of the results before continuing

2. Rebalancing Run SG-3:

a. Save your SNAP file as SG-3.med

b. Make the following changes:

1. Reduce the flow area fraction in VALVE 51 (between the boiler and separator) from 0.6 to 0.3
2. Reduce the flow area fraction in VALVE 41 (between downcomer and boiler) from 0.8 to 0.75

If the view is locked, the valve flow area fraction can be modified by changing the values in the entry boxes next to the associated valve. The value can also be changed in the Properties Window as usual

c. Re-run the model and record the results in the SG-3 column of the table

d. Save the model to preserve the changes

e. Pause for a discussion of the results before continuing

3. Rebalancing Run SG-4:

a. Save your SNAP file as SG-4.med

b. Make the following changes:

1. Control Block 203 – 575.2 K (Input for Constant 1)

c. Re-run the model and record the results in the SG-4 column of the table

d. Save the model to preserve the changes

e. Pause for a discussion of the results before continuing

4. Rebalancing Run SG-5:

a. Save your SNAP file as SG-5.med

b. Make the following changes:

1. Control Block 203 – 575.9 K (Input for Constant 1)

c. Re-run the model and record the results in the SG-5 column of the table

d. Save the model to preserve the changes

e. Pause for a discussion of the results before continuing

5. Rebalancing Run SG-6:

a. Save your SNAP file as SG-6.med

b. Make the following changes:

1. Control Block 203 - 575.0 K (this allows an investigation of the change of the flow effect without the compromise in average temperature)
2. FILL 1 – Mass flow rate 4,172 kg/s

c. Re-run the model and record the results in the SG-6 column of the table

d. Save the model to preserve the changes

e. Pause for a discussion of the results before continuing

6. Rebalancing Run SG-7:

a. Save your SNAP file as SG-7.med

b. Make the following changes:

1. FILL 1 – Mass flow rate 4,400 kg/s
2. HTSTR 930 – surface multiplier from 3102.2 to 3000.0 (in the Properties Window)

c. Re-run the model and record the results in the SG-7 column of the table

d. Save the model to preserve the changes

e. Pause for a discussion of the results before continuing

7. Rebalancing Run SG-8:

a. Save your SNAP file as SG-8.med

b. Make the following changes:

1. HTSTR 930 – surface multiplier from 3000.0 to 3102.2
2. Create a new constant control block (number -501) with a value of 0.21811615 (from SG-3 results for control block 204). This is the normalized area for VALVE 550 at the end of the SG-3 run.
3. VALVE 550 – change "Valve table independent variable" from control block 204 to control block -501 – this locks VALVE 550 to the open area at the end of the SG-3 run

c. Re-run the model and note that the results are virtually identical to the SG-3 results

d. Control block -501 – Change flow area to 0.1171

1. Adjusts fixed flow area of VALVE 550
2. Identified value by trial-and-error

e. Re-run the model and record the results in the SG-8 column of the table

f. Save the model to preserve the changes

POINTS TO CONSIDER

- How can we decide what an acceptable compromise is for a given situation?
- What counts as good agreement with a target value?
- The tables below show results computed during preparations of this exercise

Run ▶ Parameter (TRACE Data Channel) ▼	SG-1	SG-2	SG-3	SG-4	Target Value
Primary System					
Hot Leg Temperature, K (fill 1, tln-1A01)	591.1	591.4	591.4	591.4	591.4
Cold Leg Pressure, MPa (break 11, pn-11A01)	15.5	15.5	15.5	15.5	15.5
Cold Leg Temperature, K (pipe 305, tln-305A18)	560.8	558.5	558.6	558.9	558.5
Average Loop Temperature, K (control block 202)	576.0	575.0	575.0	575.2	575.0
Hot Leg Mass Flow Rate, kg/s (fill 1, fxmass-1)	4259	4400	4400	4400	4400
SG Power, MW (control block 304)	719.3	803.3	803.1	794.6	761.7
Secondary System					
Feedwater Temperature, K (fill 21, tln-21A01)	488.7	500.6	500.6	500.6	500.6
Steam Dome Pressure, MPa (tee 380, pn-380A13)	6.1	5.7	5.7	5.8	5.7
Steam Flow Rate, kg/s (valve 550, rmvm-550A09)	386	443	443	438	424.2
Downcomer Level, m (control block 101)	10.0	10.0	10.0	10.0	10.0
Recirculation Ratio, - (control block 322)	4.0	3.4	3.0	3.0	3.0
Secondary System Mass, kg (control block 401)	29319	28274	27649	27741	26000

Run ▶ Parameter (TRACE Data Channel) ▼	SG-5	SG-6	SG-7	SG-8	Target Value
Primary System					
Hot Leg Temperature, K (fill 1, tln-1A01)	591.4	591.4	591.4	591.4	591.4
Cold Leg Pressure, MPa (break 11, pn-11A01)	15.5	15.5	15.5	15.5	15.5
Cold Leg Temperature, K (pipe 305, tln-305A18)	560.3	558.5	558.6	560.3	558.5
Average Loop Temperature, K (control block 202)	575.9	575.0	575.1	575.9	575.0
Hot Leg Mass Flow Rate, kg/s (fill 1, fxmass-1)	4400	4172	4400	4400	4400
SG Power, MW (control block 304)	762.9	761.7	800.8	761.5	761.7
Secondary System					
Feedwater Temperature, K (fill 21, tln-21A01)	500.6	500.6	500.6	500.6	500.6
Steam Dome Pressure, MPa (tee 380, pn-380A13)	5.9	5.8	5.7	6.0	5.7
Steam Flow Rate, kg/s (valve 550, rmvm-550A09)	421	420	441	420	424.2
Downcomer Level, m (control block 101)	10.0	10.0	10.0	10.0	10.0
Recirculation Ratio, - (control block 322)	3.2	3.2	3.0	3.2	3.0
Secondary System Mass, kg (control block 401)	28084	27993	27657	28100	26000