Loop Closure – Exercise Problem

Objectives

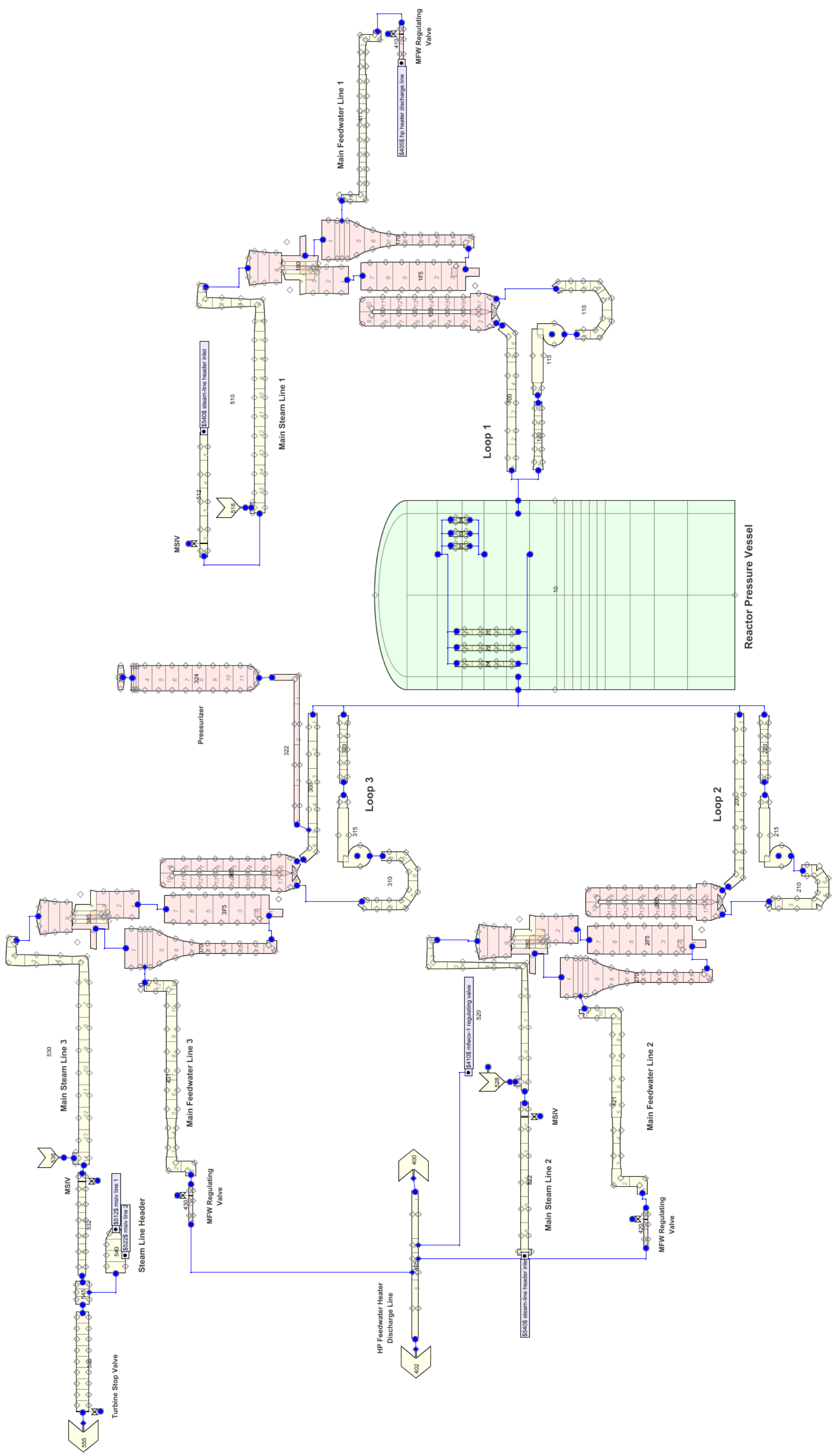
- Gain experience in using the SNAP Loop Checker routine to check for loop closure issues.
- Learn methods of finding loop closure issues and fixing problem area(s).
- Using the TRACE static-check steady state option to check for non-physical flows in a stagnant flow situation.

Model Background and Description

System thermal/hydraulic models (commercial power plants or experimental facilities) are used for a variety of transient simulations. These models can contain several closed loops, for instance, the primary loop in a pressurized water reactor (PWR) or the recirculation loop in a boiling water reactor (BWR). A PWR primary loop contains the following components, starting at the reactor vessel upper plenum: a hot leg, a steam generator, a loop seal, a reactor coolant pump and a cold leg. The cold leg is connected to the reactor vessel downcomer. When modeling closed loop systems, it is important to assure loop closure, i.e., that the elevation change through the loop sums to zero. If a loop is not closed, non-physical flows are calculated during periods where natural circulation or stagnant flows are expected.

A model of a three-loop pressurized water reactor is used for this exercise. The three primary loops should be identical in geometry and nodalization. Each loop contains a hot leg, a steam generator, a loop seal, a reactor coolant pump and a cold leg. The three hot legs are connected to the vessel component at the same elevation as the three cold legs. Each steam generator receives main feedwater from a common feedwater header and discharges steam into a common steam line header upstream of the turbine stop valve.

The figure below shows the layout of the PWR model.


Main Feedwater Line 1
MFW Regulating Valve
$405S hp heater discharge line
Main Steam Line 1
$540S steam-line header inlet
MSIV
Loop 1
Reactor Pressure Vessel
Pressurizer
Loop 3
Loop 2
Main Steam Line 3
Main Feedwater Line 3
MFW Regulating Valve
$512S msiv line 1
$522S msiv line 2
Steam Line Header
Turbine Stop Valve
HP Feedwater Heater Discharge Line
$410S mfwcv-1 regulating valve
MSIV
Main Steam Line 2
$540S steam-line header inlet
Main Feedwater Line 2
MFW Regulating Valve

Overview of Steps

1. Make a Base Static Check Calculation
2. Using SNAP to Locate Open Loop Errors
3. Correcting Loop Closure Errors
4. Run a Final Static Check Calculation

Step 1 Make a Base Static Check Calculation

1. Open up the PWR-SS.med file located in:

   Day2\Morning\TRACE_Modeling_Issues\Loop-Elevation-Closure

2. Prepare the model to make a 500 second Static-Check Steady-State calculation.
   a) Under Model Options (Navigation window) assure that the steady-state mode is using (5) Static-Check Steady-State.
   b) Set the calculation end time to 500 seconds (Timestep Data, under Model Options)
   c) To facilitate this exercise, an animation mask is available to view the mass flow response in the primary loops and in the secondary side feedwater and steam lines. In the tab titled "Job Stream", assure the "Loop-Check-Anim.med" animation model is connected (located in the Day2\Morning\TRACE_Modeling_Issues\Loop-Elevation-Closure folder).
3. Submit the base calculation
   a) Lock the view
   b) Click on the submit button.
4. Note the behavior of the primary and secondary flows.

Discussion:

There are six steady-state calculation options:

5. no steady-state calculation,
6. generalized steady-state (GSS) calculation,
7. Constrained steady-state (CSS) calculation,
8. GSS calculation with hydraulic-path steady-state initialization (HPSSI)
9. CSS calculation with HPSSI, and
10. Static-check steady-state calculation

Steady-state calculation option 5 checks to see if zero flow can be achieved with the pumps turned off and no wall-to-fluid heat transfer. This option automatically turns off all power to the pumps and fuel rods. In this situation, the loop flows should decay to zero.

For this initial static check calculation, what is observed about the primary and secondary side flows.

Step 2 Using SNAP to Locate Open Loop Errors

This step provides a process, using SNAP, to locate loop closure issues.

> TRACE does not have an internal loop closure checking routine outside of the static-check steady-state mode. As such, if a model contains loop closure issues, the code continues to execute regardless of the issues. For some transient simulations, such as a small break LOCA or long term cooling, loop closure issues can lead to some false conclusions about the simulation. TRACE provides some limited information concerning elevation change across components that is sometimes useful for finding the discontinuity.

The SNAP "Check Model" routine contains several tests on the TRACE input model including a test for loop closure. If a loop has closure issues, SNAP provides sufficient ways to find and correct the problem((s).

1. In your SNAP environment, return to the PWR-SS model.
2. Locate and click on "Tools" in the main toolbar and select "Check Model"
3. An error report window will appear that provides a report of the several tests SNAP performs a check on. Among these tests is a check for loop closures.
   a) **Note that in the loop check validation test section there are two loops that do not pass the loop closure test.**

Discussion:

It is always a good practice to perform a "Check Model" and look for issues that may affect the results of a TRACE simulation.

Step 3 Correcting Loop Closure Errors

We note that one of the loop closure errors is located in the primary side of the model:

> From VESSEL 10 to PIPE 220 to PUMP 215 to PIPE 210 to PIPE 205 to PIPE 200 and back to VESSEL 10

From this information we deduce that the loop closure issue is in Loop 2.

To facilitate this exercise step, a view of just the primary side components is provided in the "Primary Loops" tab.

1. Click on the view Tab titled “Primary Loops” at the bottom of the SNAP view window.
2. The loop error can be found two different ways:
   a) We know the hot leg and cold leg connect to the vessel at the same elevation

(level). We can go around Loop 2 and using the GRAV terms calculate the elevation change for each cell, sum them up and determine where the error might be. (Note that by clicking on any one of the components in the loop and opening up the component geometry information, SNAP already provides the elevation change for each component.) The drawback of this method is unless we know more information about the construction of this input model (i.e. a model input notebook) it may be difficult to know which modeled cell in the loop may have the wrong elevation change.

b) From the discussion at the beginning of this exercise, we know that the primary loops are identical in geometry and nodalization. One of the features of SNAP is it contains a component to component comparison. This comparison feature is activated by right-clicking on a component (such as the hot leg in loop 1) and selecting "Select Left Side to Compare" and then right-clicking on a similar component (such as the hot leg in loop 2) and selecting "Compare to ….". Note that multiple components can be selected and compared to another set of selected components. For instance, all of the components in primary loop 1 can be compared to all of the components of primary loop 2.

4. Select either option "a" or option "b" to locate and fix the loop closure issue in loop 2.
5. After fixing the input error, perform another "Check Model" to assure your correction solved the open loop issue in Loop 2.

The second loop error is in the balance of plant components and occurs along the path:

> From PIPE 540 to PIPE 545 to VALVE 532 to TEE 530 to TEE 380 to PIPE 375 to PIPE 370 to PIPE 431 to VALVE 430 to PIPE 405 to VALVE 420 to PIPE 421 to PIPE 270 to TEE 280 to TEE 520 to VALVE 522 back to PIPE 540.

To facilitate the resolution of this closure issue, a view of the balance of the plant components is provided in the "Balance of Plant" tab in the model editor.

Note in this view, PIPE 405 (feedwater header) and PIPE 540 (main steam line header) are common components to all three loops in the balance of plant.

1. Following the loop error check listed above, we conclude the loop error is either in loop 3, or loop 2. Determine which loop the loop closure issue is in.
   a) Since PIPE 405 and PIPE 540 are common among the three loops we can check loop closure between Loop 3 and Loop 1 to see if the loop closure error is in Loop 3.
   b) Select all of the components in Loop 3 and Loop 1 including PIPE 405 and PIPE 540.
   c) Once the components are selected, right-click and select "Loop Check Selection". In the Loop Closures window we can see if the selected loop **passed** or **failed** the loop closure test. From this simple loop check, which loop contains the error?
2. Since PIPE 405 and PIPE 540 are common components to the three loops, and knowing that the steam generator secondary side nodalizations are identical, we deduce the elevation error must be in either the main steam line or the main feed line of Loop 2.
3. Using one of the methods described above in correcting the primary loop closure error, locate and correct the closure error in Loop 2 of the balance of plant components.
4. Once the error has been corrected, perform another "Check Model" to assure your corrections fixes the loop closure issue.

Step 4 Run a Final Static Check Calculation

With your corrected input model perform another 500 second Static-Check Steady-State calculation.

From the information provided in the animation mask do the primary and secondary side mass flow rates decay to zero?

Discussion:

Loop closures in an input model can exist. TRACE does not terminate the calculation if there are loop closure issues. In some transients, such as a large break LOCA, open loops may not have a significant impact on the results of the simulation. However, for other transient simulations, such as a small break LOCA or a station blackout, loop closure issues can have a big impact on the results of the simulation.

While TRACE does not terminate if there are loop closure issues, SNAP is constructed to detect these issues and should be used in model construction. By using the different features available in SNAP, loop closure issues are readily detected and can be fixed.