GateCycle Model Upgrade Report for the

GateCycle Model Library's FBSUPC Model

Prepared By:

Wyatt Enterprises, LLC

July 29, 2004

Table of Contents

Overview

Model Summary

This report summarizes the upgrade of the GateCycle model library's FBSUPC model from GateCycle version 5.41 to version 5.51. The FBSUPC model is a coal fired supercritical fossil plant model with a condensing reheat steam turbine (ST) and 8 feedwater heaters. It has a single, part load off-design case named FBSUP3.

Executive Summary

The FBSUPC model was upgraded from GateCycle version 5.41 to version 5.51 without any problems. Running the model in version 5.51 led to the discovery of the issues listed below, however:

Issue Description	**Workaround (if Any)**	**Severity**
ST icons show incomplete data entry status once double clicked on in version 5.51	Go to Inlet/Exit P and Extractions input screens and click OK	Low
Supercritical state points show a quality of 0.0 when temperature < Tcritical rather than always showing quality = 1.0 as in version 5.41.	Not Applicable – This is a bug fix.	n/a
ST valve constants (kv) are 0.0 when read in CycleLink.	This is a CycleLink bug. The value in the database and shown on icon reports isthe same as in version 5.41. Use a set macro and user variable to read the Kv in CycleLink	Low
Net plant power is ~ 2 MW lower in version 5.51.	Not Applicable - This is a bug fix. Version 5.41 had energy balance errors related to ash flows in the FBOILR. Version 5.51 corrects these errors but model results will change.	Medium

In terms of execution time, version 5.51 appears to be about 21% slower than version 5.41 due to increased code size. Despite these issues and the modest decrease in execution speed, upgrading to version 5.51 is recommended for the FBSUPC model at this time.

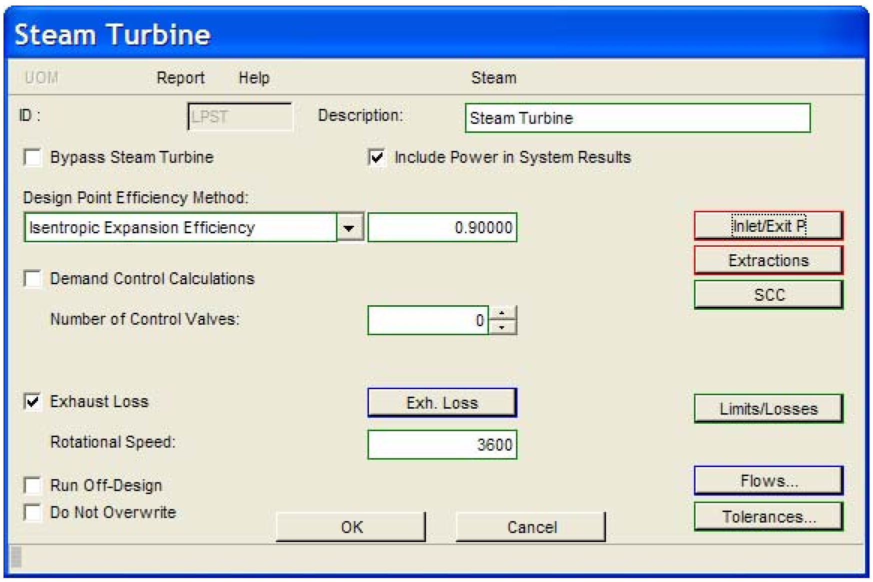
Prior Version Baseline

The FBSUPC model was run in version 5.41 prior to upgrading to establish a baseline. All cases in the model ran and converged in version 5.41 without any errors or warnings. The off design case was then perturbed by lowering the plant net power by 10% and once again the model converged but with a single equipment warning in the deaerator. Elapsed run time for the adjusted case was 4 seconds. The single equipment warning was due to a configuration problem in the deaerator and is addressed in the Model Recommendations section of this report.

Upgrade Results

Version 5.51 Upgrade

The upgrade of the model itself was uneventful and worked fine. A minor data entry problem with version 5.51 was detected upon double clicking on a steam turbine (ST) icon. Specifically, the Inlet/Exit P and Extraction buttons on the ST icon's main data entry window will have a red borders indicating incomplete data entry when this is done as shown below:



This incomplete status is then propagated preventing the use of the Run Analysis command. Double clicking on any ST icon in an upgraded model will cause this problem. The problem is easily rectified and stems from changes made to the steam turbine for version 5.51. In the case of the Inlet/Exit P button, version 5.51 has stricter input checking to ensure that an exit pressure is input for each ST icon. The database variable that stores the input status did not exist in version 5.41 so it is created upon upgrade and set to 0 which triggers the status alarm. To correct the problem you simply go to the Inlet/Exit P screen by pressing the Inlet/Exit P button and then press the OK button to dismiss the Inlet/Exit Pressure Settings form. Repeat this process for the Extractions button and then press OK on the main data entry window. You will also have to repeat these steps for all ST icons in the each case of the model. When completed, the Run Analysis command will be available again.

Beyond this ST icon status issue, there were no other problems encountered during the model upgrade process.

Calculation Results Comparison

Once the model was upgraded to version 5.51, its cases were run and the calculated results were compared to those obtained with version 5.41. All models and cases ran and converged in version 5.51 without any errors or warnings. When perturbed by lowering the desired net power by 10% the off design FBSUP3 case converged with the same deaerator equipment warning seen in version 5.41. The elapsed run time for the adjusted off design case was 5 seconds – a slight increase over version 5.41. Appendices A & B contain CycleLink output showing the comparison of all model variables for all cases. All noteworthy differences are explained below.

The largest difference in results is seen for the LP steam turbine's Valve Constant. This discrepancy turned out to be the result of a bug in the version 5.51 CycleLink as described below. A set macro was created in version 5.51 to read the valve constant for the LP steam turbine and write it to a user variable. The value written by the macro and shown on the icon report in version 5.51 is the same as that seen in version 5.41 so this discrepancy does not affect the model in any way and can be disregarded.

The next largest observed differences are the Expansion Line End Temperatures for the model's ST icons. These differences are due to the fact that the Expansion Line End statepoint is new in version 5.51 and the variables used to store its conditions in were unused in version 5.41. As unused variables, the values in 5.41 are significantly different than those in version 5.51. This discrepancy is also inconsequential.

An interesting difference was noted for the supercritical statepoints in the model. In version 5.41 the quality of all supercritical statepoints was reported as 1.0. Since quality has no real meaning in the supercritical region, it was arbitrarily set to 1.0. This is inconsistent with industry practice which is to report a quality of 0.0 for super critical statepoints at temperatures less than the critical temperature and 1.0 for super critical statepoints at temperatures above the critical temperature. Due to customer requests, version 5.51 was changed to adhere to this standard so some statepoint quality values that were 1.0 in version 5.41 are now 0.0 in version 5.51resulting in the observed difference. These differences are due to a bug fix and do not affect the model results.

A difference in macro residuals between the two cases also turns up as a large percentage difference. This is simply due to the fact that both macro residuals are very small (order of 1e-5) and this leads to a large percentage difference. Since both residuals are below the system tolerance of 0.0001, there is no cause for concern. The variance is just a side effect of GateCycle's iterative solver.

The remaining discrepancies, including an over 2 MW difference in the FBSUPC case are primarily related to a bug fix made in the fossil boiler icon for version 5.51. In version 5.41, the treatment of the energy losses due to ash flows in the fossil boiler (when using solid fuel) was incorrect. Due to the corrections made in version 5.51 the fossil boiler icon's energy balance changes resulting in a lower overall plant net power for the same boiler heat load. This power discrepancy does not appear in the FBSUP3 case since it contains a control macro that adjusts the boiler's heat load to attain a user specified plant net power. The effects of this bug fix are also noticeable in the overall energy balance error. For the FBSUPC case it goes from ~ -112 kW in version 5.41 to only ~ -15 kW in version 5.51 much closer to the theoretically correct value of 0.0 kW. Note, however that the energy balance errors of both versions are well within the system convergence tolerance of 0.001 relative to the overall energy output of ~400 MW.

Execution Time Comparison

Model execution time in 5.51 was generally a second slower than version 5.41 on any given run. This additional second results in the 50 to 100% percentage differences seen in the data below but it is not as bad as it looks since the cases converged in well under 100 iterations. Running the same case (FBSUP3) for 999 iterations in both versions gives a better sense of the difference and resulted in the following execution times:

Version	Time for 999 Iterations in FBSUP3 OD Case
5.41	28 seconds
5.51	34 seconds

The slowdown from version 5.41 to 5.51 is largely a result of the new features that were added to the software. While not many if any of these new features are used in this model, the calculations will still be slower, as a result of an increase in the number of output and database variables (= more disk reading and writing), and due this version's larger number of lines of code. In short, the price of progress.

Database Comparison

Version 5.51 has a number of new database variables that were not present or unused in version 5.41. Some of these variables (primarily in the ECON, SPHT and EVAP icons) are for GE proprietary features while others are for new features added to icons like the ST icon. These new variables are shown with a light blue background in the CycleLink workbook that accompanies this report.

Log File Comparison

There were no substantive differences in the log files generated by the two versions.

Suggested Bug Reports

Upgrading this model revealed a problem with reading the steam turbine valve constant from CycleLink. Version 5.51 CycleLink reads this variable for any steam turbine as 0.0 or incorrectly. The value in the database is the same as that in version 5.41, however, so this is not a major bug unless the value must be read in CycleLink. In that case, the following workaround can be used:

1. Create a set macro that reads the desired ST icon's valve constant and writes it to a user variable.
2. Read the user variable written by the macro in CycleLink.

The following bug report should be submitted to GE to ensure that it is fixed for the next release:

Dear GateCycle support,

When upgrading my model from version 5.41 to 5.51, I noticed that in version 5.51 I am unable to read the Valve Constant (Kv) correctly in CycleLink for any steam turbine icon in any model. The value returned by CycleLink is either 0.0 or different from that seen in version 5.41 or on the ST icon report in version 5.51. Here is a row from a CycleLink spreadsheet for this variable:

CONDST[ST]	ValveConstant[0]		Current Exit Valve Constant	0

Please investigate and correct this error in the next version of CycleLink. Thank you.

Regards,

xxxx

Model Recommendations

The model perturbation study revealed one minor configuration problem with the model's FBSUP3 off design case. Specifically, the deaerator is set up to use the "Constant P Operation: demand pegging steam" operating method. This leads to a problem at lower loads when the LP steam turbine inlet pressure (which sets the DA's pegging steam pressure) falls below the specified DA operating pressure. At best, these leads to the equipment warning mentioned earlier and at worst it could prevent the model from converging. A better DA operating method is the "vary P with pegging steam P, demand pegging steam" method.

Appendix A: Result Comparisons for Case FBSUPC

Icon	Variable Description	5.41 Value	5.51 Value	Absolute Difference	% Difference
LPST	Current Exit Valve Constant	3728554.50	57660460.00	53931905.5	1446.46%
LPST	Valve Constant (Kv)	3728554.50	57660460.00	53931905.5	1446.46%
IPST	Expansion Line End Temperature	-459.67	612.66	1072.331207	233.28%
HPST	Expansion Line End Temperature	-459.67	497.47	957.1418762	208.22%
LPST	Expansion Line End Temperature	-459.67	128.78	588.4530182	128.02%
DA1	Exergetic Efficiency (beta!)	0.47	0.98	0.515099943	110.76%
SYSTEM	Execution Time	0:00:02	0:00:04	2.31481E-05	100.00%
SYSTEM	Max. Macro Residual	0.00	0.00	-2.10867E-05	100.00%
FB1	Evaporator Inlet Quality	1.00	0.00	-1	100.00%
ECON	Water Inlet Quality	1.00	0.00	-1	100.00%
ECON	Water Outlet Quality	1.00	0.00	-1	100.00%
HPST	Current Exit Valve Constant	139097.56	0.00	-139097.5625	100.00%
HPST	Valve Constant (Kv)	139097.56	0.00	-139097.5625	100.00%
IPST	Current Exit Valve Constant	1002948.19	0.00	-1002948.188	100.00%
IPST	Valve Constant (Kv)	1002948.19	0.00	-1002948.188	100.00%
BFWPMP	Control Valve Outlet Quality	1.00	0.00	-1	100.00%
BFWPMP	Excess Outlet Quality	1.00	0.00	-1	100.00%
HPSPRY	Control Inlet Quality	1.00	0.00	-1	100.00%
IPSPRY	Control Inlet Quality	1.00	0.00	-1	100.00%
SP4	Inlet Quality	1.00	0.00	-1	100.00%
SP4	Primary Outlet Quality	1.00	0.00	-1	100.00%
SP4	Secondary Outlet Quality	1.00	0.00	-1	100.00%
SP4	Tertiary Outlet Quality	1.00	0.00	-1	100.00%
FWH6	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH6	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH5	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH5	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH7	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH7	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH8	BFW Inlet Quality	1.00	0.00	-1	100.00%

NOTE: This Table has been intentionally truncated to keep the sample report small. All Units of Measure are British.

Appendix B: Result Comparisons for Case FBSUP3

Icon	Variable Description	5.41 Value	5.51 Value	Absolute Difference	% Difference
LPST	Current Exit Valve Constant	3728554.50	57660460.00	53931905.5	1446.46%
LPST	Valve Constant (Kv)	3728554.50	57660460.00	53931905.5	1446.46%
IPST	Expansion Line End Temperature	-459.67	572.86	1032.526886	224.62%
HPST	Expansion Line End Temperature	-459.67	447.51	907.1769409	197.35%
LPST	Expansion Line End Temperature	-459.67	119.50	579.1709442	126.00%
FB1	Evaporator Inlet Quality	1.00	0.00	-1	100.00%
ECON	Water Inlet Quality	1.00	0.00	-1	100.00%
ECON	Water Outlet Quality	1.00	0.00	-1	100.00%
HPST	Current Exit Valve Constant	139097.56	0.00	-139097.5625	100.00%
HPST	Valve Constant (Kv)	139097.56	0.00	-139097.5625	100.00%
IPST	Current Exit Valve Constant	1002948.19	0.00	-1002948.188	100.00%
IPST	Valve Constant (Kv)	1002948.19	0.00	-1002948.188	100.00%
BFWPMP	Control Valve Outlet Quality	1.00	0.00	-1	100.00%
BFWPMP	Excess Outlet Quality	1.00	0.00	-1	100.00%
HPSPRY	Control Inlet Quality	1.00	0.00	-1	100.00%
IPSPRY	Control Inlet Quality	1.00	0.00	-1	100.00%
SP4	Inlet Quality	1.00	0.00	-1	100.00%
SP4	Primary Outlet Quality	1.00	0.00	-1	100.00%
SP4	Secondary Outlet Quality	1.00	0.00	-1	100.00%
SP4	Tertiary Outlet Quality	1.00	0.00	-1	100.00%
FWH6	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH6	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH5	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH5	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH7	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH7	BFW Outlet Quality	1.00	0.00	-1	100.00%
FWH8	BFW Inlet Quality	1.00	0.00	-1	100.00%
FWH8	BFW Outlet Quality	1.00	0.00	-1	100.00%
DA1	Exergetic Efficiency (beta!)	0.50	0.98	0.479346812	96.03%
SYSTEM	Max. Macro Residual	0.00	0.00	-5.17725E-05	71.79%

NOTE: This Table has been intentionally truncated to keep the sample report small. All Units of Measure are British.