Customization of GE Turbine Expansion Line Curves to Model a GE Advanced Aero Design Steam Turbine Upgrade

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by

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Abstract

Santee Cooper's Generation Department requested modeling services to evaluate performance guarantees for the GE Advanced Aero steam turbine upgrade for Winyah 1 Unit, and have a PEPSE model available for acceptance testing. The old test deck was used to confirm the vendor heat balances submitted to Santee Cooper. This was a check to confirm the gains expected from the upgrading HP and IP turbine blading. Next, a design PEPSE model was constructed using the new vendor VWO heat balances to create a special option six deck for test analysis. This example shows the uses of efficiency multipliers, controls, additional sinks, and sources to account for the test cycle leakages and other acceptance test requirements.

Introduction

Winyah #1 is one of four 260 NMW generators at Santee Cooper's Winyah Generating Station, located in Georgetown, South Carolina. It is a General Electric (GE) turbine. The boiler for Winyah #1 is rated at a maximum flow of 2,150,000 lbs./hr. 1005/1005 F superheat/reheat temperature and 2400 psig.

There were two goals for this study:

1. Verify user heat balance claims. Quantify and confirm the expected gain in turbine efficiencies, generation, and heat rate improvement.
2. Build a test deck for acceptance testing. A design PEPSE deck was constructed to be the base for the conversion to a special option six deck for test data reduction.

The result of the heat balance verification confirm the expected performance gains. Thus, the additional cost upgrade was accepted. The second goal was just completed and the testing confirmed the units upgrades met the guaranteed performance.

PEPSE Modeling

New design incorporated a new nozzle box to allow greater flow, upgraded aero high pressure turbine blading, upgraded aero intermediate pressure turbine, and new low pressure turbine L-0 diaphragms and tip seals. Since we already had a test deck, confirming the submitted heat balances required no additional modeling. All heat balance temperatures, pressures and flows were input into the current special option six (test data reduction) PEPSE heat balance. These inputs use the 89XXXY series cards for each component.

Modeling the unit to obtain a new upgrade design deck was not as complicated as building a new deck. This was a result of having no changes in the steam cycle component and steam flow diagram. The cards that needed updating involved the input and turbine cards.

The PEPSE component GE general turbines were used to obtain a first iteration of the model. Since PEPSE is based on the 1974 GE procedures, the result was a PEPSE heat balance that did not match the vendor heat balance. The major areas of difference were the HP and IP turbine section efficiencies, and generator losses. Consultation with the vendor confirms that there was enough difference between the aero design and the older design that the 1974 procedures needed to be adjusted. General Electric sent the information on the HP, IP, and LP turbine efficiencies for their VWO heat balance along with the fixed and variable generation losses.

The fixed generator losses were input on card 011011 as follows:

011011 802.0, 0.0

Where card 011011 is the generator, optional input card descriptions are:

Generator mechanical loss in kW = 802.0 (variable name BKMCLI)

Generator electrical loss in kW = 0.0 (variable name BKELE)

Variable losses were not scheduled.

The efficiency multipliers for the HP and IP turbines were obtained by using the following control cards for the HP turbine:

840100 EFMULT, 100, .8685, 0.0, 1.0,. EFFSEC, 240

840109 .5, 1.4

The description of the inputs is as follows:

Card Number	= 840100 (control card)
EFMULT	= The alpha-numeric name of the control variable you want to find
100	= The component number of the model location for the control variable
.8685	= The goal variable for this control
0.0	= Default value of conveyance criteria for the goal variable
1.0	= Coefficient factor to be used as a multiplier in defining the goal variable

EFFSEC = The goal variable alpha-numeric name

240 = The component name of the goal variable

Card Number = 840109

.5 = Lower limit of the control variable

1.4 = Upper limit of the control variable

The control cards for the IP turbine were similar, but with different control and goal variables.

IP turbine and cards for the initial guess for these multipliers were as follows:

701008 1.00

702308 1.00

The result of running these controls was an efficiency multiplier for the HP turbine of 1.03308 and IP turbine of 1.00502. With these corrections, the PEPSE design model reconciled to within .18% of the gross generation and .16% of the heat rate indicated in the vendor heat balance. The major difference lies in the flow though the IP and LP turbines along with PEPSE calculating a higher LP section efficiency at the VWO point on the heat balance.

Modeling Changes Required for Acceptance Testing

The tuned design model was then converted to (type 8) general turbines, and a new test deck was constructed. Only the type 8 turbine cards are needed to be updated. Some of the test requirements necessitated model upgrades to account for measurement of the following:

Boiler feed pump seal injection

Boiler feed pump seal leakage

N-1 packing leakoff flow

Condenser hotwell level changes (makeup or losses)

Deaerator level changes (makeup or losses)

The N-1 leakage modeling changes required changing the turbine shaft leakage splitters, type 64 to a fixed flow splitter, type 61. Boiler feed pump seal injection, and leakage was modeled by inserting a fixed flow splitter after the condensate pump and injecting it to the inlet of the boiler feed pump. Only the difference of the injection and leakage is assigned to the splitter. Hotwell and deaerator tank level changes are accounted for by adding sources or sinks for these flows. A change in level that caused flow out of the deaerator or hotwell is modeled as a source and gains were modeled as sinks. This gives configuration provides results closely modeling actual unit operating conditions during the test.

Results

Using the original test model, Santee Cooper was able to verify the preliminary vendor heat balance. This confirmed that the gains that the vendor guaranteed were thermodynamically possible. The predicted gain in kW output was 14,900 and heat rate reduction of 50 Btu/kWh. This additional savings justified the upgrade to the AERO-HP IP turbine, blading, and diaphragms.

The second challenge was met by building a design deck using GE type turbines to match the supplied vendor heat balances. The table below provides a comparison of the tuned PEPSE model to the vendor heat balances.

Steam Flow	Load	Heat Rate Heat Balance	Heat Rate Model	kW Heat Balance	kW Model
2,088,295	5%OP	7,659	7,656	318,587	318,816
1,982,793	VWO	7,671	7,683	303,726	304,272
1,888,323	95%	7,676	7,664	291,965	292,451
1,363,108	70%	7,732	7,720	218,974	219,355

Conclusions

This paper describes the successful development and implementation of a PEPSE turbine cycle model and its use in meeting specific requests by Santee Cooper management. In this case, a model was used to evaluate vendor performance estimates for management decision support and in verifying actual performance levels achieved. Key elements in the success of this project were the relative ease in adapting PEPSE's native turbine performance procedures to a non-standard design (AERO) and versatility in easily accepting model changes for specific test requirements. The ability to provide management with accurate, timely decision support services and performance information is becoming increasingly valuable with the emergence of free competition in the energy market.

References

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

1 - PEPSE computer code, NUS Inc., PO box 50736, Idaho Falls, Idaho, Version 60G: 1996

2 - PEPSE Manual: volumes I, II, III, IV, NUS Inc., PO Box 50736, Idaho Falls, Idaho

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