Using Optimization Software to Improve Efficiency & Reduce GHG Emissions

Peter Spinney, NeuCo McIIvaine Webcast, Feb. 2010





- EPA Endangerment Finding
 - Murkowski Procedural Challenge
 - Industry Lawsuits
 - Current Status
- Kerry-Lieberman-Graham
- Other Legislative Proposals
 - Collins-Cantwell (Cap and Dividend)
 - Voinovich-Carper (Power Plant Only)



- No commercial emissions control systems for CO₂
 - Improving efficiency is the only proven option
- Real-time Optimization can improve efficiency & reduce CO₂ by 1.5% to 2%
- Co-benefits
 - Improved competitive position via lower variable costs
 - Reduced NOx and/or reagent costs
 - Improved control over CO and opacity
 - Increased reliability and commercial availability



Optimization: Integrate Formerly Separate Emissions & Efficiency Silos

- In past, emissions and efficiency 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
- Optimization integrates management of emissions, fuel, reagent costs and tradeoffs between them



Product	% Change	Tons CO2/yr	Svgs (\$/yr) @ 7.50/Ton
CombustionOnt	-0 375%	18 278	\$137 082
	0.07070	10,210	ψ107,00 2
SootOpt	-0.350%	17,059	\$127,943
MaintenanceOpt	-0.375%	18,278	\$137,082
PerformanceOpt	-0.400%	19,496	\$146,221
Total	-1.500%	73,110	\$548,328



- Optimization alone can't solve GHG issues, but is the most cost-effective means to reduce CO₂
- Currently monetized efficiency, emissions, and availability benefits already have compelling payback
- Optimization suite can reduce CO₂ by 1.5-2%

•Annual Benefits for 500 MW Coal-Fired Unit: Currently Monetized and w/CO2 at \$7.50/ton

Product	NOx-Related	Fuel Savings	Availability	Total \$/Yr	CO2 \$/yr	Total w/CO2
CombustionOpt	\$302,348	\$322,576	\$0	\$624,924	\$137,082	\$762,006
SootOpt	\$75,587	\$301,071	\$360,939	\$737,597	\$127,943	\$865,540
MaintenanceOpt	\$0	\$322,576	\$892,785	\$1,215,361	\$137,082	\$1,352,443
PerformanceOpt	\$0	\$705,020	\$851,241	\$1,556,262	\$146,221	\$1,702,482
Total	\$377,935	\$1,651,243	\$2,104,966	\$4,134,144	\$548,328	\$4,682,472



NeuCo Optimization Suite





ProcessLink® Platform

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
 - Constraint performance (Mill Dp's, Fan Amps, O2 split)

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- Burner T - 02 Bias	ik A (56.528)	- Burner Tilt B ((81.558)	:54:2	12:49:0	- NOx (0 - RHT_8	(998.656) (998.656)	RHT_A (1006) StackCO (14.20	3)	Setpoints (Deviations) O2 Split Sum of Fdr Bi Sum of Aux B	percent a unitless ic unitless	-0.24 7.81 -0.01		-0.36 0.39 0.03	
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APS Analysis of C'Opt HR Impact at Units 1-3

HR Improvement







- 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

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Reheat Steam Temperatures Tolk U2









Proprietary and Confidential

The Optimization Standard™

leuCo

Tolk Unit 2 Superheat Spray Flows







APH Gas Inlet Temperatures Tolk U2



~ 30° F Reduction in Average Temperatures



Boiler Efficiency with SootOpt off and on





Comprehensive Boiler Optimization

- Interrelated boiler variables must be continually managed
 - Combustion quality, fuel & air mixing, gas & steam temps, fouling, tube erosion, & emissions
 - Fluctuating constraints & changing objectives add complexity
- Independently optimizing combustion & sootblowing delivers value, but leaves benefits on the table







PerformanceOpt

- Provides deep understanding of unit subsystem performance and alerts users to performance deviations
- Using:
 - 1st Principles Models (full mass & energy balance)
 - Neural Networks
- To Improve:
 - Heat rate
 - Capacity
 - Reliability
 - Operational awareness

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C Turbine Extraction HP FF Degradation(ft^2)	0.5	0.49		84	41	11		Actual (1 hr)	Expected (1 h
Turbine Extraction HIP FF Degradation(ft^2)	0.81	0.82		82	96	48	NUND	10.920	10.000
Low Htr HIP Cleanliness	1.09	1.18		81	91	47	HUNK	10,030	10,000
Change in Boiler Economizer Cleanliness	1.07	1.12		65	62	25	NTHR-corr	8,388	8,441
🔩 High Dry Gas Loss(%)	4.78	4.38		35	39	13 💌			
Optimization Analysis							Boiler Eff	86.75	86.90
Instrumentation and EOOS Controllable Los	ses						Load	191	none
ID Name Units Raw V Raw S	Validat Min	Max P	roces Proce: 🔺	Equipmen	it 🔺	Service 🔺	I		
1CDV DISSOLVE unitless 0 🔴	0	20 0		A HIP DR	IP	Off	Ac	thal and Expected NUHR (1	Hour Aue.)
1PA5 EXPECTED klb/h N/A 🔴	0	100 N	/A 📒	B HIP DR	IP	On	•	Actual NUHR 📃 Espec	1ed NUHR
1BFV BOILER BL klb/h N/A 🛑	0	800 N	/A 🔴	BFP A		On			12,000,00
1PAV COND FLO klb/h N/A 🛑	0	1500 N.	/A 📒 🗧 🗸	BFP B		0n			- 11,500.00
				CNDP A		On			- 11,400,00
— RawvalueStatus — DataValueStatus -	— II in ValueStatus —	IllativalueStatus		CNDP B		On			- 11,2000 - 11,000,00
				CWPA		On			- 10,300.00
				CWP B		On			- 10,600,00
				FD Fan A		On			- 10,200,00
				FD Fan B	1	On Ť			- 10,000,00
									- 9,500,00
		— Gros	s Millí — Boiler	Efficiency-	NTHR				- 9,400.00
	الديدار الم	250.00 1	92.00 -	C C C C C C C C C C C C C C C C C C C		1			- 9,0000 - 9,000,00
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- **Unit:** Ameren's Sioux Unit #2, 450 MW
- Usage: The following problem was identified during the close-out meeting for PerformanceOpt. Customer asked NeuCo to explain one of the triggers on the home page.
- Incident: Air had entered the heater during low load and gotten trapped thus adversely affecting heater performance at higher loads.
- Fix: The heater was manually vented during a break in the meeting. The performance immediately returned back to normal.



Diagnosing the Problem

- An experienced operation supervisor noted that this heater had experienced venting problems in the past
- The heater shell pressure drops below atmospheric pressure during low load operation, sucks air in to the shell, and the air was not being removed properly
- The air in the heater restricts the extraction steam flow from the turbine, reducing the heater performance
- Using the context data available in PerformanceOpt, it was possible to confirm this diagnosis



Resolution of the Problem

- During the meeting, the heater was manually vented by operations and the TTD stabilized at a reasonable level (see last 1/10th of the plot below).
- Resolution of this problem results in a ~50 Btu/kWh in Net HR improvement valued at ~\$215,000 / year.





MaintenanceOpt[®]

- Alerts user to potential equipment health issues and expedites problem diagnosis
- Using:
 - Neural Networks
 - Expert Rules
 - Other Optimizer Alerts
- To Improve:
 - Unit uptime
 - Speed of issue resolution
 - Efficiency

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Proprietary and Confidential

M'Opt and P'Opt Working Together

 Routine review of triggers indicates alerts on the condenser backpressure and cleanliness have triggered. Backpressure is at 3.05 when expected to be 2.2, and the cleanliness is at 0.55 when expected to be 0.88.



The Optimization Standard[®]

 Condenser Cleanliness significantly changes from expected at approximately 10am



The Optimization Standardⁿ

 Condenser backpressure increases significantly at the same time





 Low condenser cleanliness and high condenser backpressure indicates inadequate air removal equipment performance

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Action List Tools			
Issues to Screen Flagged Issues Problems to Resolve	Problems for N	Veuco Snoozed Alerts All Alerts	
👫 🍆 🚩 Opt 🛛 Equipment 🔺 Issue	<u> </u>	Likely causes	Diagnostic rule
U2 M' Boiler Boiler Excess O2 Deviation	Increase(perc	c Cycle Isolation Dumping Extra Heat to (IF Condenser Cleanliness is Low
🙀 F P'Opt Boiler Change in Boiler RH Cleanlir	ness	Inadequate Air Removal Equipment Pe	Condenser Backpressure - Actual is Higher than normal
M'Opt Condenser Condenser Backpressure In	crease(inHg)	Air Binding in the Condenser Waterbox	AND further investigation indicates
P'Opt Condenser Low Condenser Cleanliness	(fraction)	Condenser Tube Sheet Blockage Condenser Tube Fouling	Manual air removal flow readings are normal and switching redundant air removal equipment for 1 hour reduces the backpressure.
🙀 U2 M' FD Fans FD FAN CURRENT DEV Inc	creasing(A)	Cooling Water Flow Rate Measurement	тисы
M'Opt Pulv B Pulv B Power Change(kW)			Review performance of air removal equipment including heat exchanger on
U2 M' Pulv C Pulv C DP Increase(delta_ini	H2O)		mechanical pumps. Clean, repair, or replace equipment.
P'Opt Turbine Turbine Extraction HIP FF D	egradation(ft' 🚽		
C Show Impacts C Show Causes Context Data Attachments Problem History Equip	pment History		🔥 Add Issue 🛛 🃚 View Log
Linit Load		Condenser Cleanliness	Midel Inputs
and			a - A - Million and a second second
BP ////////////////////////////////////			Sat Cond
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The Optimization Standard

Problem Resolution

 Maintenance crew reconnects the vacuum pump and performance returns to normal



The Optimization Standard^m

- PerformanceOpt indicates equipment degradation through high-fidelity model of thermal processes
- MaintenanceOpt indication of equipment degradation through empirical models of on-line signals as well as potential problems detected through manual inspection
- Some problems that would escape notice through one or the other methodology become obvious when viewed through both
- MaintenanceOpt also surfaces problems detected by NeuCo's closedloop optimizers
- PerformanceOpt informs closed-loop optimizers though virtual on-line analyzers indicating important boiler performance parameters not directly measured
 - Coal quality, boiler efficiency and heat rate for CombustionOpt
 - Boiler cleanliness and heat rate for SootOpt

Optimization Won't Solve the Problem But Part of the Solution

- Achieve lowest-cost CO₂ reductions
- Demonstrate proactive commitment
- Simultaneously achieve operations improvements:
 - Reduced NOx and/or reagent costs
 - Improved control over CO and opacity
 - Increased reliability and commercial availability
- Newer regulations (based on tons and not lb/mmBtu rates) mean that every incremental heat rate improvement results in fewer tons of CO₂, SO₂, and Mercury







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