A Global Approach to Soot Cleaning Optimization at Dynegy’s Baldwin Energy Complex

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Agenda

- Baldwin Energy Complex Overview
- Motivations for Optimization
- Soot Cleaning Optimization
- Looking Ahead
Dynegy’s Baldwin Energy Complex

3 - 600 MW Units
1970-1975

Units 1 & 2 Cyclone Fired
14 Cyclones/Unit

Unit 3 Tangential-Fired
6 Mills

PRB Coal
Conversions
1999 & 2000
Baldwin Unit 3

- CE Drum-type Boiler
- Pulverized T-Fired: Six Pulverizers
- Furnace Dimensions: 52’ x 58’, 180’ tall
- SOFA, Low NOx Burners
- Steam Conditions
  - Flow: 4.2 MLb/Hr
  - SH/ RH Temperature: 1005F/1005F
  - Throttle Pressure: 2425 Psig
Baldwin 3 – Ash Deposition

- **PRB Coal**
  - Intermittent Wall Deposition
  - Division Panels
  - SH Pendant
  - Horizontal SH
Unit 3 Sootblowing Operation prior to 2006

- High variability in PRB coal
- Water Cannons and Heat Flux Sensors in Furnace area
- PrecisionClean and standard IK’s in convection pass
- ASI control system to operate water cannons & sootblowers

- Prevailing sootblowing guidelines:
  - Water cannons operator initiated when attemperation spray flows high
  - Operator initiated sequences in the convection pass – normally a sequence of most IK’s running continuously
  - Monitor furnace-to-economizer and furnace-to-reheater differential pressures; Increase sootblowing if differentials increase
Motivations for Optimization

- Full Load PRB operation requires tight control
  - Loss of spare mill at full capacity
  - Small process changes have significant effects
  - Seasonal impacts to heat rate

- Expectations
  - Ability to control key parameters on consistent basis
  - Ability to compensate for changes in coal quality
  - Improved understanding of available data and its use for improved operations
  - Ability to optimize controls to meet plant objectives
Why Optimize Soot Cleaning?

Cleaning actions (or lack thereof) affect many plant parameters:

- Slagging/fouling impacts heat transferability
- Capacity: Steam and gas temperatures, spray flows, differential pressures, fan limits
- Performance: Boiler efficiency, heat rate
- Emissions: NOx, Opacity, LOI, CO
- Availability/Reliability: Waterwall/tube longevity, EFOR, equipment wear-and-tear
What SootOpt Does

- Optimizes boiler cleaning based on unit-specific objectives:
  - Improves Heat Rate including Reheat & Superheat steam temperature control
  - Improves emissions control (NOx, opacity, CO)
  - Balances tradeoffs between furnace/backpass absorption
  - Reduces O&M costs by avoiding unnecessary boiler cleaning actions and reducing tube wear and thermal stressing
  - Compensates for off-design fuels and operations
  - Leverages existing soot cleaning instrumentation, models, equipment and control systems
ISB & SootOpt installed in 2006 on Unit 3

- Upgraded sootblowing controls to Diamond SentrySeries 1500 Intelligent Sootblowing Control System (ISB)
- Added thermocouples and thermoprobe behind pendent reheater for heat transfer calculations
- Installed NeuCo’s SootOpt for adaptive optimization of sootblowing operation (NeuCo’s CombustionOpt neural optimizer already in operation for furnace combustion)
Diamond Intelligent Sootblowing System
How SootOpt Interfaces with ISB
ProcessLink Platform: Enterprise Architecture

PlantAdvisor

Unit 1 UnitAdvisor

Unit 2 UnitAdvisor

Unit 3 UnitAdvisor

CombustionOpt

SootOpt

PerformanceOpt

MaintenanceOpt
Models Learn from Data

Model NOx Predictions (blue) vs. actual Measured NOx (red) before and after sustained training on plant data.
Improved Model Fidelity with CombustionOpt & SootOpt Integrated

NOx model with CombustionOpt & SootOpt integrated

Blue = NN Model Predicted
Green = Actual

NOx model with just SootOpt
Improved Model Fidelity with CombustionOpt & SootOpt Integrated

Blue = NN Model Predicted
Green = Actual

NOx model with CombustionOpt & SootOpt integrated

NOx model with just CombustionOpt
### Optimization Advice

<table>
<thead>
<tr>
<th>Description</th>
<th>Ranked Operational Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convection area no permit or not in auto</td>
<td>0.90</td>
</tr>
<tr>
<td>Some Econ IKs below min required ops</td>
<td>0.50</td>
</tr>
<tr>
<td>Some PlatSH IKs below min required ops</td>
<td>0.50</td>
</tr>
<tr>
<td>Some RH IKs below min required ops</td>
<td>0.50</td>
</tr>
<tr>
<td>Furn zone 2 (Seq22) auto operations &lt; minimum</td>
<td>0.40</td>
</tr>
<tr>
<td>Furn zone 10 (Seq30) auto operations &lt; minimum</td>
<td>0.40</td>
</tr>
</tbody>
</table>

### What's Going on Now and Why

<table>
<thead>
<tr>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(FCM) Zone permits for all furnace area sequences suspended due to low furnace exit gas temp</td>
</tr>
<tr>
<td>(SCE) Permit for all convection area sequences suspended due to low furnace exit gas temp</td>
</tr>
<tr>
<td>(SCE) Operator has suspended permit for DivSH(Seq51) while bottom ash cleaning is underway</td>
</tr>
</tbody>
</table>

### Optimization Benchmarks

#### Graph

![Graph showing optimization benchmarks](image)

### Benefit vs Missed

<table>
<thead>
<tr>
<th>Metric</th>
<th>Benefit</th>
<th>Missed</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (Etu/kWh)</td>
<td>119</td>
<td>488</td>
</tr>
<tr>
<td>NOx (lb/MMBtu)</td>
<td>0.0015</td>
<td>0.0061</td>
</tr>
</tbody>
</table>
## Visibility into Heuristics

### Unit 3: SootOpt Analysis

<table>
<thead>
<tr>
<th>Sys</th>
<th>Enabled</th>
<th>Active</th>
<th>Min</th>
<th>Actual</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pause all convection sequences, FEOT violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>1,900</td>
<td>1,993.1</td>
<td>degF</td>
</tr>
<tr>
<td>Pause all convection sequences, load violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>400</td>
<td>633.6</td>
<td>MV/V</td>
</tr>
<tr>
<td>Pause all convection sequences, FEOT violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>600</td>
<td>693</td>
<td>degF</td>
</tr>
<tr>
<td>Pause all convection sequences, tilt violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>-0.3</td>
<td>5</td>
<td>%</td>
</tr>
<tr>
<td>Pause RH(53), RH spray violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>23.6</td>
<td>75</td>
<td>kib/h</td>
</tr>
<tr>
<td>Pause DivSH(51) and MktSH(32), RH temp violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>9/5</td>
<td>995</td>
<td>degF</td>
</tr>
<tr>
<td>Pause Nose(53), RH(53) SH outlet temp violation</td>
<td>SCE</td>
<td>Yes</td>
<td>No</td>
<td>980</td>
<td>990.2</td>
<td>degF</td>
</tr>
<tr>
<td>Pause all convection sequences but DivSH(51), DivSH running</td>
<td>SCE</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator has inhibited DivSH(51)</td>
<td>FCM</td>
<td>Yes</td>
<td>No</td>
<td>-0.3</td>
<td>5</td>
<td>%</td>
</tr>
<tr>
<td>Pause all furnace sequences, FEOT violation</td>
<td>FCM</td>
<td>Yes</td>
<td>No</td>
<td>1,900</td>
<td>1,993.1</td>
<td>degF</td>
</tr>
<tr>
<td>Pause all furnace sequences, load range violation</td>
<td>FCM</td>
<td>Yes</td>
<td>No</td>
<td>400</td>
<td>633.8</td>
<td>MV/V</td>
</tr>
<tr>
<td>Pause all furnace sequences, SH outlet temp violation</td>
<td>FCM</td>
<td>Yes</td>
<td>Yes</td>
<td>995</td>
<td>990.2</td>
<td>degF</td>
</tr>
<tr>
<td>Pause all furnace sequences, RH spray violation</td>
<td>FCM</td>
<td>Yes</td>
<td>No</td>
<td>5</td>
<td>23.6</td>
<td>kib/h</td>
</tr>
<tr>
<td>Pause all furnace sequences, RH outlet temp violation</td>
<td>FCM</td>
<td>Yes</td>
<td>No</td>
<td>975</td>
<td>995</td>
<td>degF</td>
</tr>
<tr>
<td>Inhibit convection zones, high opacity</td>
<td>SCE</td>
<td>No</td>
<td>No</td>
<td></td>
<td>19</td>
<td>100</td>
</tr>
<tr>
<td>Inhibit convection zones from cleaning while clean</td>
<td>FCM</td>
<td>No</td>
<td>No</td>
<td></td>
<td>5.9</td>
<td>6</td>
</tr>
<tr>
<td>Allow convection to clean while clean, high Hp</td>
<td>FCM</td>
<td>No</td>
<td>No</td>
<td></td>
<td>5.8</td>
<td>7</td>
</tr>
<tr>
<td>Adjust convectionuffle ratio, high Hp</td>
<td>FCM</td>
<td>No</td>
<td>No</td>
<td></td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Request convection clean on time, high Hp</td>
<td>SootOpt</td>
<td>No</td>
<td>No</td>
<td></td>
<td>23.6</td>
<td>40</td>
</tr>
<tr>
<td>Inhibit furnace zones from cleaning while clean</td>
<td>SootOpt</td>
<td>No</td>
<td>No</td>
<td></td>
<td>23.6</td>
<td>40</td>
</tr>
<tr>
<td>Allow furnace zones to clean while clean, high RH sprays</td>
<td>SootOpt</td>
<td>No</td>
<td>No</td>
<td></td>
<td>23.6</td>
<td>40</td>
</tr>
<tr>
<td>Adjust furnace flux biases, high RH sprays</td>
<td>SootOpt</td>
<td>No</td>
<td>No</td>
<td></td>
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SootOpt Sensitivities:
Net HR
Integrating SootOpt & CombustionOpt improves NOx performance
NOx & HR vs MW (w/CombustionOpt + SootOpt)

Baseline

SootOpt only

CombustionOpt only

CombustionOpt & SootOpt

NOx = blue

HR = green
Average Daily Attemperation Spray Flows

- Manual
- SootOpt & ISB Enabled
- Manual

Graph showing various flow rates for Manual and SootOpt & ISB Enabled conditions.
Decreased sootblower activity when SootOpt turned back on
SootOpt/ISB Results Thus Far

- Operating on Unit 3
  - Decreased sootblower operation count
  - Attemperation spray flows are controlled to less than 50 klbhr with SootOpt/ISB whereas before spray flows would at times be above 100 klbhr
  - Initially due to the split attemperation flow control (2 reheat controllers & 2 superheat controllers), steam temperatures would drop to 950F which could effect MW output. Recent changes have reduced that drop to 980F
  - Improvements in NOx rates have been seen when CombustionOpt and SootOpt are working together

- Being installed on Unit 2 in February 2007
  - Unique opportunity to quantify contributions of individual ISB control and instrumentation components