Working with Sensitivity Studies Using Linked Input and Output Components

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Abstract

Rainey Station requested a study on the heat rate effects of recirculating water through the low-pressure economizer. This is required to keep the exhaust gas at a high enough temperature to prevent any back end corrosion. To do this a sensitivity study was setup over about 100 different cases. In this paper, we show how to make the model work in a sensitivity study with linked input and output components. It is important to know that in this model there are three drums to balance each having a different supplying component. This adds complexity to the model and possible convergence problems. A modeler needs to know what components supply the drum flows especially when the drum control is invoked. The answer to running a linked input and output component model is in knowing how the model balances three drums and what components are supplying the flows.   It was determined that passing too much data from the output to the input component was detrimental to the model's ability to achieve cycle convergence.

Introduction

Santee Cooper is a state owned utility in South Carolina with a current net generating capacity above 5,050 MW. This paper is about a modeling study on the combined cycle unit that our Rainey Station requested. Rainey station is a mixture of a combined cycle unit and simple cycle gas turbines. There are five simple cycle gas turbines at this site: three 74 MW and two 146 MW units. The combined cycle unit has two 146 MW gas turbines and a 155 MW steam turbine. This station burns natural gas as a primary fuel.

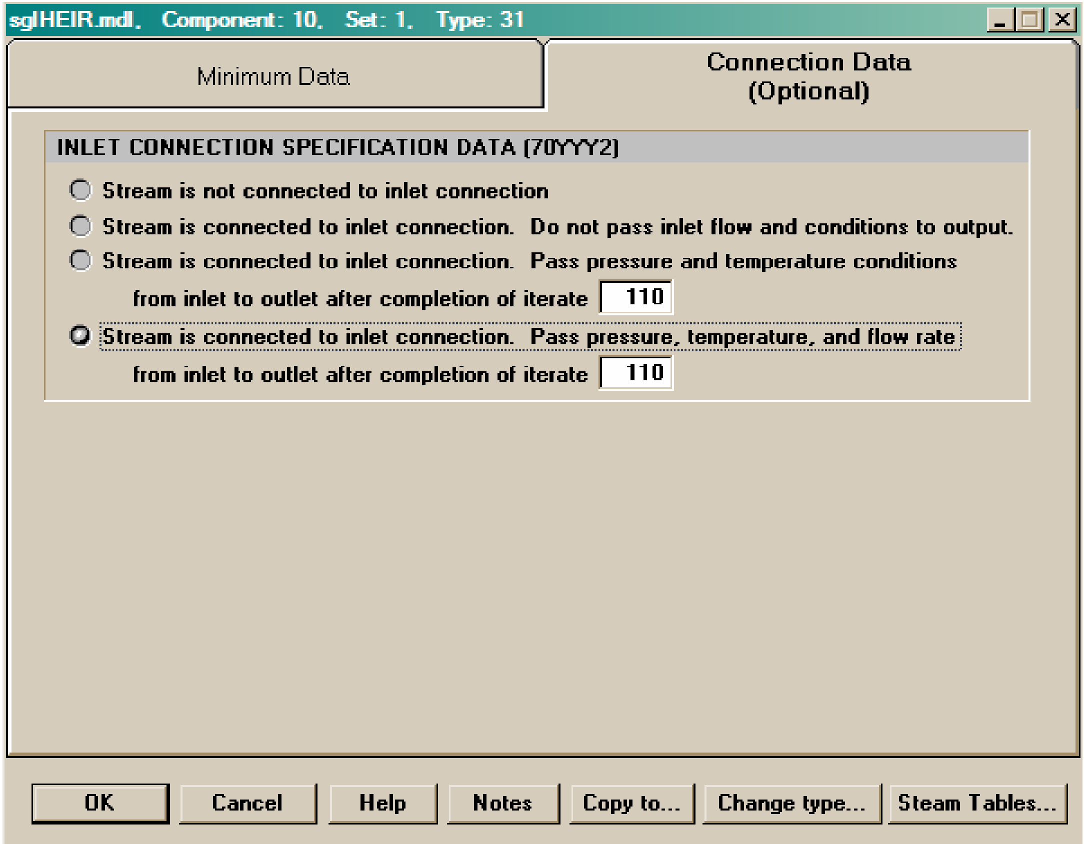
As noted previously the study came about because of a question from the station “With one gas turbine what condenser pressure or circulating water temperature is optimal for heat rate?” This was not all the information they requested the station also wanted to know the answer for two operating conditions. These conditions were with and without the economizer recirculation line operational. They also needed the answer over a range of air and water temperatures. The recirculation system was not in the original heat balance of this recovery steam generator (HRSG) PEPSE® model of this unit. Therefore, I added three components to the PEPSE® model that mimics this mode of operation. This recirculation system was setup to keep the economizer inlet water temperature at or above 116°F. The reason for this is to keep the gas side temperatures high enough so that the sulfur does not cause corrosion in the back end of the HRSG.

This paper is about some challenges in the running the X, Y & Z sensitivity study using a closed loop model that links the input and output components. To complete the study on the effects of not running this system in the single gas turbine cycle operation on performance. In the end, the solution was the selection of the proper method for transferring the flow rate value from the output to the input components.

Modeling

Rainey Station PEPSE® models were completed a few years ago to match the full load heat balances for both single and twin gas turbine (GT) operation. A copy of the PEPSE® schematic is the end of this report. Being a combined cycle model, it has many differences from your typical turbine/boiler models. This is a model with one HRSG in operation so there are only three drums in the cycle. They each operate at different pressures, which are low pressure, intermediate pressure and high pressure. The unit does not have any feedwater heaters simplifying the turbine cycle but the HRSG flows to each turbine vary and turbine flow increases as you proceed to lower pressures.

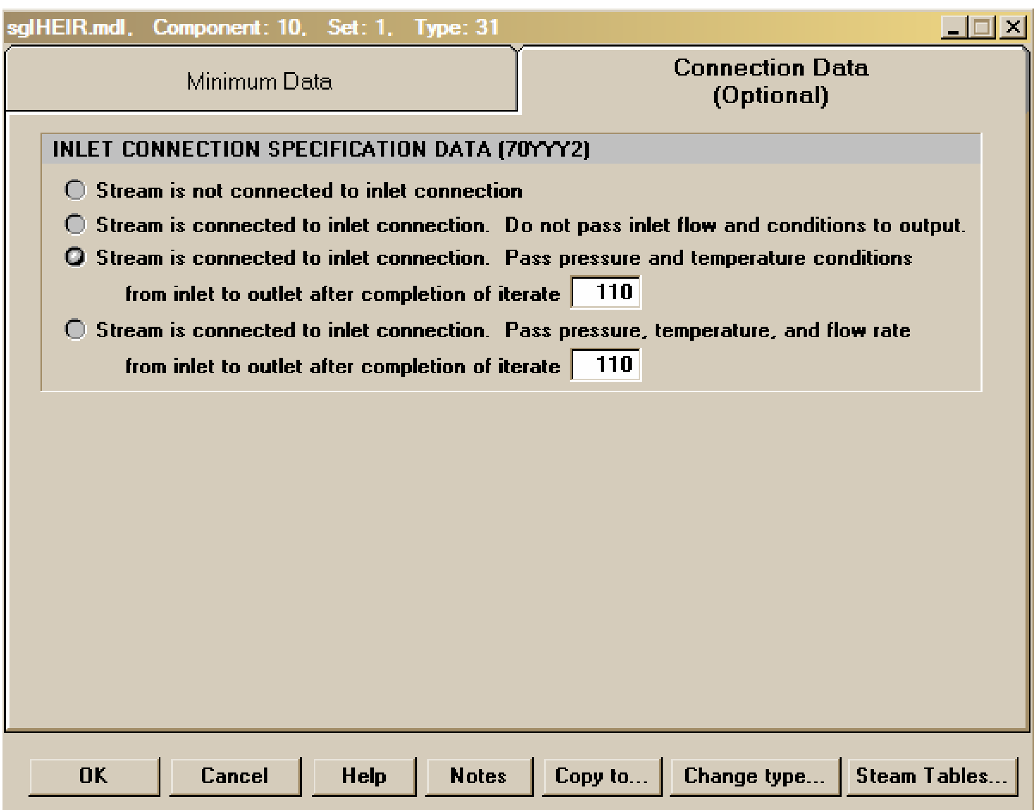
I first added the recirculation system to my single GT model and ran the X, Y & Z sensitivity study with it turned off. In reviewing the results, noticed that the condenser outlet temperature was not transferring the temperature from the sink/output component. To address this, I linked the sink/output component to the source/input component and reran the model. The link was from the drain of the condenser to the input of the condensate pump, passing pressure, temperature and flow rate from the drain (outlet) to the inlet. This is the bottom radio button on the connection data tab of the input component. (See next figure)



At this point, the model ran to an abnormal termination. I was able to make the model converge by setting up the component to transfer the data from output to input at iterate 110 with a minimum iteration count to be 115 in the generic data convergence “card”. These were chosen since it appeared that by iteration 110 the model was generally well behaved. In addition it was necessary to insure that all cases ran at least to the 115th so that the 110th iterate would be reached. After these changes, the model with the heat exchanger turned off, ran to completion.

Next was to run the same sensitivity study with the recirculation system operational. In everyday operation when recirculation is occurring, the inlet water to the economizer is maintained at 116°F. To do this a control was added for the recirculation of flow that maintains 116°F economizer inlet temperature. To get the results needed I realized that having a performance mode economizer was not a good idea. In performance mode, there are not any changes in the exit gas temperatures on the economizer gas side. To have these gas side changes occur a heat transfer (UA) coefficient needs to be added (UAHRD) and UAEXP (exponent for generalizing UA at load) inputs to component 350 (the LP economizer). When this change was introduced, the economizer gas side temperatures now changed as expected, as other conditions varied. It is at this point the model in sensitivity mode would not run more than one or two cases, after which it would abnormally terminate. In addition, to get these cases to run it was required that the recirculation flow was within 2,000 lbs/hr of the final model flow result. I sent all this information to Scientech (Gene Minner and Byron Hansen) to see if they could figure out what was causing the model's inability to run all sensitivity study cases to completion.

In an attempt to make the model more stable, Gene converted all the heat transfer components from performance mode to using the UA coefficients. This did not stabilize the model enough to let it run to completion in the sensitivity study mode. After reviewing how PEPSE balances the drum component, he realized that one of the three drums was using the linked input component as a source of supply flow. At this point, we changed the inlet connection specification from the last radio button to the third one. This connection type does not let the flow pass from the outlet or sink component, but still allows both temperature and pressure conditions to be passed on. (See figure below)

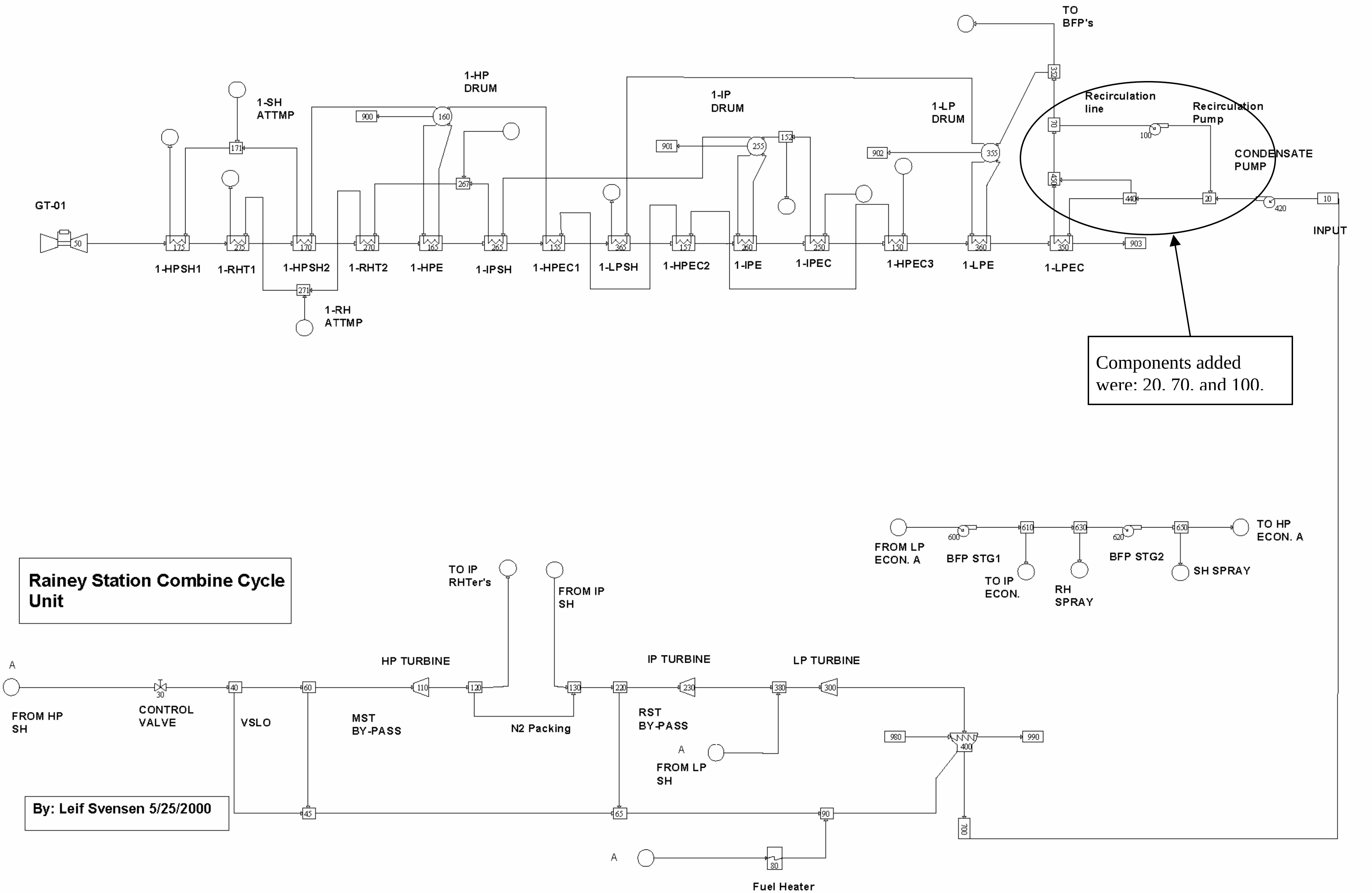


The model now ran in the sensitivity mode to completion with the heater recirculating the economizer flow.

The logic to this change is as follows: one of the drums uses a control to adjust the flow rate coming from component 10 (the input component for this model). Forcing component 100’s (the sink) flow rate to component 10 interferes with the control’s doing its job. The effect is that the control is given bogus information from behind the scenes. Hence, the reason why the model would run only after all the control “jitters” settled down, which turned out to be greater than 110 iterations.

Summary

When linking an output (or sink) component to an input (or source) component one must be careful about passing the data from output port to input port. The user needs to look at the model’s controls either imbedded (like the drum balance) or added and decide on what information the can be passed without influencing the control in question. On another note, the study revealed that the heat rate impact of having the economizer recirculation on was between 1 and 15 Btu/kWhr and that at ambient operating ranges there was not a limit on low circulating water temperature. As expected the higher economizer recirculation flows yielded the larger changes in heat rate.



TO BFP's
1-HP DRUM
1-SH ATTMP
1-IP DRUM
1-LP DRUM
Recirculation line
Recirculation Pump
CONDENSATE PUMP
INPUT
GT-01
1-HPSH1
1-RHT1
1-HPSH2
1-RHT2
1-HPE
1-IPSH
1-HPEC1
1-LPSH
1-HPEC2
1-IPE
1-IPEC
1-HPEC3
1-LPE
1-LPEC
1-RH ATTMP
Components added were: 20, 70, and 100.
FROM LP ECON. A
BFP STG1
TO IP ECON.
RH SPRAY
BFP STG2
SH SPRAY
TO HP ECON. A
Rainey Station Combine Cycle Unit
TO IP RHTer's
FROM IP SH
HP TURBINE
IP TURBINE
LP TURBINE
A
FROM HP SH
CONTROL VALVE
VSLO
MST BY-PASS
N2 Packing
RST BY-PASS
FROM LP SH
By: Leif Svensen 5/25/2000
Fuel Heater

References

The following references were used during the course of analysis and in the preparation of this paper.

1 - PEPSE computer code, Scientech Inc., 200 South Woodruff, Idaho Falls, ID 83401

2 – PEPSE manual: Volumes I, II, III, IV, Scientech Inc., 200 South Woodruff, Idaho Falls, ID 83401