On Load Boiler Cleaning Optimization Technologies

October 11, 2012
Outline

- Review of Best Available On Load Cleaning Optimization Technologies,
  - SMART Feedback Devices
  - On load cleaning control integration into different optimization goals for the power boilers
  - How to select the right feedback technology
  - System Integration
- Case study on tube life and reliability optimization
- Case study on SCR temperature control
- Case study on Plant Heat Rate Optimization
- Case studies on Fuel Flexibility System Introduction
Clean Energy Solutions

- Part of the Clyde Bergemann Power Group
  - Privately held
  - US corporation
- 30 business units worldwide
  - 17 of which include production facilities
- Over 1,500 employees

Vision:
- #1 Global Enterprise providing innovative Products and Solutions for Clean Power Generation

Currently Providing Solutions in Six Fields:
- Air Pollution Control
- Material Handling
- Boiler Efficiency
- Air & Gas Handling
- Energy Recovery
- Firing Solutions
On Load Boiler Optimization

Decision:
The uppermost goal is to preserve boiler efficiency and availability. Here, an evaluation takes place of all recommended cleaning actions using current process data and stored operating events. The most suitable cleaning strategy will be selected and triggered.

Analysis:
Software modules as intelligent units continuously analyse and interpret data in real time. They provide recommendations concerning where, how and when to clean. These recommendations are forwarded to the decision level.

Diagnostics:
Different sensors continuously monitor important process parameters feeding back key data for analysis.
ON LINE DIAGNOSTICS
SMART Feedback Devices

Monitor Boiler Performance

CONVECTION
SMART Gauge

TDM Thermo Dynamic Model

FURNACE
SMART Flux Sensor
SMART Gauge™ System

- Monitors Weight Accumulation on pendants
- As deposits stick to the tub banks the overall weight of the tube bank increases
- This increase in weight is detected by the Smart Gauges located on the hanger rods
- The strain gauges relay the increase in weight to the ISB system
- The ISB system then operates the correct sootblower to remove the deposit
SMART Gauge™ System

- Direct Measurement System
- Strain Gauge Technology
- Installed on Pendant Rods
  - Measures Weight Gain from Ash Build-up
  - Detects Clinker Formation

SMART Gauge Install

Reheat Pendant Ash Weight from SmartGauge

Delta Weight on gages (lbs.)

SMART Gauge Install
Thermodynamic Model

Objective

• Calculate heat transfer rates of tube banks in convection pass using real-time boiler process data

Function

• Uses real-time data to create a Cleanliness Factor

Heat Transfer Efficiency [zone] = \( \frac{\text{Heat Transfer Rate in Real-Time}}{\text{Maximum Theoretical Heat Absorption}} \)

• Tube banks are cleaned only when HTE is below required rate
• Prioritizes sootblowers based on effectiveness of previous cleaning event
ThermoDynamic Model

- Monitors Inlet and Exit Temperatures and Flows for each heat exchanger
- As deposits stick to the tub banks the overall heat transferred (Q) to the tube banks decreases
- This decrease in heat transfer is detected by the Thermodynamic model
- The TDM relays the decrease in heat transfer to the ISB system
- The ISB system then operates the correct sootblower to remove the deposit
SMART Flux Sensor
How to Select the Right Feedback Technology?

<table>
<thead>
<tr>
<th>System</th>
<th>Clinker Formation</th>
<th>Loss in Heat Transfer</th>
<th>Ash Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMART Gauge</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>TDM</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
SMART Sootblowing

- System “learns” SB#2 was more effective
- Initiates SB#2 first next time
SMART Retract

- Targeted Sootblowing
- Variable Intensities:
  - Variable Helix
  - Stop & Go
  - Variable Pressure

<table>
<thead>
<tr>
<th>SMART FEATURE</th>
<th>CUSTOMER BENEFIT</th>
</tr>
</thead>
</table>
| Dual Motor Drive            | ✓ Infinite cleaning patterns  
                               | ✓ Independent rotation and traversing speeds                                     |
| Variable Helix              | ✓ Targeted cleaning for fouling conditions specific to that tube bank            |
| Variable Cleaning Pressure  | ✓ Remove difficult slag by increasing blowing pressure, or eliminate tube erosion by reducing blowing pressure in real-time |
| Variable Intensity          | ✓ Stop the nozzles at specific tube banks that need additional cleaning, or speed through tube banks that are already clean |
SMART Retract Strategies

- Cleaning Intensities

| Zone 1 | Zone 2 | Zone 3 | Zone 4 |
SHFM & TDM in Operation
SmartGauge
(Monitoring deposit weight)

ThermoDynamic Model
(Monitoring the cleanliness factor by measuring heat transfer rate)
Furnace Cleaning with SMART Cannons

- When slag begins to build up on the furnace walls the measured heat flux starts to decrease.
- Once the heat flux drops below a certain value known as the backstop a signal is sent to the ISB to operate the water cannon for that zone.
- The water cannon cleans the slag buildup on the furnace wall causing the Heat flux to increase.

Calculate Thermal Impact
System Integration

DCS can be the primary Operator Interface

- Windows based HMI Application
- OPC Server for PLC & DAQ Communications

Ethernet, Modbus, DH+, Serial.

SmartConvection™

- Ethernet

HMI

- Ethernet

AB's ControlLogix PLC Panel

- Ethernet

DAQ Panel

- Ethernet

SmartSensor™

- SmartSootBlower

- SmartGauge™

Plant DCS

Ethernet

Ethernet

Ethernet

Ethernet

Ethernet

Ethernet

Ethernet
Cleaning Strategy for Plant Heat Rate Optimization
600 MW Coal Fired Plant Simulation
Simulations: PHR and MW Optimization

### Current Conditions

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<tr>
<th></th>
<th>PHR Improv</th>
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<tbody>
<tr>
<td>PHR</td>
<td>10,013 Btu/kWh</td>
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<tr>
<td>kW</td>
<td>553,699 kW</td>
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</table>

### PHR - 1 Cleaning Scnr

<table>
<thead>
<tr>
<th>SB#</th>
<th>Estimated Q Improvement</th>
<th>MW Improv</th>
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</thead>
<tbody>
<tr>
<td>SB#1</td>
<td>0.16%</td>
<td>3</td>
</tr>
<tr>
<td>SB#2</td>
<td>0.02%</td>
<td></td>
</tr>
<tr>
<td>SB#3</td>
<td>0.02%</td>
<td></td>
</tr>
<tr>
<td>SB#4</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>SB#10</td>
<td>0.01%</td>
<td></td>
</tr>
<tr>
<td>SB#11</td>
<td>0.01%</td>
<td>25 kW</td>
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<tr>
<td>SB#12</td>
<td>0.00%</td>
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### PHR - 2 Cleaning Scnr

<table>
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<tr>
<th>SB#</th>
<th>Estimated Q Improvement</th>
<th>MW Improv</th>
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<tbody>
<tr>
<td>SB#5</td>
<td>0.80%</td>
<td>0</td>
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<td>SB#6</td>
<td>0.60%</td>
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<tr>
<td>SB#7</td>
<td>0.40%</td>
<td>161 kW</td>
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<tr>
<td>SB#8</td>
<td>0.20%</td>
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</table>

### ECONOMIZER

<table>
<thead>
<tr>
<th>SB#</th>
<th>Estimated Q Improvement</th>
<th>MW Improv</th>
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</thead>
<tbody>
<tr>
<td>SB#17</td>
<td>0.05%</td>
<td>3</td>
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<td>SB#18</td>
<td>0.01%</td>
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<tr>
<td>SB#19</td>
<td>0.01%</td>
<td>0 kW</td>
</tr>
<tr>
<td>SB#20</td>
<td>0.00%</td>
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### R Preheater Cleaning Scnr

<table>
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<tr>
<th>ZONE</th>
<th>Estimated Q Improvement</th>
<th>MW Improv</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZONE#1</td>
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<td>3</td>
</tr>
<tr>
<td>ZONE#2</td>
<td>0.02%</td>
<td></td>
</tr>
<tr>
<td>ZONE#3</td>
<td>0.01%</td>
<td></td>
</tr>
<tr>
<td>ZONE#4</td>
<td>0.00%</td>
<td></td>
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Successful Cleaning Optimization Strategy

- Targets are not static numbers.

- Keeping each heat exchanger at the same cleanliness level at all times is not the right approach for optimum heat rate and back end gas temperature control.

- SmartClean System makes decisions based on key Performance Targets such as:
  - Main Steam Temperature
  - Hot Reheater Temperature
  - Economizer Exit Gas Temperature
  - Furnace Exit Gas Temperature
  - Plant Heat Rate

- The system uses simple heat balance and optimization algorithms to realize these targets and derives the local cleanliness targets dynamically.
Cleaning Strategy for Boiler Back End Temperature Control
Automated Setpoint Optimization (2010 Platform) – Ex: EEGT Control Loop

EEGT Set point is 745°F

Measured EEGT is 670°F

Delta change in the zone settings
Successful Cleaning Strategy

- **Cleanliness Targets are not static numbers.**
- The cleaning ability in a heat exchanger is dependant on the number of sootblowers available for the area.
- If half of the sootblowers are out of duty around a pendant, the system adopts to the new condition and adjusts its targets based on the self learning algorithms.
- When new blowers are made available to clean a section, SmartClean learns the effectiveness of the new blowers and revises its targets accordingly.
SMART Clean Cleaning Strategy
SMART Clean Technology

Dealing with change in sootblower availability

Target adjustment is made automatically by the system

SMART Clean adjusts its target based on the new condition.
CASE STUDY
PRB Fuel Conversion
Flue Gas DP Comparison for 3 identical PRB Coal Fired Boilers

- DP for U1
  - No Smart Clean
- DP for U2
  - No Smart Clean
- DP for U3
  - With SMART Clean
Background

- Dynegy Havana Power Station in Havana, Illinois
  - 488MW B&W wall fired, Sub Critical
  - PRB coal
Operational Challenges After Fuel Switch

- Heavy ash build-up
- Degradation of precipitator performance
- Higher FEGT and EEGT
- Higher superheater temperature and higher superheater spray flows
- Boiler flue gas draft pressure increase
- Impact on induced draft (ID) fan.
- Higher heat rate
- Forced outages due to sootblowing induced tube leaks and ESP pluggage
- Capacity limitations (10-20 MW de-rate)
SMART Clean™ System

SMART CONVECTION
48 Retractable Sootblowers

TDM Thermo Dynamic Model

SMART FURNACE
4 SMART Cannons
44 SMART Flux Sensors
Boiler Furnace

Water Cannon coverage

Original wall blower coverage

Water Cannon coverage

Legend:
- Water Cannon
- Water Cannon cleaning zone
- Wall blower


Cleaning Surface comparison

- 43 wall blowers clean 40% of Furnace
- 4 Water cannons clean 80%
- Furnace Cleaning Surface was Doubled.
- Therefore, Wall Blower taken out operation.

SMART Clean increased Cleaning Surface by 6287 ft²
Main Steam Temperature Improvement

Steam temperature control compared to fuel flow

Improvement in steam temperature control
E.E.G.T. Improvement

\[ \Delta 50 \, ^\circ F \text{ on the high end} \]

\[ \Delta 30 \, ^\circ F \]

Left Economizer Exit Gas Temperature (°F)

Right Economizer Exit Gas Temperature (°F)

Total Fuel Flow (Klb/hr)

Left EEGT Before SMART Clean
Left EEGT After SMART Clean
Linear Average of Left EEGT Before SMART Clean
Linear Average of Left EEGT After SMART Clean

Right EEGT Before SMART Clean
Right EEGT After SMART Clean
Linear Average of Right EEGT Before SMART Clean
Linear Average of Right EEGT After SMART Clean
F.E.G.T. Improvement

- **Calculation Inputs**
  - Average HF improvement = 10%
  - Base line Plant Heat Rate = 10900
  - Nominal Power Generation = 488 MW
  - Furnace Heat Transfer = 36% of total heat absorbed
  - HHV of Coal = 8800 btu/lb

- EEGT Improved by 30 F
- FEGT (calculated) improved by ~ 85 F
Dynegy Havana reduced their CO₂ by 1.09% (2.48 T/hr)
Economical Analysis

- Total savings ranges from $2.2M to $7.5M
  - 0.59% Plant Heat Rate improvement = $287,000
  - Elimination of 2 days forced outages from furnace tube leaks and ESP pluggage ranges in savings from $500,000 to $1,300,000
  - Elimination of average 15 MW Derate ranges in savings of $1,400,000 to $6,000,000
CASE STUDY

Reliability and Tube Life Improvement
Both Sequential and SmartClean ISB had similar number of operations/day.

However, ISB initiated 92% of the cleaning operations below the clean level of 0.9 CF, reducing the risk of over cleaning and tube erosion.
20 F reduction in Economizer Exit Gas Temperature (~0.6% improvement in Boiler Efficiency)
Resolving Heat Transfer Imbalance

NON-ISB

Intermediate & High Temperature Secondary Superheater - Non ISB

ISB

Intermediate & High Temperature Secondary Superheater - ISB

Zone 9 Left

Zone 10 Right

Zone 9 Left Side

Zone 10 Right Side
CASE STUDY

SCR Temperature Control
Located near Roxboro, N.C.

1983 dual-boiler (Foster Wheeler) unit fired with Bituminous Coal. 800MW Gross.

Clyde Bergemann SMART Clean Intelligent Sootblowing System was installed and commissioned in June 2010 along with 84 Clyde Bergemann VS sootblowers.
New Wallblowers

New gas temperature probes

Split Backpass
**SCR Inlet Flue Gas Temp Control**

- **Challenge:**
  - Furnace fouling is an impact on SCR inlet gas temperature
  - The effect of furnace cleanliness needed to be taken out of the equation to improve the SCR inlet gas temperature control

- **Solution:**
  - Keep furnace cleanliness stable thus stabilize FEGT
  - How?
    - Set cleanliness targets dynamically => A sliding scale FEGT target was determined for each firing rate
    - Clean the furnace via SMART Clean => Wall Blowers were tied into closed loop control and system was run in automatic mode which operates the wall blowers that has the greater effect on FEGT more frequently
FEGT clean target is adjusted as a function of the feedwater flow rate to stabilize furnace cleanliness.
SmartClean ISB– PGN MAYO

EEGT and SCR Inlet Gas Temp Control

Reduction in Retractable Operations

PHR Improvement
Questions?