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Addressing CAIR with Optimization

The Clean Air Interstate Rule (CAIR) is a formal Environmental Protection Agency (EPA) administrative order that codifies into law many provisions first proposed as part of President Bush's Clear Skies legislation. In addition to the five-month "Ozone Season" – during which NO_x caps and associated allowance trading applied to the 19 states included in the Clean Air Act Amendments (CAAA) of 1990 – CAIR imposes a 60 percent incremental NO_x reduction, expands the geographic scope to cover nine additional states, and layers on top of the existing 5-month market a separate 12-month cap and associated trading market. To place CAIR in historical perspective, regulations between 1970 and 2006 decreased US NO_x levels by 41 percent. CAIR by contrast, requires a 60 percent reduction in just six years (2009-2015).

Power generators in the 28 Eastern States and the District of Columbia are making near-term capital investments in order to meet CAIR's 2009-2010 NO_x and SO_2 reduction deadlines. Most CAIR responses will include NO_x control hardware systems. While hardware solutions effectively lower NO_x, they often do so at the expense of efficiency, combustion degradation and increased complexity of operations. NO_x reductions and efficiency improvements achieved with optimization software have been well documented, and are playing an increasingly important role in helping generators to comply with emissions regulations such as CAIR. The decision about whether to take a hardware or software approach to meet emissions standards is not a mutually exclusive one. In many cases, the best approach is a hybrid one that combines both.

This paper examines CAIR's implications with respect to hardware and software alternatives, the challenges of each, and the role that optimization can play as the integration engine that manages tradeoffs between goals, processes and systems.

THE CAIR MANDATE

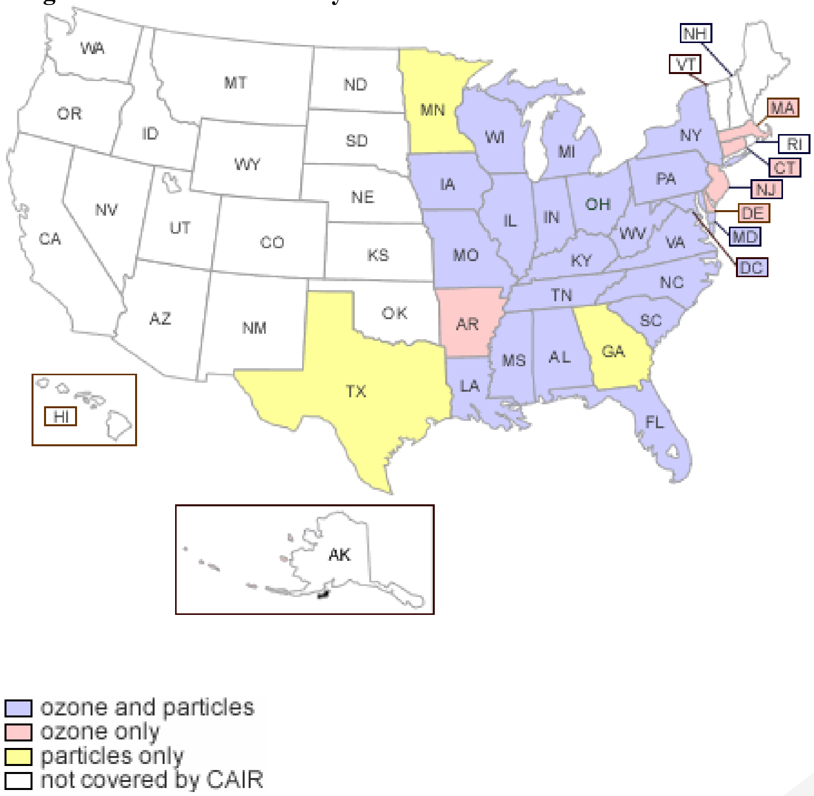
CAIR codifies into law many of the requirements proposed under President Bush's Clear Skies initiative. It demands the largest reduction in air pollution since the Clean Air Act Amendments, and will require the 28 Eastern States and the District of Columbia to reduce, below 2003 levels, emissions of nitrogen oxides (NO_x) and sulfur dioxides (SO_2) by 60 and 70 percent, respectively. Under CAIR, states may achieve the required emissions reductions using one of two compliance options:

1) Participate in an EPA-administered interstate cap and trade system, or
2) Meet state air emission limits through measures of the state's choosing.

Most states will likely implement CAIR through the "cap and trade" approach used to meet the State Implementation Procedures (SIP) employed for CAAA 1990. The first phase of NO_x

reductions begins in 2009 and the first phase of SO_2 reductions begins in 2010. The second phase of both SO_2 and NO_x reductions starts in 2015.

Diagram 1: States Affected by CAIR



FINANCIAL IMPLICATIONS

These new requirements are already causing higher allowance prices in CAIR's forward market for annual allowances. While current allowance values for this market have been trading in the $2500-$3500 range, allowances for this market are just now being allocated. These prices are consistent with the US Energy Information Administration's (EIA) long-term market modeling, which indicate that CAIR annual allowance prices are likely to vary between $2400 and $7700 per ton over the 2009-2014 timeframe.

Contrast these prices with current CAAA Ozone Season allowance prices, which are currently trading in the $500-$750 range. Between the expected price range and the addition of a yearround cap and trading market, the value of reducing any given amount of NO_x is expected to increase by at least six to 12 times current prices for the CAAA Ozone Season allowance market.

CONTROL TECHNOLOGIES TO ADDRESS CAIR

Much of the "low-hanging fruit" for NO_x reduction has already been picked. Generators have been able to choose from a variety of compliance alternatives – from fuel switching, pollution control hardware and software, to buying excess allowances from companies that have reduced their emissions under cap and trade provisions. The combination of pre-existing federal, regional, state, and local NO_x regulations, however, has resulted in the majority of the most affordable hardware changes – low- NO_x burners, overfire air, and fuel switching – have already been implemented. Many generators will face a difficult choice between adding SCRs to units previously seen as too small to justify such and investment; or buying allowances in a costly, uncertain, and volatile allowance trading market.

Neural network software systems that optimize boiler processes are one of the most cost-effective methods to reduce NO_x. These solutions can be implemented and producing benefits in as little as 10-14 weeks. NeuCo's CombustionOpt® solution streamlines the combustion process, resulting in lower NO_x emissions by between 10 and 25 percent. The SootOpt® solution reduces NO_x by another 2.5-10 percent by correctly proportioning heat transfer and reducing "hot spots" that result from ineffective cleaning. When integrated, these software solutions let the end user view and manage interactions between combustion processes and soot blowing systems, thereby minimizing conflicts between complex goals such as low NO_x and steam temperatures.

The decision about whether to take a hardware or software approach to meet emissions standards is not a mutually exclusive one. In fact, in many cases the best approach is a hybrid one.

Hardware Approaches

Most CAIR responses will include NO_x control hardware, ranging from combustion controls to post-combustion selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) systems. These systems reduce NO_x emissions, but often do so at the expense of efficiency, combustion degradation, reagent costs, and increased complexity of operations.

NO_x removal hardware solutions are usually considered in the following sequence: low NO_x burners, overfire air, SNCR and SCR. The ranges of improvements are highly variable since all of these options are dependent on the original boiler design, fuel mix, and how hard a unit is being fired to make load or respond to automatic dispatching.

Low NO_x burners can reduce NO_x emissions by 20 to 40 percent, but they may also have a negative impact on water wall corrosion, loss on ignition (LOI), steam temperature and efficiency (due to loss of radiant heat transfer in the furnace.)

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Overfire air can reduce NO_x by another 10 to 20 percent and is often undertaken at the same time as low-NO_x burners. It can have similar challenges as low-NO_x burners, and sometimes the boiler design prevents overfire air from being a viable option.

SNCR systems provide 20 to 40 percent NO_x reduction and are typically implemented after low NO_x burners and overfire air have been installed. The challenge is to balance the combustion process (flue gas concentrations as well as temperature) as much as possible throughout the entire load range to maximize SNCR efficiency while minimizing the cost of reagent to meet compliance. There are some concerns about the viability of SNCR technologies for larger units.

SCR systems can provide NO_x reductions in the range of 75 to 90+ percent. This ability led many power producers affected by CAAA 1990 regulations to assume that the addition of SCRs would solve their NO_x compliance issues. However, these systems introduced a new set of problems including unacceptable ammonia slip; escalating ammonia costs; ammonium bi-sulfate buildup; and opacity resulting from poorly controlled temperatures and high SO_2-to-SO_3 conversion rates.

Software Approaches

One of the most cost-effective methods to reduce NO_x emissions is to optimize the boiler processes using neural network software systems. The goal of each optimizer is to understand current and potential performance, and to take or recommend actions to close the gap. While individual NeuCo optimizers such as CombustionOpt and SootOpt can address NO_x individually, they are even more effective when integrated. When used together, CombustionOpt and SootOpt provide a comprehensive boiler optimization solution that not only addresses ever-more-stringent emissions challenges, but increases efficiency and availability at the same time.

CombustionOpt

CombustionOpt manages the tradeoffs between NO_x, CO and fuel efficiency through closed-loop optimization of the fuel/air and temperature distributions in the furnace while adhering to all applicable measured or modeled operating constraints. The system uses neural networks and other advanced artificial intelligence technologies to extract knowledge about the combustion process and determine the optimal balance of fuel and air flows in the furnace. It optimizes fuel-air ratios in real-time by calculating and applying the changes that should be made to key controllable parameters, such as dampers, feeders, burner tilts and overfire air, to best meet performance goals given current conditions and constraints. These supervisory set-point biases are passed to the DCS continually in closed-loop. CombustionOpt streamlines the combustion process given the instrumentation and controls that are already in place, resulting in lower NO_x emissions between 10 and 25 percent.

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In addition to reducing NO_x emissions, CombustionOpt improves fuel efficiency, minimizes LOI and opacity, and improves the consistency of operations. Unlike NO_x control hardware, CombustionOpt can reduce NO_x emissions while simultaneously improving boiler efficiency, which results in fuel cost savings and associated SO_2 and CO_2 benefits. It can also help to manage the complexity of post combustion systems such as SCRs, SNCRs or FGDs by improving the efficiency of reagent usage and/or increasing the amount of NO_x or SO_2 removed.

Stand alone CombustionOpt Benefits include:

- NO_x reduction: 10 – 25%
- Heat rate improvement: 0.5 – 2%
- CO reduction: 30 – 50%
- LOI improvement: 20 – 40%
- Opacity control: 10% – 30%
- Improved operating consistency
- Lower reagent costs
- Reduced ammonia slip

SootOpt

SootOpt dynamically determines boiler cleaning actions that optimally balance the unit's heat rate, reliability, and NO_x objectives. A closed-loop optimization software application, SootOpt directs existing soot blowing control systems to take action in real-time to best meet the unit's overall heat rate, reliability, and emissions goals. SootOpt reduces NO_x by correctly proportioning heat transfer and reducing "hot spots" that result from ineffective cleaning.

SootOpt works in conjunction with existing soot blowing controls and instrumentation. It uses adaptive modeling and plant-specified rules to optimize the activity of these systems with respect to their effect on multiple simultaneous global performance objectives. SootOpt is also a powerful analysis tool, providing key process insights that support improved situational awareness and better decision making.

Stand alone SootOpt benefits include:

- NO_x reduction: 2.5 – 10%
- Heat rate improvement: 0.5 – 1.5 %
- Improved reliability
- Fewer plugging and fouling events
- Reduced opacity violations

Hybrid Hardware / Software Optimization Solution

Combining software and hardware approaches will often yield the most beneficial results for lowering NO_x.

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Combustion optimization software can provide benefits beyond emissions reductions. It can counterbalance the negative impacts of post combustion systems, streamline the operations of combustion controls and post combustion systems, and act as the integration engine that manages tradeoffs between the systems.

By integrating CombustionOpt with low NO_x burners, NO_x reductions of up to 50 percent have been achieved. NeuCo has demonstrated incremental NO_x reductions relative to low-NO_x burners going all the way back to its first CombustionOpt installation at Mirant-Canal Unit 2 in 1998. The original 1990's low-NO_x burners increased LOI and more recent versions create high gaseous CO. For the newer low-NO_x burners, CombustionOpt is able to identify the source of the CO (such as mill performance, primary air transport velocity, individual burner operation and secondary air temperature) and uses available levels to minimize or eliminate the CO excursions. CombustionOpt typically reduces both the average level and variability of LOI regardless of burner type simply as a result of better fuel-air mixing and improved combustion. Where on-line LOI monitoring is available, it can be very effectively addressed by CombustionOpt as either an objective or constraint.

Adding overfire air to low NO_x burners and CombustionOpt has provided NO_x reductions up to 60 percent. For a recent CombustionOpt installation at four 50 MW coal-fired units, for example, a one-year payback was achieved by extending the NO_x reduction – from 0.4 lb/mmBtu to a range between 0.22-0.25 lb/mmBtu – to steady operations below 0.25 lb/mmBtu throughout the operating range of the units.

Overfire air, low NO_x burners and other NO_x control retrofits tend to create opacity excursions, particularly on units with older and/or undersized precipitators. On these units CombustionOpt balances the combustion process and fuel-air balance, which helps to maintain or lower the opacity issues as the unit is fired for NO_x or pushed to respond in a cycling mode.

Integrating low NO_x burners, overfire air and an SNCR can provide NO_x reductions by up to 78 percent; with an SCR, reductions can increase to 90+ percent, depending of the coal being burned. These ranges assume the original design fuel for the boiler. PRB blending will typically increase the NO_x reductions when combined with low NO_x burners and overfire air, but may negatively affect the reductions provided by SNCRs and SCRs. Even where SCR reductions are bolstered by a partial or complete PRB conversion, burning PRB can greatly increase the propensity for slagging, given the greater sensitivity of molten slag viscosity to both stoichiometry and temperature. Proving the ability to simultaneously reduce boiler NO_x, ammonia consumption, and slagging for units with SCRs has been an important focus of NeuCo's four-year, $19.1 million DOE Clean Coal Power Initiative project at Dynegy's Baldwin Energy Complex. The results at these 600 MW units designed for Illinois Basin coal but converted to 100 percent PRB and retrofitted with SCRs are compelling.

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Extending the Solution

In order to meet the environmental and market challenges, power generators need to address multiple goals and plant subsystems based on market prices for fuel, reagents, credits and MW hours. It is no longer sufficient to independently optimize the combustion process for NO_x regulations, the soot blowing process for opacity and slagging, and steam temperatures for efficiency, especially when fuel blending/switching or spot purchasing of coal is being used as part of the plant's operating strategy. When varying fuel is part of the plant's strategy, many times it is the tradeoff issues such as LOI, low mill/pulverizer outlet temperatures, low air flow (FD, PA and ID), slagging in the furnace and back passes, high or low reheat and superheat steam temperatures, and flue gas temperatures, which need to be balanced as well as possible in order to meet overall plant objectives.

Advanced Instrumentation

The ability of these systems to optimize is enhanced when they can leverage advanced instrumentation and controls to better manage tradeoffs and improve the consistency of operations under all load conditions. Examples of advanced instrumentation and control include heat flux sensors, strain gauges, water lances and cannons, fuel and air measurements for each burner, modulation of individual secondary air dampers, additional analyzers for the flue gas (economizer outlet, ductwork and stack CEMs), Furnace Exit Gas Temperature (FEGT), in-furnace lasers for multiple gas analysis, etc.

As on-line LOI particulate analyzers have been commercialized, they have become available for combustion optimization to explicitly control LOI and the ash sale revenues depending on it. NeuCo has proven the ability to leverage in-site LOI indicators to minimize LOI and reclaim fly ash sales that were not commercially feasible since low-NO_x burners had been retrofit.

As fuel blending/switching became recognized as an economic NO_x/SO_2 strategy, additional instrumentation and control was often needed to increase the knowledge of where and when the slagging was occurring and provide more effective means of removing it while the unit is in operation as opposed to taking a de-rate to shed the slag or a forced outage to remove the slag. In today's market most utilities in the earlier compliance areas who practice fuel switching, blending or spot purchase coal have recognized that combustion optimization and soot optimization need to be integrated; therefore, allowing the use of the combustion controls (fuel and air) to help minimize the slagging condition from developing rather than waiting to remove it once it has occurred.

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OPTIMIZATION: PART OF A BROADER STRATEGY

The NO_x reductions and efficiency improvements achieved with optimization software have been well documented, and these systems are playing an increasingly important role in helping generators to comply with emissions regulations such as CAIR. Just as important as the NO_x reductions achieved by these systems is the role they play in informing compliance strategies and helping to leverage and streamline the operation of instrumentation and hardware investments.

When optimization is deployed early and as part of a comprehensive compliance strategy, it can inform subsequent decisions and allow proactive power producers to minimize the capital associated with meeting compliance requirements. In fact combustion optimization can be used to ascertain a unit's true baseline NO_x emissions, i.e., how low NO_x emissions can go given current unit configuration. This can aid in the evaluation of hardware and control investments.

As instrumentation and control investments are made, optimization can convert the information obtained by advanced instrumentation into actionable knowledge; mitigate the negative impacts of emissions controls; and drive more efficient operations of SCR and SNCR systems.

Given their inherent ability to work with existing and future data, control and instrumentation investments, optimization systems will not become obsolete. In fact they become more powerful as additional instrumentation and control levers are added. Their ability to integrate with those investments means that optimization solutions are an investment that can be leveraged for years to come.