Finding Lost Megawatts at the Harrison Power Station

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Introduction

In today's climate of rising fuel costs, deregulation, and increased environmental awareness, it is essential that each power station manage their costs and resources to be competitive. One element of this is to determine areas of equipment degradation and how this degradation affects the performance of the plant and its cost of doing business. At the Harrison Power Station, plant data is routinely collected and analyzed using PEPSE (Performance Evaluation of Power System Efficiencies), a steady-state energy balance software program. Using spreadsheet access, the data is fed into PEPSE where it is used to calculate current plant and individual component performance. These performance indicators are then compared to design performance or performance from an earlier period to determine if degradation has occurred and, if so, the cost of such degradation. This procedure was applied to the Harrison Power Station, with the methods and the results presented here.

Unit Description

The Harrison Power Station is made up of 3 identical supercritical pulverized coal-fired units located near Clarksburg, WV. The units came on line in consecutive years in the early 1970's. The boilers were manufactured by Foster-Wheeler and the turbines by Westinghouse. Main steam pressure is 3615 psi, main steam flow at full load is 4.9×10^6 lb/hr, and main steam and reheat temperatures are 1010^oF. Each of the 3 units is capable of producing 720 MW at full load.

Data and Testing

Personnel at the Harrison Power Station conduct periodic performance tests on all the units to find degraded equipment and breaches in cycle isolation. Data is collected using calibrated test equipment, plant instrumentation, and manual gauges read by plant personnel. This data is assembled and organized into 1-hour averages. Approximately 100 points throughout the unit, both turbine cycle and boiler, are obtained and used. Of the data collected in the plant, the following items are used for routine analysis:

Turbine Cycle

- Main Steam Temperature and Pressure
- Feedwater Flow
- Gross Generation
- 1st Stage Pressure
- Cold Reheat Temperature and Pressure
- Hot Reheat Temperature and Pressure
- Crossover Temperature and Pressure
- Extraction Pressures to All Feedwater Heaters
- Outlet Temperatures from All Feedwater Heaters
- Drain Temperatures from All Feedwater Heaters
- Condenser Pressures (two zones)
- Discharge Temperatures and Pressures from Condensate Pumps and BFP's

Boiler

- Economizer Inlet Temperature
- Air Heater Air Outlet Temperature
- Air Heater Gas Outlet Temperature
- Stack Temperature
- Furnace Exit Gas Temperature
- Cold Reheat Temperature and Pressure
- Hot Reheat Temperature and Pressure
- Main Steam Temperature and Pressure
- Ambient Air Conditions
- Pulverizer Outlet Temperature
- Fuel Flow and Ultimate Analysis

The data that is collected and used typically represents at or near 100% power. For proprietary reasons, actual data values are not presented here.

Performance Issues

No specific performance issues were pending at the Harrison Power Station. Current performance issues are day-to-day or periodic issues similar to other stations. Equipment begins to wear, tubes get fouled or leak, boilers begin to slag, instruments drift, all as part of an overall deterioration of an aging plant. Periodic testing, as discussed in the previous section, is used to find these problems and identify larger ones before they become costly.

Finding the Problems

Harrison Power Station personnel use the PEPSE software to pinpoint degraded equipment and to quantify that degradation in terms of lost generation, increased heat rate, and lost revenue. PEPSE is a steady-state energy balance software program that simulates the plant. This is done by the development of a plant schematic or "model" that mimics the actual plant components and their connections. The user builds this schematic in a Windows environment by dragging and dropping plant component icons onto the screen from a component library. This library contains all the components found in any power plant.

A PEPSE turbine cycle model and boiler model were constructed to simulate the Harrison Power Station units. Because they are of identical design, the same base models were used for all three units. These models are shown in Figures 1 and 2. The general procedure for developing these models and the specifics for the Harrison Power Station models are given below.

The first step is to develop base models using the original vendor designs. For the turbine cycle, this original design is represented by the turbine vendor heat balance diagrams and thermal kit. For the boiler, the original boiler manufacturer specification sheet and various drawings showing the boiler layout are used. These models are useful for checking the validity of the model layout, model data, and operation, and should be used for studies that relate back to the original design as the base point. Because they use the fixed data from the vendors, these models are often not flexible enough to respond to changing boundary conditions or changing conditions in the plant.

The next step is to characterize the individual components using detailed geometric and heat transfer information. For example, for the condenser this would include tube material, tube inside and outside diameter (or BWG), tube length, and number of tubes. Other heat transfer surfaces in the boiler and turbine cycle require similar types of information. By using this detailed characterization, the models can respond to changes in load and boundary conditions and are ideal for studies involving operations changes, design changes, component degradation, and other studies where the original equipment performance is no longer valid.

Each of the three units operates slightly differently; therefore, when analyzing actual plant data, separate cases were performed for each unit, each starting with the common base model. A technique in PEPSE known as Special Option 6 was used along with the plant data to establish the benchmark performance (step 1), reduce the test data (step 2), correct the test data to standard (or benchmark) conditions (step 3), and finally perform a series of upgrades (steps 4 – N) to find the performance benefit of upgrading each current component's performance to it's benchmark performance. This entire procedure is processed automatically within PEPSE, steps 1 – N.

The benchmark performance may be based on the original design from the turbine and boiler vendors, the acceptance test, a previous performance test, or some other previous plant condition. The acceptance test is the ideal benchmark, but few plants have this. Results from a past performance test also make a good benchmark, and are usually available. For the Harrison Power Station, the benchmark was based on a turbine vendor heat balance that was developed using data from a previous plant condition and the turbine vendor's guarantee of a new HP turbine performance.

Reducing the test data is the technique where the raw data (pressures, temperatures, flows, etc.) are used to define performance parameters for the individual hardware components in the plant. This raw data is used to define efficiencies, heater TTD's, and other parameters used to measure hardware performance. PEPSE has a technique that can look at each piece of raw data and determine if it is good or bad, based on a set of user-defined criteria. If the data does not meet these criteria, it can be tagged, replaced, or clipped using pre-defined limits. For ease-of-use, a Visual Basic routine was imbedded in an Excel spreadsheet during this study to automatically pass the raw data from the spreadsheet into PEPSE. The plant data is retrieved from the plant process computer via a spreadsheet, so this process proved to be the quickest and most error-free method of data transfer. In fact, the entire PEPSE analysis was managed and performed from this routine inside the Excel spreadsheet.

Because tests are rarely performed with the same boundary conditions (main steam pressure and temperature, reheat temperature, condenser pressure, etc.) as the condition to which it is being compared, the benchmark, it is necessary to correct the test performance to benchmark boundary conditions. This technique uses the test component performance parameters (from step 2) and the benchmark boundary conditions (from step 1) to determine the plant performance that would have occurred if the test had been performed using benchmark boundary conditions. The result "corrects" the test results to these standard boundary conditions. However, an assumption must be made here. It must be assumed that the individual component performance parameters, determined from the test data, do not change with changing boundary conditions. How good is this assumption? It depends on how different the two sets of boundary conditions are. The user's judgment should be used here. At the Harrison Power Station, the differences were small because tests are normally performed at nearly the same conditions each time. This is the step that many inquire as to whether the manufacturer's correction curves have been built into PEPSE. The answer is "no". Because PEPSE is calculating the energy balance for the different boundary conditions, correction curves are not needed. The PEPSE heat balance calculation handles all the "corrections" by the nature of its calculation. In fact, most manufacturers' correction curves are generated using heat balance software calculations like PEPSE's.

The upgrade steps are the heart of the test data analysis process because they quantify each component's degradation. This is a series of steps where the component performance parameters from the test are replaced, one-at-a-time, with the benchmark performance parameters. Generation improvement, heat rate improvement, and yearly cost savings are reported for each parameter. Table 1 shows the results of a representative analysis of the upgrade step process. THIS DOES NOT REFLECT THE RESULTS AT THE HARRISON POWER STATION. THE RESULTS AT THE HARRISON POWER STATION CONTAIN PROPRIETARY INFORMATION AND CANNOT BE SHARED IN THIS PAPER. Using results like those shown in Table 1, Harrison Power Station personnel can immediately pinpoint the problems and degraded areas, and their impact on the plant. Economic decisions can then be based on these results.

Once the model is set up, as described above, data from the spreadsheet for any of the three units may be input and results obtained in seconds.

The Future

These test data analysis models will continue to be used on a regular basis for all three Harrison Power Station units to find degraded equipment, lost megawatts and to assess their economic impact. In addition, the models will be used in many other capacities and studies, such as:

Turbine Cycle

- Feedwater Heater Replacement
- Tube Plugging Effects
- New HP Turbines
- Cooling Tower Upgrades
- Enthalpy Drop Tests

Boiler

- Reheat Design Changes
- Cleanliness/Sootblowing Effects
- Fuel Changes

Conclusion

Software tools used to analyze the thermodynamics of steam power plants have become increasingly popular as economic pressures have increased. Market forces such as deregulation, higher fuel prices, and environmental concerns force utilities to be proactive in their search for better performance and lower costs. The Harrison Power Station is taking an active approach in tackling these issues.

Table 1

Test Data Analysis Sample Results Using PEPSE

(NOT Representative of Harrison Power Station Results)

Upgrade Case	Upgrade Item	Lost MW (MW)	Lost Heat Rate (Btu/kW-hr)	Cost ($/yr)
1	HP Turbine	0.80	42	$63,066
2	IP Turbine	4.14	188	$282,295
3	LP A Turbine	1.04	78	$117,122
4	LP B Turbine	0.54	41	$61,564
5	Heater 5	0.34	5	$7,508
6	Heater 4	0.02	6	$9,009
7	Heater 3	0.04	1	$1,502
8	Heater 2	0.74	56	$84,088
9	Heater 1	0.04	2	$3,003
10	Gland Steam Condenser	0.00	0	$0
11	Air Ejector	0.00	0	$0
12	Boiler Feed Pump	0.10	2	$3,003
13	Condensate Feed Pump	0.00	0	$0
14	Air Heater	0.60	40	$60,063
15	Primary Superheater	1.01	62	$93,097
16	Secondary Superheater	3.78	105	$157,665
17	Primary Reheater	4.00	106	$159,166
18	Secondary Reheater	0.60	10	$15,016
19	Economizer	6.03	202	$303,317
	TOTAL	23.82	946	$1,420,482

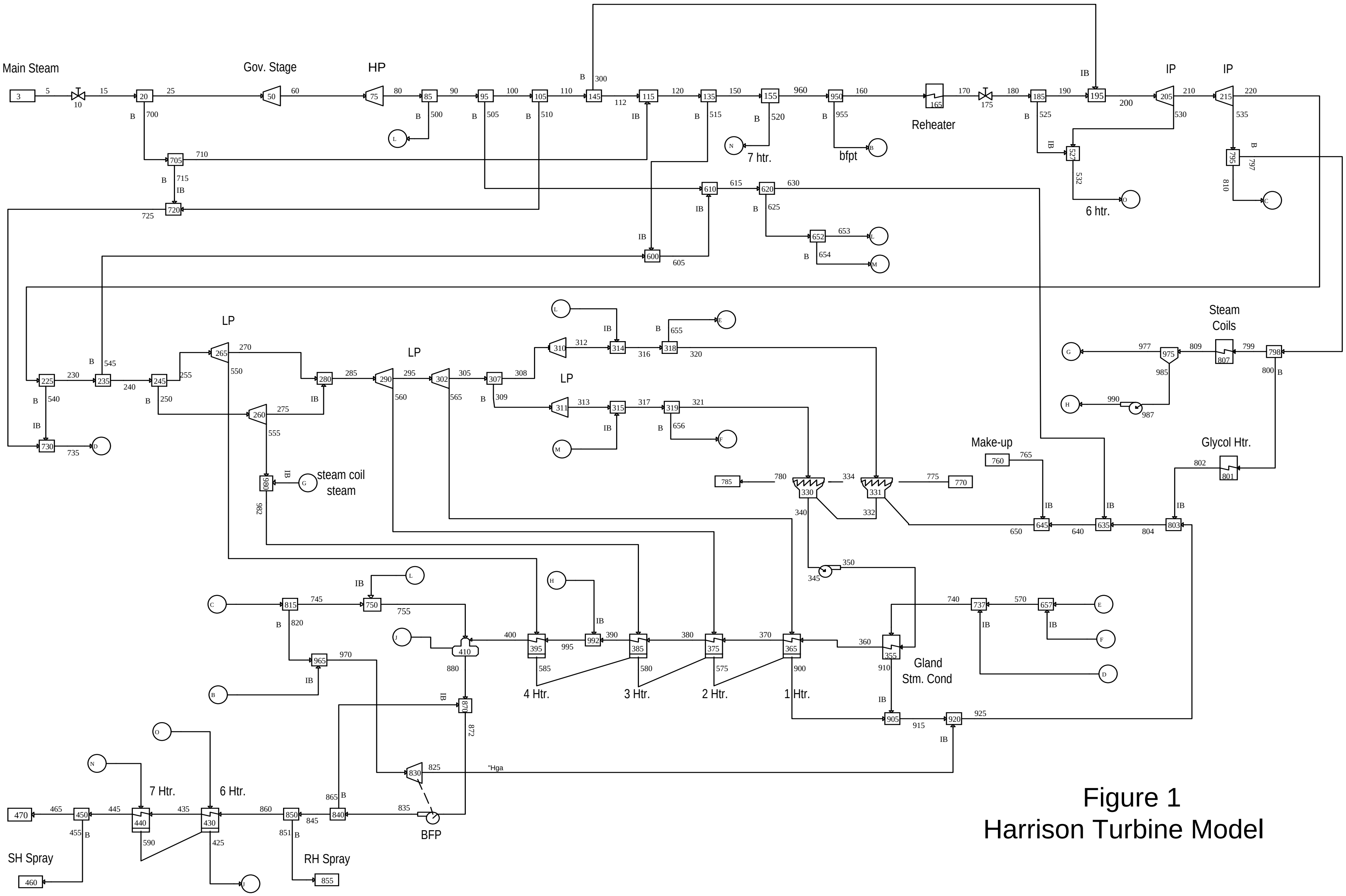

Figure 1
Harrison Turbine Model

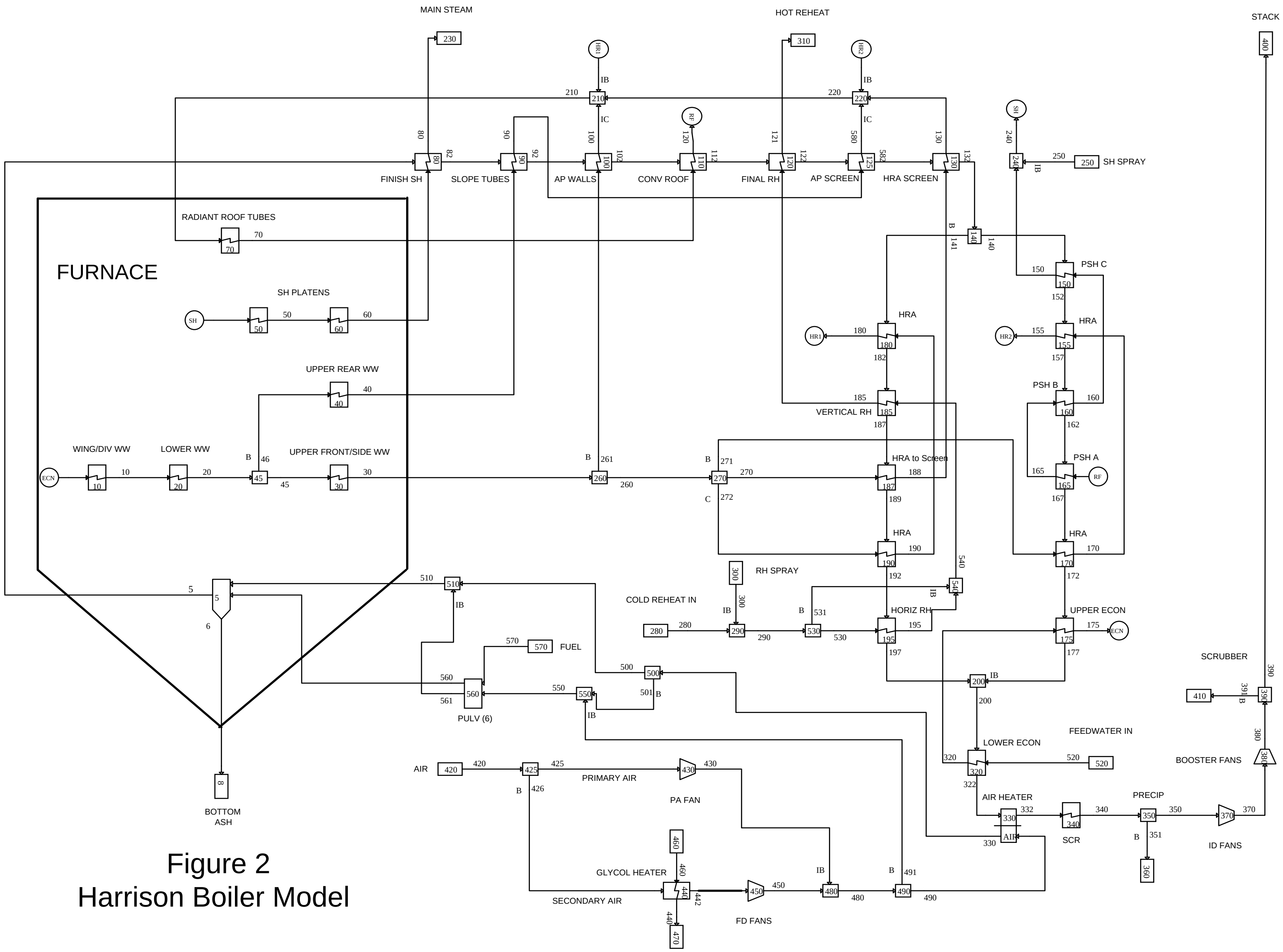

Figure 2
Harrison Boiler Model