Boiler Optimization for Emissions, Efficiency and Availability

Mclvaine Hot Topic Webinar
September 27th, 2012
Today’s Fossil Generation Challenges

- Unprecedented regulatory uncertainty
  - Utility MACT
  - Federal CO₂ regulation
  - Subsequent Clean Air Act Requirements (NAAQS, Regional Haze, etc.)
  - CSAPR???

- Traditional and new sources of market volatility
  - Demand uncertainty (fighting the last war)
  - Fuel and allowance price volatility
  - Technological uncertainties

- All add to challenges bringing new capacity on-line
- CCCTs & renewables force new operating profiles
- Aging assets operating well beyond design life
- Graying work-force and skills shortage

*Do more with less and manage the risks!*
On February 16, 2012, EPA published the Mercury and Toxics Standards (MATS) rule

MATS establishes national emissions limitations and work practice standards for certain hazardous air pollutants (HAP) emitted from coal- and oil-fired electric utility steam generating units.

The rule will result in about a 90% reduction from uncontrolled power plant emissions of mercury, nine other toxic metals, and three acid gases, all listed as hazardous air pollutants in the 1990 Clean Air Act Amendments.

The rule affects about 1,100 coal-fired and 300 oil-fired units.

Compliance with the rule is required for existing units by April 16, 2015.

For existing units, the rule specifies both heat input-based emission limits (lb/TBtu) and electrical output-based limits (lb/GWh) for Hg.
“Best Practices” Requirements

- The rule creates a variety of new work practices standards
- Units must burn natural gas or distillate oil during periods of start-up.
- Emissions control systems must be operated during periods of start-up and shutdown.
- Optimization of NOx and CO, combined with "best practices" efforts to maximize fuel efficiency must be demonstrated and documented for the EPA
  - Intended to minimize output of non-measurable HAPs (e.g. Dioxin, Furin, etc.
  - Optimization of NOx and CO is required using prescribed technologies
  - All boilers subject to requirements for “tune-ups” and demonstration of best practices for boiler efficiency
Units with Neural Network Optimization Get Favorable Regulatory Treatment

- Neural network optimization is explicitly addressed by MATS in three ways
  - Neural network optimization systems qualify for the requirement in the rule for "optimizing NOx and CO."
  - Units with optimizers can defer the initial EPA "best practices" requirement by a year.
  - Units with optimizers also qualify for less frequent subsequent evaluations to every 48 months.

- These provisions provide further evidence that the US EPA recognizes the value of optimization with respect to regulatory objectives relating to emissions and efficiency.
Longer-Term Strategic Implications for Current and Emerging Emissions Regulation

- Minimize capital commitments while emerging regulatory changes make clear which units can survive and which cannot
- Inform future capital decisions for surviving units with better understanding of true (optimal) baseline performance
- Better equip surviving units to cope with:
  - Greater demands on existing emissions control hardware
  - Process changes and variable costs for new emissions hardware
  - Operational profiles associated with fundamentally altered markets
    - Influx of renewables with intermittent generation output profiles
    - Reduced capacity factor due to more efficient newer capacity coming on-line
    - Problems associated with aging assets and changes from design conditions
    - Greater operational challenges with fewer skilled operators and engineers
    - Ever-greater needs to “push the envelope” in order to “stay in the money”
Integration of Emissions & Efficiency Silos

- Emissions and efficiency used to be addressed by different “silos” within power generation organizations
- Efficiency efforts often took back-seat to emissions
  - Regulatory “pass-through” clauses
- Fuel costs often handled fleet-wide
- CO₂ has brought efficiency and emissions together
- Reagent costs for NOx create large new “non-fuel” O&M cost

**Bottom Line:** Must integrate management of emissions, fuel, reagent costs and tradeoffs between them
NeuCo’s ProcessLink® Platform

- ProcessLink is the technology platform upon which all NeuCo optimizers are built:
  - Employs multiple modeling and optimization techniques to provide best hybrid asset optimization solutions
  - Integrates disparate data sources and knowledge, enabling objective-driven performance across units, plants or an entire fleet
  - Integrated modeling and optimization engine relates process behavior to global objectives
  - Supports optimizer integration and action coordination
  - Process behavior and equipment health issues surfaced though comprehensive alerts
  - Flexible GUIs, portals, and automated reporting
ProcessLink® System Architecture

Closed-loop Systems Control & Optimization

- BoilerOpt®
  - CombustionOpt®
  - SootOpt®

Real-time Monitoring and Decision Support

- PerformanceOpt™
- MaintenanceOpt™

Applications

Services

- Optimization services
- Modeling services
- Monitoring services

ProcessLink® Engine

- Neural Networks
- Model Predictive Control (MPC)
- 1st Principles Dynamics Models
- AI Expert Systems

Plant I&C Systems Interfaces and Network (DPC, etc)
Asset Optimization with ProcessLink®

- **Maximize Availability/Reliability**
  - Predictive analytics for equipment health
  - Early warning for impending failures
  - Minimizing unnecessary outages
  - Better use of planned down-time
  - Reduced tube leak outages

- **Minimize Operating Costs**
  - Continuous heat rate minimization
  - Detection of equipment problems with efficiency impacts
  - Minimize reagent usage

- **Optimize Emissions Control (NOx, CO, Opacity, CO₂)**
  - Avoid exceedances and de-rates
  - Exploit allowance trading strategies
  - Optimize trade-offs between emissions and other objectives
  - Get ahead of the curve with CO₂ reductions

Proprietary and Confidential
ProcessLink Availability Mechanisms

- Reduced Boiler Tube Leak Outages
  - Less unnecessary cleaning (SootOpt)
  - Avoided thermal stress (SootOpt & C’Opt)

- Avoided Slagging/Fouling De-Rates & Outages
  - Pro-active cleaning for vulnerable surfaces (SootOpt)
  - Improved stoichiometry control (CombustionOpt)
  - Tighter control of gas path temperatures (SootOpt & C’Opt)
  - Reduced ammonium bi-sulfate air heater pluggage (SootOpt & C’Opt)

- Fewer Equipment Failure Outages
  - Proactive detection/diagnosis of impending failures (M’Opt/P’Opt)
  - Better knowledge of equipment degradation states (M’Opt/P’Opt)
  - Generally improved situational awareness (all products & alerts)
CombustionOpt®

- Provides real-time closed-loop optimization of fuel and air biases

- Using:
  - Model Predictive Control (MPC)
  - Neural Networks
  - Design of Experiments (direct search)
  - Expert Rules

- To Improve:
  - NOx
  - CO
  - Heat rate
  - Steam temps
  - Opacity
  - Reagent utilization
  - Constraint performance (Mill Dp’s, Fan Amps, O2 split)
CombustionOpt Optimization

- Typical operating range
- Boiler Efficiency Increase
- NO\textsubscript{x} Reduction

- CombustionOpt operating range
- CO
- NO\textsubscript{x}

- Boiler Efficiency

- Excess Fuel
  - Excess Air
CombustionOpt Analysis: Model (Causality)
Combining Neural with MPC

- Etc
- NOx
- CO
- Heat Rate
- Fan Constraints
- Aux Air Constraints
- Neural Optimization
- Feeder Bias
- Coal Air Bias
- Aux Air Bias
- O2 Bias
- OFA Biases
- WB/furn dP Bias
- ...
In addition to Direct Search and NN & MPC models, NeuCo may use Expert Rules to:

- Calculate MV constraints
- Use reactive override under special conditions (e.g., high CO)
- Exclude model training data under certain conditions
- Define models and/or objectives specific to mill combinations
- Switch entire constraint and/or objective profiles
How CombustionOpt Addresses Fuel Changes

- All CombustionOpt installations have coal variability
- Many have fuel blending (PRB/Bituminous/Lignite, etc.)
- In most cases there is no real-time fuel quality measurement
- In some cases manual inputs used, but not many
- CombustionOpt’s inputs infer fuel quality from many data sources
- Optimization uses directional as opposed to absolute process knowledge
- On-line learning and model validation finds models best-suited for current fuel blend from past history
DCS Integration

Loop Enable/Disable

Operator Bias

NeuCo Bias

Applied Bias
- Provides real-time closed-loop optimization of soot cleaning equipment

- Using:
  - Expert Rules
  - Neural Networks

- To Improve:
  - Sootblowing consistency
  - Unnecessary sootblowing
  - Steam temps
  - Sprays
  - Leverage on heat rate
Boiler Cleanliness Optimization

- Too little cleaning
- Too much cleaning

- SootOpt® operating range
- Typical operating range

- Sample rule: If reheat sprays high, then clean furnace
- Sample rule: Clean furnace once per shift unless reheat temps are low

- High risk of slagging
- Boiler Efficiency
- High risk of erosion
- NOx
Overview: How SootOpt Works

Zone Selection
Rules-based:
- Fuzzy
- Heuristic
- First Principles
- Operating History

Zones are defined according to plant layout and sootblower media piping

Blower Selection
Model-Prediction- and/or Rules-Based:
- Optimal Blower Start
- Operating History
- Effectiveness

One Blower Selection Module per Zone
Authorized Users Can Change Status or Annotate Alerts
## Unit 3: SootOpt Analysis

### Zone Selection

<table>
<thead>
<tr>
<th>Goal</th>
<th>Zone</th>
<th>Spray flow</th>
<th>SH temp high</th>
<th>RH temp high</th>
<th>SH temp low</th>
<th>RH temp low</th>
<th>RH temp below</th>
<th>APH 3A DP</th>
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<td>Lower RH Steam Temp</td>
<td>RH_Platen</td>
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Overview of Boiler Performance Parameters and Associated Sootblower Activities
NRG Texas Limestone Generating Station

- T-fired boiler 913 MW firing Lignite and PRB
- Ten fuel elevations equipped with a low-NOx burner/over-fire air system
- Cold-side ESP and wet FGD
- DCS control system is a Bailey Infi-90
NOx Distribution: CombustionOpt and SootOpt Both Off

NOx Distribution: CombustionOpt and SootOpt Both On
A vs. B RH Temps: Off

A vs. B RH Temps: On
Optimization History at CPS Energy

- CombustionOpt on coal-fired units for NOx reduction
  - Spruce: 546 MW CE t-fired w/Ovation DCS: Installation 2001
  - Deely: 2 x 446 MW CE t-fired w/Honeywell DCS: Installation 2004

- Multivariate predictive control added in 2007 for:
  - Explicit steam temperature control
  - Minimize attemperation sprays
  - Incremental heat rate and NOx reduction

- SootOpt added in 2010/2011 for availability/efficiency
J.K. Spruce Power Plant

- Calaveras Power Plant Complex, South East of San Antonio, TX
- J.K. Spruce 1 commissioned in 1990
- 600 MW Alstom-CE T-fired units
- Emerson Ovation DCS
- Spruce 2 commissioned 2011: 750 MW CE T-fired boiler with SCR
Analysis of Integrated BoilerOpt Benefits at JK Spruce Unit 1
JK Spruce 1 BoilerOpt Benefits Summary
April 2011 Analysis

- Heat Rate improvement of 0.5-1.0%
- Losses Boiler Efficiency of 0.13-0.78%
- NOx reduction of 4-8%
- Improved control of
  - O2 Average Minimum and Balance
  - APHGIT Max and Balance
  - SH and RH Sprays and Balance
  - SH and RH Temps and Balance
- Reduction in Blower Operations
  - Average 20%
  - No economizer tube leaks since SootOpt installed
Objective: <0.125

Average = 0.132

Average = 0.122
BoilerOpt Impact on Spruce 1 Heat Rate

Objective: Down

Average = 9856.6

Average = 9799.9
BoilerOpt Impact on Spruce 1 O$_2$ Average

Objective: >1.5

Average = 2.14%

Average = 1.89%
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<tr>
<th>Spruce Unit 1</th>
<th>KPI</th>
<th>Units</th>
<th>OFF</th>
<th>ON</th>
<th>Delta (ON - OFF)</th>
<th>Delta (%)</th>
<th>+/-</th>
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<td>Gross MW</td>
<td>MW</td>
<td>571.15</td>
<td>564.57</td>
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<td>Heat Rate</td>
<td>Btu/kWh</td>
<td>9661.32</td>
<td>9556.74</td>
<td>-104.58</td>
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<td>Blr Eff</td>
<td>%</td>
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<td>84.77</td>
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<td>NOx</td>
<td>#/MMBtu</td>
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<td>0.121</td>
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<td>CO</td>
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<td>123.06</td>
<td>16</td>
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<td>O2 Avg</td>
<td>%</td>
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<td>1.912</td>
<td>-0.365</td>
<td>-16.03%</td>
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<td>RH Temp E</td>
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<td>klb/h</td>
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<td>21.89</td>
<td>6.99</td>
<td>46.91%</td>
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Overall Xcel SPS Optimization Initiative

- Xcel SPS decided to adopt boiler optimization software (fuel-air and heat transfer components)
- Tested NeuCo’s BoilerOpt® system at Tolk station early-mid 2009
- Applied to Harrington Unit 3 in October 2009
- Rolled out to Harrington Unit 2 and Unit 1
- Sootblowing optimization on Unit 1 was last component to be completed
BoilerOpt at Xcel Harrington

- **Units 1, 2 and 3 similar units:**
  - CE T-Fired boilers
  - 360 MW each
  - Often on AGC between 180 and 360
  - 5 Pulverizers
  - LNBs, CCOFA and SOFA
  - Foxboro I/A DCS
- Baghouses on U2 & U3
- ESP on U1
Harrington 3 Long-Term Trends

No wind, no Optimization

Wind/SPP dispatch, no Optimization

Wind/SPP dispatch, with Optimization
Harrington Benefits Summary:
All Three Units

- NOx reductions 10-12%
- Improved consistency of operations both in Combustion and Sootblowing domains
  - Better balanced process, temps, sprays, CEMS, O2, CO
  - Fewer IR operations
  - Able to move load around with wind without CEMS penalty
  - More insight and awareness into what’s going
  - Optimizers provide the tools to effect change in complex situation
  - Continuing to see improvement
Initial Tolk 2 CombustionOpt Results: NOx

2 day NOx compare

0 0.05 0.1 0.15 0.2 0.25 0.3 0.35

400 420 440 460 480 500 520 540 560 580 MW

0.25 lb/MBTU
0.2 lb/MBTU
0.15 lb/MBTU

CombustionOpt OFF
CombustionOpt ON
Tolk Blower Count Trends
Initial Results at Xcel Tolk 2: SootOpt

- Operators have less to worry about
  - Takes the right actions, consistently
- Changing MW profile not a problem
- SH & RH temps better balanced
- Attemperation sprays significantly reduced
- Air Preheater gas inlet temps significantly reduced
- Boiler Efficiency increased
Continuous Improvement
Xcel Tolk example
Using new knowledge

- After reviewing the results and our recommendations with plant
  - Adjustments were made to the existing Zone/blower map in SootOpt to account for blowers affecting both RH and Platen sections.
  - Adjustment were made to deal with a cross-over between DivSH and PlatenSH that had a noticeable effect
  - Adjusted existing rules and thresholds
  - Added rules that inhibit cleaning when section deltaTemp is at or above it’s normal mean, given operating conditions
  - [Next] Add rules that propose cleaning when section deltaTemp is sufficiently below it’s normal mean
Recent Results: Blower Counts

Tolk U2

≈ - 20%

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Recent Results: NOx, CO

Trend Tolk2

Gross MVV A (549.992)  STACK NOx (D)  STACK CO (51.305)

Proprietary and Confidential
Recent Results: RH Temps
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
Boiler Optimization for Improving SCR Operations

- **Challenge:** to operate boiler with acceptable SCR performance under changing operating conditions
  - Acceptable NOx removal levels
  - Minimizing NH$_3$ usage and slip
  - Avoiding SO3-related issues (visible plume, air heater fouling)

- **CombustionOpt**
  - Lower, more balanced NOx profile at SCR inlet
  - Compensating for local catalyst degradation or fouling
  - Less & more balanced NOx = less close to SCR design limits

- **SootOpt**
  - Better control of temperatures throughout the gas path
  - Sootblowing informed my load, gas temps, NOx, etc.
  - Tighter control keeps temps within window needed by SCR
  - Avoiding temp excursions on high side reduces SO2=>SO3 conversion rate and associated side-effects

Proprietary and Confidential
Indirect Optimization Benefits

- Process Illumination
- Tradeoff Management
- Expertise Codification
- KPI-Focused Workflow
- Analysis & Decision Support
- Set-Point Refinement
- Dynamic Uncertainty Management
Breadth, Depth, and Flexibility

- Optimization can provide benefits in all these areas:
  - Heat Rate – NOx – MW – Commercial Availability
  - CO₂ – Opacity – SO₂ – Equipment Reliability
  - LOI – Particulates – Hg – Steam Temps
  - CO – Ramp Rates – NH₃ usage – Attemperation Sprays
  - Aux Power – Operational Consistency – Slagging & Fouling

- Maximum benefits can only be achieved with an integrated platform approach

- Platform designed for fleet-wide application, where benefits can be realized in manner best suited to differing organizations
  - Plant use
  - Centralized “war room”
  - Tailored service offering
  - Any combination of these
Questions?
For more information please contact:

Peter Spinney
spinney@neuco.net
617-587-3103