An Integrated Approach to Boiler Optimization

Presented by:
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Peter Spinney – NeuCo

Reinhold NOx Roundtable & Expo
February 6, 2007
Agenda

- Optimization Overview
- Integrated Boiler Optimization
- Boiler Optimization Project at Baldwin
Role of Optimization

- The process of turning reams of complex data into actionable knowledge that delivers bottom line benefit

- An Optimizer Must:
  - **ACT:** continuously identify actions that can improve asset performance
  - **INFORM:** provide insight into what actions were taken or advice given and why
  - **QUANTIFY:** the benefits & missed opportunities

Data Sources:

- **ERP**s (e.g. SAP)
- **CMMS**s (e.g. Maximo)
- **Monitors** (e.g. GeneralPhysics)
- **Analyzers** (e.g. Zolo)
- **Detectors** (e.g. SmartSignal)
- **Historians** (e.g. OSI)
- **DCS**s (e.g. ABB)

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Types of Optimizers

- NeuCo currently has 4 commercially-available Optimizers:
  - **CombustionOpt®**: Optimizes fuel & air mixing to lower emissions and improve heat rate
  - **SootOpt®**: Optimizes sootblowing activity to improve reliability, heat rate and emissions
  - **PerformanceOpt®**: Identifies efficiency and capacity bottlenecks and the actions required to control the corresponding losses
  - **MaintenanceOpt™**: A diagnostics center for the detection, diagnosis and prioritization of maintenance problems

- And there are more on the way:
  - DOE CCPI-2 NRG Texas Limestone
  - Customer Teaming
Importance of an Integration Platform

- Integrating disparate data and knowledge sources
- Standardizing metrics allowing performance comparisons and tradeoffs across equipment, units and plants
- Coordinating actions towards common business objectives, instead of competing
- Prioritizing the most important actions you can take to achieve your objectives
- Creating transparency and accountability by bridging islands of information and understanding
Agenda

- Optimization Overview
- Integrated Boiler Optimization
- Boiler Optimization Project at Baldwin
What does Integrated Boiler Optimization Mean?

- Integrated optimal operation of combustion, boiler cleanliness, steam temperatures, and total boiler performance
- Real-time management of multiple objectives, constraints, and tradeoffs:
  - Monetized objectives
  - Coordination of individual Optimizers toward global objectives
  - Sharing real-time knowledge between multiple solutions
    - CombustionOpt
    - SootOpt
    - PerformanceOpt
    - MaintenanceOpt
- Recognition that priorities and operating conditions change in dynamic and complex ways
Integrated Boiler Optimization Benefits

- Ensuring that total operating costs are minimized in face of changing conditions and cost factors
- Adhering to all applicable constraints
- Integration of real-time operations with maintenance needs
- Managing tradeoffs between instantaneous and longer-term costs and financial performance
- Making the whole more than the sum of the parts!
Boiler Optimization Components

- Optimizers
  - CombustionOpt
  - SootOpt

- Technologies
  - Neural Networks
  - Model Predictive Control
  - Expert Systems/Heuristics
  - Simulation Engine
  - Integrated Object Library
  - Analysis Tools
CombustionOpt Overview

◆ Context:
  - Combustion controls manipulate a few variables (such as O2) as a function of load, leaving 35-100 fuel and air injection points that significantly impact combustion performance to infrequent offline tuning or operator tweaking

◆ What CombustionOpt Does:
  - Provides real-time closed-loop optimization of fuel and air mixing by manipulating all relevant fuel and air injection points

◆ Using:
  - Neural network and model predictive control technologies

◆ To Achieve:
  - NOx, heat rate, steam temp, CO and opacity improvements
CombustionOpt Analysis

Unit 3: CombustionOpt Analysis

Graphs showing trends and data analysis for Unit 3.
SootOpt Overview

◆ Context:
  ■ Sootblowing controls rely on interval-based or operator-initiated cleaning actions, or when using intelligent sootblowing systems, rely on zone cleanliness set points, ignoring the fact that optimal heat transfer requires varying cleanliness over time and across zones

◆ What SootOpt Does:
  ■ Provides real-time closed-loop optimization of unit performance by manipulating all relevant sootblowing controls

◆ Using:
  ■ Expert systems, neural networks and model predictive control

◆ To Achieve:
  ■ Reliability, heat rate, steam temp and emissions improvements
SootOpt Analysis
Visibility into Heuristics

### Unit 3: SootOpt Analysis

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SootOpt Tools

Unit 3: SootOpt Analysis

Rolling 24 Hour Summary

- Zone is clean
- Zone resists cleaning (still trying)
- Zone is fouling
- Zone resists cleaning (no longer trying)
- Zone is dirty

Graph showing distribution of cleaning states over 24 hours.
SootOpt Sensitivities: Net HR
Agenda

- Optimization Overview
- Components of Integrated Boiler Optimization
- Boiler Optimization Project at Baldwin
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
NeuCo’s CCPI Project @ Baldwin

- About the Clean Coal Power Initiative (CCPI)
  - $1.3 B initiative to demonstrate clean coal technologies in the field
  - Sponsored by DOE’s National Energy Technology Laboratory
  - NeuCo’s project at Baldwin selected as Round 1 winner in 2004

- Five integrated optimization modules, parallel development
  - SCR
  - Combustion
  - Soot blowing
  - Performance
  - Maintenance

- Products developed iteratively with multiple releases
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
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
Initial CombustionOpt Benefits

- Reduction in NOx average and variability
  - BEC Unit 3 already one of the lowest NOx coal-fired units in North America
- Increased process knowledge
- Improved consistency across operators and shifts
- Empirical validation of boiler cleanliness interactions
Unit 3 Sootblowing Operation prior to SootOpt

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

- Prevailing sootblowing guidelines:
  - Water cannons operator initiated when attemperation sprays 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
Baldwin 3 – Ash Deposition

- PRB Coal
  - Intermittent Wall Deposition
  - Division Panels
  - SH Pendant
  - Horizontal SH
Upgraded sootblowing controls to Diamond SentrySeries 1500 Intelligent Sootblowing Control System (ISB)

Added thermocouples and thermo-probe behind pendent reheater for heat transfer calculations

Installed NeuCo’s SootOpt for adaptive optimization of sootblowing operation

Integrated SootOpt with Diamond furnace (FCM), backpass (SCE) and Automatic Interface module (AIM)
SootOpt - Diamond SentrySeries 1500 Interface

(ACE) Adaptive Cleaning Expert
ACE Module generates Cleanliness Setpoints

(SCE) Soot Cleaning Expert
SCE provides Clean/Dirty, CF, Bypass*

(FCM) Furnace Cleanliness Module
FCM provides Clean/Dirty, Hflux, Bkstop

Convection

(AIM) Automatic Interface Module
AIM provides Seq #

Furnace

Adaptive Sootblower Prioritization (Conv Region Only)

(SIM) Sootblower Interface Module

Region and Zone Permissives

Note: Pausing an active sequence or zone does not prevent others from being serviced

SB PLC

WC PLC

Clean/Dirty Threshold (SCE)
Sequence Triggered

Bypass* Limit Sequence stopped or removed from queue

Region and Zone Permissives
SootOpt/ISB Interaction
**Improved Model Fidelity with CombustionOpt & SootOpt Integrated**

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Improved Model Fidelity with CombustionOpt & SootOpt Integrated

NOx model with CombustionOpt & SootOpt integrated

Blue = NN Model Predicted
Green = Actual

NOx model with just SootOpt
1 Year of Data (MW, NOx, SootOpt Biases)
CombustionOpt Impact on NOx

Reduced average NOx to ~ 0.09 & found lower NOx envelope
Combined Impact on NOx

Significantly improved NOx reduction (0.085 range)
CombustionOpt Impact on Heat Rate

No significant impact on Heat Rate; trading off for NOx
Combined Impact on Unit Heat Rate

Combined system contributed to Heat Rate benefit while also lowering NOx
Average Daily Attemperation Spray Flows

[Graph showing spray flows for Manual and SootOpt & ISB Enabled modes]

Legend:
- Green: BA3 Gross Load
- Blue: SH Spray Flow
- Red: RH Spray Flow
IK Activity Manual vs ISB/SootOpt

Decreased sootblower activity when SootOpt turned back on.
SootOpt Helps Detect Underlying Problems: Increased Furnace/Convection Pauses Due to FEGT < 1900 f.
Boiler Optimization Results Thus Far

- Improved NOx and Heat Rate with decreased variability
- Decreased sootblower operation count
- Attemperation spray flows controlled to less than 50 klbhr with SootOpt/ISB whereas before spray flows would at times be above 100 klbhr
- Initially split in attemperation flow control caused steam temps drop to 950F which could effect MW output. Recent changes have reduced that drop to 980F
- Provided early detection into anomalies in ISB activity caused by instrumentation failure
- Improved transparency into complex behavior of ISB
- Real-time tradeoffs between objectives and performance benchmarking
Looking Ahead

- Complete Integration of CombustionOpt and SootOpt and at Unit 3
- Complete installation of SootOpt on Unit 2
- Integrate CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt and MaintenanceOpt at Unit 2
- Further refine CombustionOpt, PerformanceOpt & MaintenanceOpt at Unit 1
- Further refine Unit and Plant Advisors
- Subsequent refinement and releases based on feedback from Baldwin and other NeuCo Showcase sites