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To help power plants weather the industry's sea change

by Peter Spinney

The power generation industry is being put to the test. Concern about potential environmental regulations is compounded by a loss of talent and institutional knowledge as a disproportionate fraction of the industry's workforce approaches retirement. And while new plants with improved efficiency and lower emissions are being planned or built, consumption projections indicate that the U.S. will need to continue relying on an aging power infrastructure for some time.

The page is turning for one of the nation's largest and most crucial industries. Remaining economically viable will require squeezing performance from existing assets, reducing emissions, more effectively transferring knowledge, synthesizing and acting upon an increasing amount of plant data, and managing and balancing goals on a plant- and fleet-wide basis.

What if science was able to equip a power plant with a "brain," a centralized hub that could sort through the huge flow of data, consider multiple objectives, apply experience and memory, and then direct or take actions toward achieving goals in real time?

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Tackling critical issues with optimization

Power generators are taking the first steps to incorporate systems that can help them survive the industry's coming sea change. From turbine upgrades, low-NOx burners, selective catalytic reduction (SCR) and flue gas desulfurization (FGD), to distributed control systems (DCSs), data historians, intelligent soot blowing systems and advanced sensors, these technologies address emissions, efficiency and reliability, and generate abundant and valuable data about plant operations.

And yet, presenting people with reams of information does not guarantee action, and certainly does not assure that when they do take action, their decisions will always be correct. Plant staff can wade through hundreds of data points in order to make a single decision, and still lack visibility into how that choice will affect other aspects of performance. In today's power plant environment, operators and engineers are expected to perform the nearly impossible tasks of managing multiple interdependent systems with often contradictory goals, digesting thousands of data points with a comprehensive understanding of possible trade-offs, and driving every action toward achieving plant-wide goals on a 24x7 basis.

Or are these tasks impossible after all? We know that organic living systems successfully manage millions of data points and align actions towards complex goals. Enter optimization. Optimization is a part of the rapidly maturing field of artificial intelligence (AI), the science and engineering of intelligent machines—particularly computer programs. These intelligent machines are modeled after neural processes used by living systems. They have the ability to learn, remember, adapt, prioritize and optimize in a complex environment. The goal is to create computer programs that can consistently solve problems that are too large or complex for humans alone to address, or tackle problems which, if automated, could free people to focus on other things.

Many plants have already begun employing integrated, real-time optimizers. They're realizing results that include reduced NOx and ammonia costs, improved heat rate and reliability, increased annual megawatt output, reduced greenhouse gases, better opacity control, lower generation costs, and greater availability. These software solutions integrate disparate data sources and knowledge, enabling optimized and objective-driven performance across units, plants and an entire fleet.

Optimization project: Dynegy's Baldwin plant

Dynegy Midwest Generation's Baldwin Energy Complex hosts the nation's most significant integration of real-time asset optimizers for coal-fired power generation. Begun in 2004 and concluding at the end of this year, this $19.1 million Clean Coal Power Initiative (CCPI) technology development and demonstration project was a cost-shared effort between the Department of Energy and NeuCo, Inc., hosted by Dynegy's Baldwin plant.

Built in the early 1970s, Baldwin has three 600-MW units. Units 1 and 2 are opposed wall cyclones equipped with SCRs that operate on a year-round basis. Unit 3 is a Combustion Engineering tangentially-fired boiler with separated overfire air and low NOx burners. The plant converted to 100 percent Powder River Basin (PRB) coal in 1999 and 2000.

In 2003, prior to the optimization initiative, Baldwin's NOx performance was already impressive: 0.070 lbs/MMBtu on the two cyclone units and 0.1 lbs/MMBtu on Unit 3. Between 2003 and 2004, Baldwin worked with a vendor to

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adjust burners and dampers on Unit 3, which helped lower NOx to the 0.095–0.098 lbs/MMBtu range. All three base-loaded units had high capacity factors and an average net heat rate of about 10,000 Btu/KWH. Emerson Ovation Systems provided boiler control across the site, with Diamond Power controlling soot-blowing activity, and with OSIsoft's PI system serving as the plant-wide data historian. Tools from SmartSignal and Matrikon were used for detecting equipment anomalies and analyzing DCS alerts.

"Generally, the plant performed well. But we wanted to further explore opportunities where we could do better with emissions, efficiency and availability," said Joe Naberhaus, senior director, Dynegy Midwest Regional Operations.

The optimization project was selected for the CCPI program in 2003 and began in 2004. Over the next four years, NeuCo and Baldwin worked together to develop and install integrated optimization modules to optimize the plant's SCR, combustion, sootblowing, thermal performance, and maintenance systems and processes.

The modules were developed to provide stand-alone functions and benefits; they were not treated as monolithic applications, but rather configurations of a common, distributed platform. The technologies best suited to optimize each process differed, but the core approach was the same: Leverage appropriate optimization techniques to determine the best operating parameters and either directly adjust the parameters or recommend actions.

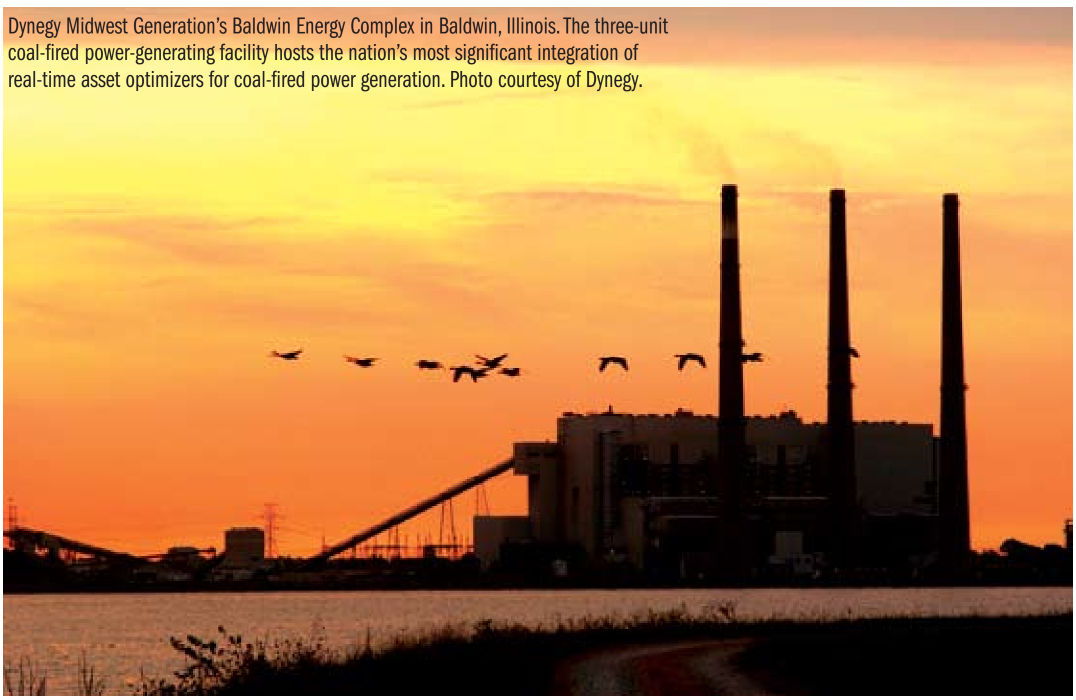
This platform-centric approach enabled synergies between the optimizer modules. For example, MaintenanceOpt, a product designed to more efficiently and effectively detect, diagnose and resolve reliability, capacity and efficiency problems, can leverage PerformanceOpt's first principles thermal model and real-time simulations to determine the impacts of detected anomalies and provide contextual data to help with problem diagnosis. CombustionOpt, which provides closed-loop optimization of fuel and air mixing in the furnace, works most effectively when its models are combined with those of SootOpt, a closed-loop application that dynamically determines and drives globally-optimal boiler cleaning actions.

> No one had ever applied AI-based optimization technologies to a power plant system on such a broad scale.

"No one had ever applied AI-based optimization technologies to a power plant system on such a broad scale," said Curt Lefebvre, president and CEO of NeuCo, Inc. "Since Baldwin and NeuCo were paving the way, we were learning as we went along. It was sometimes difficult, but we were also excited and encouraged by the results."

Within six months, Baldwin had reduced NOx. While this early success encouraged the team, developers were challenged by Baldwin's two cyclone boilers, whose unique design made them unresponsive to traditional combustion optimization approaches. To further complicate matters, the cyclones were burning 100 percent PRB coal, as opposed to the high-sulfur Illinois coal for which they were designed.

"Some of the plant's features, such as the cyclone boilers and the fact that Baldwin was already running a tight ship, made for a pretty challenging optimization effort," said John McDermott, vice president of product management at NeuCo. "But we figured that if NeuCo could optimize this plant, it would be a valuable learning situation for applying this technology to other plants."



Dynegy Midwest Generation's Baldwin Energy Complex in Baldwin, Illinois. The three-unit coal-fired power-generating facility hosts the nation's most significant integration of real-time asset optimizers for coal-fired power generation. Photo courtesy of Dynegy.

After initial versions of the optimizers were installed and tested, subsequent versions were developed to incorporate feedback from Baldwin's staff. The plant saw more significant results as the system became more user-friendly and was rolled out to a broader team. "We needed the optimizers to work in the day-to-day life of the plant," said Stan Sander, managing director at Baldwin. "For instance, looking at user interfaces for each optimizer just wasn't going to fly; the team had enough screens to look at. Working with

NeuCo we decided that MaintenanceOpt would become the interface for alerting us to issues identified by all of NeuCo's optimizers, comparing their relative importance and diagnosing and taking action." Examples of issues recently identified and diagnosed with the help of MaintenanceOpt include an air duct leakage, condenser tube fouling, a leaking balance drum relief valve, and a bad thermocouple that impeded soot cleaning and caused rising boiler differential pressures.

"We were excited when we saw how the optimizers worked together to generate results that were greater than if they were used as stand-alone products," McDermott said. "It's the 1+1=3 effect." For example, on Unit 3, running the combustion optimizer alone yielded a significant NOx improvement but required a slight heat rate penalty, whereas running the combustion and soot solutions in tandem resulted in further NOx reductions while also reclaiming the initial heat rate degradation. (NOx reduction was Baldwin's primary goal and both NOx and heat rate were running so tightly that some HR sacrifice was required).

Achieving balance

At the end of 2007, the CCPI initiative at Baldwin officially concludes. While the optimization benefits are still being evaluated, plant staff are positive about the improved performance thus far. NOx on Unit 3 now has a yearly average of 0.089 lbs/MMBtu with no post-combustion controls. "No one thought the optimizer could do better than 0.095," said Sander. "But after it was installed our NOx levels have consistently run below that level." The unit is also experiencing consistently lower reheat sprays, improved steam temperatures and reduced sootblower counts.

On the cyclone units, a 15 percent to 20 percent NH_3 reduction in 2006 over 2005, combined with improved SCR performance, lowered operating costs. And, thanks to a more recent cyclone quality initiative, Units 1 and 2 are experiencing more consistent cyclone stoichiometry and early results indicate a reduction in cyclone slagging. This in turn has reduced Baldwin's ammonia flows on each unit and is expected to result in less ammonia usage in the future.

Finally, enhanced alerting and diagnosing of process and equipment anomalies on all units is helping Baldwin staff to detect and resolve issues on a more proactive basis. Dynegy's Naberhaus explained: "The optimization solutions will help us take a more holistic and proactive stance as we work to achieve a balance among reliable, economic and environmentally responsible operations."

Optimization is helping Dynegy Baldwin take a more holistic and proactive stance towards operations.