GAS-SIDE OPTIMIZATION OF FOSSIL-FIRED POWER GENERATION

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MCILVAINE HOT TOPICS
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THE POWER INDUSTRY IS CHANGING

Generational Turnover in Equipment and Staff
30% of the electric utility workforce is projected to retire within the next 5 years
But large uncertainties in emissions regulation

Impact of Renewables & Changing Costs, Demand & Regulations
Renewable energy predicted to become the world’s largest source of electricity within 15 years
Coal based power expected to contribute over 30% of the world’s electricity through 2025
Variable fuel prices & quality affect operating margins
Units designed for baseload now cycling continuously
Growing pressure to reduce emissions affect operations

1 U.S. Energy Information Association (EIA), 2016
MAJOR FOSSIL-STEAM-FIRED BOILER DESIGNS

• Pulverized Coal
  • Wall-fired
  • Tangentially Fired
  • Turbo

• Circulating Fluidized Bed (CFB)
  • Pressurized
  • Atmospheric
  • Bubbling

• Stoker

• Integrated Gasified Coal Combined Cycle
OPPORTUNITIES FOR EFFICIENCY & EMISSIONS PERFORMANCE

• Boiler
  • Thermal performance monitoring
  • Boiler tuning
  • Combustion optimization
  • Boiler cleanliness optimization

• Air Quality Control Systems (AQCS)
  • SCR tuning
  • SCR/SNCR optimization
  • FGD optimization
  • Hg optimization

• Turbine
  • Thermal performance monitoring
  • Sliding pressure throttle control

• Balance of Plant
  • Cooling tower, condenser, outlet water temperature, etc.
COAL QUALITY IS IMPORTANT

• Heat content, sulfur, hardness, grind-ability and other chemical constituents have big implication.

• Major classifications based on heat content: in descending order:
  • Anthracite
  • Bituminous
  • Subbituminous
  • Lignite
  • Peat

• Powder River Basin (PRB) coal in US a major emissions compliance strategy

• Boilers burning off-design fuels have challenges and opportunities

• Large wave of conversions from coal to natural gas in early phase

• Outcome will be affected by both regulation and natural gas processes
BOILER OPTIMIZATION

• Applies AI optimization in a real-time closed-loop application

✓ Integrates fuel / air and sootblowing management
✓ The same brain operates 24 X 7 X 365
✓ Integrates directly into plant control
✓ Provides analytics on premise and to remote users
✓ Deploys integrated optimization – MPC, neural networks, heuristics, first principals – to best address complex, real world problems in closed loop
**TYPICAL BOILER OPTIMIZATION BENEFITS**

400 MW UNIT FIRING PRB W/80% CAPACITY FACTOR

<table>
<thead>
<tr>
<th>Benefit Type</th>
<th>Plant Y Unit 1</th>
</tr>
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<tbody>
<tr>
<td>Availability (W/Avoided MATS Lost Revenue)</td>
<td>$811,286</td>
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<tr>
<td>Fuel Savings</td>
<td>$567,148</td>
</tr>
<tr>
<td>NOx Reduction Value</td>
<td>$26,254</td>
</tr>
<tr>
<td>Avoided MATS Inspection/Tuning/Testing Costs</td>
<td>$86,667</td>
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<tr>
<td><strong>Total Availability, Fuel, Nox &amp; MATS Benefits</strong></td>
<td><strong>$1,491,355</strong></td>
</tr>
<tr>
<td>Potential CO2 Benefits</td>
<td>$357,500</td>
</tr>
<tr>
<td><strong>Total Potential Benefits</strong></td>
<td><strong>$1,848,855</strong></td>
</tr>
</tbody>
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TYPICAL COMBUSTION OPT BENEFITS

• NOx reductions of 10-15%
• Boiler efficiency increase of 0.5-0.75%
• CO controlled to desired limit
• Better ramping and load-following performance
• Reduced opacity excursions
• Avoided tail-chasing behavior
• Better adherence to fan and mill amp limits
• Improved situational awareness and process insight
IMPACT ON OPERATIONS & PERFORMANCE

Before IMPACT ON OPERATIONS & PERFORMANCE

After IMPACT ON OPERATIONS & PERFORMANCE
SAME UNIT 1 FIVE YEARS LATER (1/1/05)
EXIT GAS TEMPERATURE IMPACT

Average Exit Gas Temp

PL & O2 ON

PL OFF

Frequency (%)

0% 5% 10% 15% 20% 25% 30%

Average Exit Gas Temp

240 250 260 270 280 290 300 310 320 330 340

PL & O2 ON

PL OFF

PL & O2 ON

PL OFF
Soot Blower Control System HMI
RECENT RESULTS: RH TEMPS

STEAM TEMPERATURES
TYPICAL GAS INLET TEMPS

SOOTOPT OFF VS. ON
SCR/SNCR SYSTEMS & OPTIMIZATION

- Reduce Reagent Usage
- Lengthen Maintenance Intervals
- Avoid Ammonia Slip
- Reduce risk of Ammonium Bisulfate & Sulfur Trioxide deposits
- Control “Blue-Plume” Opacity Excursions
- Tighter, condition-based gas temperature control
- Better Manage System Interactions
Impact on NH$_3$ Usage

WITHOUT Optimization, 400–600 klb/hr NH$_3$ flow needed to meet NOx target

WITH Optimization, 300–400 klb/hr NH$_3$ flow needed to meet NOx target
DCS SCREEN EXAMPLE
Boiler and Back-end Process Causality Chain

Exogenous & Disturbance Variables
- Fuel Quality
- Ambient Temp
- Barometric Pressure
- Inlet H2O Temp
- MW Demand
- Ramp Rate

Manipulated Variables
- Fuel Flow
- Fuel Distribution
- Air Flow
- Air Distribution
- Boiler Cleaning
- Temp Controls
- Sorbent Injection

Process States
- NH3 Injection
- Fuel-Air Mix
- Heat Transfer
- SH Temp
- SH Sprays
- RH Temp
- RH Sprays
- Gas Temps

Process Performance
- CO
- NOx
- SO2
- Gross HR
- Ash Deposition
- Carbon-in-Ash
- Slagging
- Erosion
- Corrosion
- Thermal Stress

Cost Streams
- Fuel Usage
- Reagent Usage
- Catalyst Life
- FGD Sorbent Usage
- DSI Usage
- ACI Usage
- Net Ash Disposal
- Forced Outage Rate

Streams
- Exogenous & Disturbance Variables
- Manipulated Variables
- Process States
- Process Performance
- Cost Streams