GateCycle Model Upgrade Report for the

GateCycle Model Library's 2x3PRH Model

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Overview

Model Summary

This report summarizes the upgrade of the GateCycle model library's 2x3PRH model from GateCycle version 5.51 to version 5.52. The 2x3PRH model is a 3 pressure level reheat combined cycle fossil plant, with 2 Gas Turbines (GTs), 2 Heat Recovery Steam Generators (HRSGs) and 1 Steam Turbine (ST). It has no off-design cases.

Executive Summary

The 3xPRH model was upgraded from GateCycle version 5.51 to version 5.52 without any problems. Running the model in version 5.52 led to the discovery of the issues listed below

Issue Description	**Workaround (if Any)**	**Severity**
Elapsed Run Time goes up for this model	Not possible	Low
STs, GTs, Data Gas Turbines (GTDATA), Duct Burners, Splitters, Attemporators, Deaerators and General Heat Exchangers have new variables added to the database.	Not Applicable – These are related to new features.	n/a
GTDATA reported shaft power variable was different.	Not Applicable – This is bug fix. Version 5.51 had stored net power in the database for this variable.	n/a
Condensing Steam Turbine "expansion line exit" conditions and efficiency changed.	This is a change in definition of the flow data arrays in the database. The Flow[6] variables are now defined as ELEP instead of UEEP. If you want access to the UEEP, use the ST exit conditions.	Low
GT: Inlet air molecular weight = 0.0 in 5.52	No work-around. But no effect on overall results, unless this variable was accessed and used in macros or CycleLink.	Low
Duct Burners energy loss is not 0.0, even though burner control method is set to 0.0 F temperature change.	Instead of 0.0 temperature change, the method No Enthalpy Change could be used.	Low

Despite these issues, upgrading to version 5.52 is recommended for the 2x3PRH model at this time.

Prior Version Baseline

The 2x3PRH model was run in version 5.51 prior to upgrading to establish a baseline. All cases in the model ran and converged without any errors or warnings. The design case was then perturbed by lowering the ambient temperature by 20F and once again the model converged without errors or warnings. The elapsed run time was 19 seconds when forcing 999 iterations to be executed on the test PC.

Upgrade Results

Version 5.52 Upgrade

The upgrade of the model itself was uneventful and worked fine.

Calculation Results Comparison

Once the model was upgraded to version 5.52, its case was run and the calculated results were compared to those obtained with version 5.51. All models and cases ran and converged in version 5.52 without any errors and warnings.
When perturbed by lowering the ambient temperature by 20 F the design 2x3PRH case converged with no additional warnings or errors seen in version 5.41. 21 iterations were needed to converge after changing the ambient temperature by 20F in both versions. No change in stability of the model was seen.
Appendices C & D contain CycleLink output showing the comparison of all model variables for all cases. All noteworthy differences are explained below.

Execution Time Comparison

Model execution time in 5.52 was generally slower than version 5.51 on any given run. Running the sample case (2x3PRH) 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 2x3PRH Case**
5.51	19 seconds
5.52	25 seconds

The slowdown from version 5.51 to 5.52 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

New variables

Several new variables were added to the database in 5.52 with an initial value of 0. lb/hr, 0R, 0 psia, 0 Btu/hr, 0 ft etc. After running the model, these variables might be non-0 if they are calculated in 5.52.

Summary of most important new variables
Several new variables exist for the ST, GTDATA icons, which are variable for GE-proprietary methods.
Splitters have a new method, for stabilizing the pressure based split up calculations.
General Heat Exchangers, Deaerators and Attemporators have been modified to allow for salt/sea water calculations.
Steam Turbines: new methods for common usage: flow capacity performance factors were added. Admission methods were added.
Duct burners and GTs now have fuel damping factors. This is especially useful if a mixer upstream of the fuel inlet port mixes different fuel types.
GTs: now allow for multiple bleed ports, a second fuel ports and a diluent port.

For more detail, please see Appendix A and the Excel spreadsheet that comes with this report.

Newly activated variables.

Some of these are variables are newly "activated" in 5.52. Newly activated variables are variables that already existed in 5.51, but were never used. The variables that are newly activated are listed Appendix B.

These newly activated variables will have no influence on your overall calculations in this model. But they might be useful in case you want to use GT bleed ports in later models.

Variables with different values between the cases

Some variables existed in both versions, but show differences.

See Appendix C for the 60F ambient temperature case.
See Appendix D for the 40F ambient temperature case.

Ignoring the minor differences in the economizers and pumps, the major differences observed were as follows:

Summary of most important differences in variables between 5.51 and 5.52
CONDST: exit conditions, and group stage efficiency. This is due to a change in definition of variable Enth[6] and Qual[6]. This array index 6, was previously used to store the UEEP conditions. In version 5.52, this now stores ELEP conditions. Storing ELEP is more useful, since the UEEP conditions are already known by looking at the exit conditions of the steam turbine. Nevertheless, this change, might ruin macros that use these variables. In this particular model, these variables are not used. The change in definition of these variables has no influence on overall performance calculations, provided no macros or CycleLink spreadsheets use these variables.
SYSTEM: the energy balance is –12 kW off in one case (5.51), + 11 kW in the other. Not a problem relative to the overall energy flows in / out of the cycle.
GTD2: the variable reported as: “shaft work” was equal to the variable labeled “net power” in 5.51, but is now equal to the variable “engine shaft power” in 5.52. This is a bug fix.
GT: calculated values for compressor discharge molecular weight and inlet air molecular weight are missing in 5.52. This can be considered a new bug.
BURNER: Both cases have burners with no temperature change, one would expect 0 loss. This is due to a very small difference in the gas enthalpy lookup between the two versions. This is normally too small to notice, but since energy loss is calculated by multiplying the enthalpy times flow rate, the “problem” becomes noticeable. This is a small bug. Notice the difference in enthalpy despite the rest of the conditions being the same, see the log file when increasing the debug output level: ---- Component Flow Table -------- --[lb/hr]----[F]----[psia]----[BTU/lb]- Inlet Gas: W,T,P,H = 3500792.8 1125.1 14.696 282.15 Exit Gas: W,T,P,H = 3500793.0 1125.1 14.696 282.16

Log File Comparison

No major differences in the log file exist at debug level 0. Some minor differences were noted, however. For the original case (case 2x3PRH): one in the input checking section, one after iteration 2 (and 3). No additional differences in the case where the ambient temperature was changed by 20F (case 2x3PR1). (except a 2 Btu/hr heat rate difference)

Input checking:
5.51:
FULHTR (HEATX): demand flow rate from cold exit controlled (set) by GT port Fuel Inlet

5.52:
FULHTR (HEATX): demand flow rate from cold exit controlled (set) by GT port Primary Fuel Inlet

Notice the name of the fuel port has changed. This is because in 5.52, the GT icon now has two fuel ports, one for the primary fuel and one for additional fuel.

After iteration 2:
5.51:
All components converged. Largest resid = 1.2675e-005 for component DEAER

5.52:
All components converged. Largest resid = 4.2253e-007 for component DEAER

This slight difference in residual has no effect on the actual convergence. Both are well within system convergence tolerance for this model of: 0.001.

Suggested Bug Reports

The following bug reports should be submitted to GE to ensure the issues they highlight are fixed for the next release:

Dear GateCycle support,

When upgrading my model from version 5.51 to 5.52, I noticed that in version 5.52 the following variables were no longer correctly calculated and incorrectly set = 0.:

GT[GT]	MW[3]		Compressor Discharge Molecular Weight
GT[GT]	MW[0]		Inlet Air Molecular Weight

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

Regards,

xxxx

Dear GateCycle support,

When upgrading my model from version 5.51 to 5.52, I noticed that in version 5.52 and version 5.51 a duct burner energy loss was calculated despite my input of 0 pressure drop and 0 temperature change.

Duct Burner Report:

```
Current Values: -------------------------------------------------------
Temperature Change                               0.0    F
LHV Fuel Consumption                             0.0    BTU/hr
Actual Burner Heat Loss                       7684.9 BTU/hr
Fuel Compression Work                            0.0    kW
Pressure Drop                                    0.0
Actual Combustion Efficiency                     0.0
Actual Burner Heat Loss Fraction                 0.0
Burner Heat Utilization Factor                   0.0
Extent of Reaction                               0.0
```

Log file output:

```
---- Component Flow Table --------------[lb/hr]----[F]----[psia]----[BTU/lb]-
 Inlet Gas: W,T,P,H   =                3500792.8  1125.1    14.696   282.15
 Exit Gas:  W,T,P,H   =                3500793.0  1125.1    14.696   282.16
```

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

Regards,

xxxx

Appendix A: New Database Variables in 5.52

GT[GT]	SecondFuelMode[0]		2nd Fuel Flow Method
GT[GT]	CalcDiluentCompressorInletRatio[0]		Calculated Diluent Compressor-Inlet Ratio
GT[GT]	CalcDiluentFuelRatio[0]		Calculated Diluent Fuel Ratio
GT[GT]	CalcFuelSplitRatio[0]		Calculated Fuel Split Ratio: Fuel2/Fuel1
GT[GT]	CalcFuel2Fraction[0]		Calculated Secondary Fuel Fraction: Fuel2 / Fuel_total
GT[GT]	DesiredDiluentCompressorInletRatio[0]		Desired Diluent Compressor-Inlet Ratio
GT[GT]	DesiredDiluentFlow[0]	lb/hr	Desired Diluent Flow
GT[GT]	DesiredDiluentFuelRatio[0]		Desired Diluent Fuel Ratio
GT[GT]	DesiredFuelSplitRatio[0]		Desired Fuel Split Ratio: Fuel2/Fuel1
GT[GT]	DesiredSecondaryFuelFlow[0]	lb/hr	Desired Secondary Fuel Flow
GT[GT]	DesiredFuel2Fraction[0]		Desired Secondary Fuel Fraction: Fuel2 / Fuel_total
GT[GT]	DiluentMode[0]		Diluent Flow Method
GT[GT]	FuelLimitMode[0]		Fuel Flow Limit Method
GT[GT]	MaxFuel1Flow[0]	lb/hr	Maximum Primary Fuel Flow
GT[GT]	MaxFuel1HeatInput[0]	BTU/hr	Maximum Primary Fuel Heat Input
GT[GT]	MaxFuel2Flow[0]	lb/hr	Maximum Secondary Fuel Flow
GT[GT]	MaxFuel2HeatInput[0]	BTU/hr	Maximum Secondary Fuel Heat Input
GT[GT]	MaxTemperature[0]	F	Maximum Temperature
GT[GT]	CalcCompIPBleedFrac[0]		Calculated Compressor IP Bleed Fraction
GT[GT]	CalcCompIPBleedPressure[0]	psia	Calculated Compressor IP Bleed Pressure
GT[GT]	IPBleedFlowConfigMethod[0]		Compressor IP Bleed Flow Method
GT[GT]	IPBleedPressureConfigMethod[0]		Compressor IP Bleed Pressure Method
GT[GT]	DesignCompIPBleedFlow[0]		Design Compressor IP Bleed Flow
GT[GT]	DesignCompIPBleedPressure[0]	psia	Design Compressor IP Bleed Pressure
GT[GT]	DesiredCompIPBleedFlow[0]	lb/hr	Desired Compressor IP Bleed Flow
GT[GT]	DesiredCompIPBleedFrac[0]		Desired Compressor IP Bleed Fraction
GT[GT]	DesiredCompIPBleedPressure[0]	psia	Desired Compressor IP Bleed Pressure
GT[GT]	SecondFuelLHV[0]		2nd Fuel Lower Heating Value
GT[GT]	SecondFuelType[0]		2nd Fuel Type
GT[GT]	SecondFuelWaterEnth[0]		2nd Fuel Water Enthalpy

NOTE: This Table has been intentionally truncated to keep the sample report small.

Appendix B: Newly Activated Variables in 5.52

GT[GT]	Enth[7]	BTU/lb	Comp. IP Bleed Enthalpy
GT[GT]	Pres[7]	psia	Comp. IP Bleed Pressure
GT[GT]	Temp[7]	F	Comp. IP Bleed Temperature
GT[GT]	Ar[5]		Comp. Disch. Bleed Argon
GT[GT]	CO2[5]		Comp. Disch. Bleed Carbon Dioxide
GT[GT]	H2O[5]		Comp. Disch. Bleed H2O
GT[GT]	N2[5]		Comp. Disch. Bleed Nitrogen
GT[GT]	O2[5]		Comp. Disch. Bleed Oxygen
GT[GT]	CO2[7]		Comp. IP Bleed Carbon Dioxide
GT[GT]	CO[7]		Comp. IP Bleed Carbon Monoxide
GT[GT]	H2O[7]		Comp. IP Bleed H2O
GT[GT]	N2[7]		Comp. IP Bleed Nitrogen
GT[GT]	O2[7]		Comp. IP Bleed Oxygen
GT[GT]	Ar[3]		Compressor Discharge Argon
GT[GT]	CO2[3]		Compressor Discharge Carbon Dioxide
GT[GT]	H2O[3]		Compressor Discharge H2O
GT[GT]	N2[3]		Compressor Discharge Nitrogen
GT[GT]	O2[3]		Compressor Discharge Oxygen

Appendix C: Result Comparisons for Case 2xPRH, Tambient = 60F

Icon	Variable Description	5.51 Value	5.52 Value	Absolute Difference	% Difference
GT	Comp. IP Bleed Temperature	-459.67	60.00	519.6700325	113.05%
SYSTEM	Execution Time	0.00	0.00	1.15741E-05	100.00%
SYSTEM	Final Iteration Residual	0.00	0.00	-1.30982E-05	100.00%
GT	Compressor Discharge Molecular Weight	28.85	0.00	-28.85053444	100.00%
GT	Inlet Air Molecular Weight	28.85	0.00	-28.85053444	100.00%
GT	Inlet Air Enthalpy	0.00	0.00	1.32229E-05	98.78%
GTD2	Inlet Air Enthalpy	0.00	0.00	1.32229E-05	98.78%
SYSTEM	Ambient Enthalpy	0.00	0.00	1.32229E-05	98.78%
SYSTEM	Net Error in Energy Bal.	58538.95	66091.52	7552.570313	12.90%
SYSTEM	Energy Balance Error	17.16	19.37	2.213531494	12.90%
BURNER	Actual Burner Heat Loss	961.52	1068.36	106.8356934	11.11%
CONDST	Current Group Stage Eff. - Stage Group 1	0.87	0.90	0.030814886	3.55%
CONDST	Design Group Stage Eff. - Stage Group 1	0.87	0.90	0.030814886	3.55%
GTD2	Shaft Work	170705.28	175984.81	5279.53125	3.09%
CONDST	Expansion Line End Quality	0.93	0.92	-0.009599805	1.03%
CONDST	User Input Extr. Enth. - Main Outlet	1032.11	1022.11	-10	0.97%
CONDST	Expansion Line End Enthalpy	1032.11	1022.11	-10	0.97%
HPPUMP	Pump Work	-717.64	-715.66	1.987670898	0.28%
SYSTEM	Time of Cycle Run	0.83	0.83	-0.002083333	0.25%
SYSTEM	Cycle Power Requirements	1115.54	1113.35	-2.187988281	0.20%
IPMIX	Outlet Pressure	390.37	390.00	-0.371459961	0.10%
RHTMIX	Outlet Pressure	406.64	406.27	-0.371490479	0.09%
IPPUMP	Pump Work	-272.28	-272.05	0.221038818	0.08%
SYSTEM	Steam Cycle BOP Losses	3000.34	2998.15	-2.188476563	0.07%
HPPUMP	Exergetic Efficiency (beta!)	0.98	0.98	0.000233233	0.02%
HPECON	Cold Side Approach Temperature	90.91	90.93	0.018615723	0.02%
HPECON	Desired Cold Side Approach Temp	90.91	90.93	0.018615723	0.02%
CNDPMP	Pump Work	-125.62	-125.64	-0.020828247	0.02%
HPECON	Calculated Duty	50443100.00	50449268.00	6168	0.01%

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

Appendix D: Result Comparisons for Case 2x3PR1, Tambient = 40F

Icon	Variable Description	5.51 Value	5.52 Value	Absolute Difference	% Difference
SYSTEM	Net Error in Energy Bal.	-39657.99	37209.58	76867.57031	193.83%
SYSTEM	Energy Balance Error	-11.62	10.91	22.52859592	193.83%
GT	Comp. IP Bleed Temperature	-459.67	40.00	499.6700287	108.70%
GT	Compressor Discharge Molecular Weight	28.91	0.00	-28.91065979	100.00%
GT	Inlet Air Molecular Weight	28.91	0.00	-28.91065979	100.00%
SYSTEM	Max. Macro Residual	0.00	0.00	-3.61507E-05	4.02%
CONDST	Current Group Stage Eff. - Stage Group 1	0.87	0.90	0.030856192	3.55%
CONDST	Design Group Stage Eff. - Stage Group 1	0.87	0.90	0.030856192	3.55%
DBURN2	Desired Temperature Change	0.01	0.01	0.000244141	3.39%
DBURN2	Temperature Change	0.01	0.01	0.000244141	3.39%
GTD2	Shaft Work	182902.86	188552.30	5649.4375	3.09%
BURNER	Actual Burner Heat Loss	7462.24	7684.94	222.6923828	2.98%
GTD2	Energy Balance Difference	0.02	0.02	-0.000323983	1.97%
GTD2	Desired Rel. EBDifference	0.02	0.02	-0.000323983	1.97%
DUCT	Desired Temperature Drop	-0.01	-0.01	-0.00012207	1.67%
DUCT	Temperature Drop	-0.01	-0.01	-0.00012207	1.67%
CONDST	Expansion Line End Quality	0.93	0.92	-0.009598553	1.03%
CONDST	User Input Extr. Enth. - Main Outlet	1031.69	1021.69	-9.998718262	0.97%
CONDST	Expansion Line End Enthalpy	1031.69	1021.69	-9.998718262	0.97%
CONDEN	Aux Steam Inlet Quality	0.05	0.05	0.00026311	0.48%
MIXFHO	Outlet Quality	0.05	0.05	0.00026311	0.48%
SYSTEM	Time of Cycle Run	0.49	0.49	0.002083333	0.43%
FULHTR	Calculated Pinch (Hot Out - Cold In)	76.27	76.57	0.296707153	0.39%
FULHTR	Desired Pinch (Hot Out - Cold In)	76.27	76.57	0.296707153	0.39%
HPPUMP	Pump Work	-715.91	-713.86	2.054199219	0.29%
FULHTR	Hot Outlet Enthalpy	122.25	122.54	0.29637146	0.24%
FHTR2O	Outlet Enthalpy	122.25	122.54	0.29637146	0.24%
MIXFHO	Primary Inlet Enthalpy	122.25	122.54	0.29637146	0.24%
MIXFHO	Secondary Inlet Enthalpy	122.25	122.54	0.29637146	0.24%

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