How IT can cut losses in power generation

A Greenbang report | © Greenbang

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Our activities include market-opportunity research, due-diligence, customer segmentation and market-readiness services for our clients. We specialise in smart-technology (supply-and-demand technology), networks and IT, large business transformation, resources and sustainability.

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Our readers are:

- Investors
- Business owners and Business professionals
- IT and technology professionals
- Business and governmental strategists and planners. ■

Introduction

A lot of attention has been paid to smart-grid technologies that can manage end-user demand for electricity, identify outages on the grid and reduce transmission and distribution losses. But there are also opportunities to use software, analytics and management tools to make electricity-generating power plants themselves more efficient.

In fact, power generators around the world are feeling new pressures to make their plants "smarter." With places from California to Australia putting a price on carbon emissions, electricity producers see a bottom-line benefit to improving plant efficiency. New regulations on other types of emissions such as nitrogen oxides (NOx) are having a similar impact. And the addition of more renewable—and intermittent—energy sources onto the grid are making fossil-fuel power plant operations increasingly complex.

Finally, as demand for electricity keeps growing, operators often find that—compared to building new facilities—it's less expensive to retrofit an existing power plant to reduce losses and "wring" more energy output from the same input. That's especially important as utilities in many regions are finding it increasingly difficult to win regulators' approval for rate hikes to cover new construction.

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A global power plant snapshot

Around the world, there are more than 177,000 power-generating plants using everything from coal to hydro to solar.

In 2010, the world produced a total of 21,366 terawatt-hours (TWh) of electricity, with nearly 41 percent of that—8,698 TWh—coming from coal and/or peat. Another 22 percent of electricity—4,768 TWh—was generated using natural gas, and 4.6 percent—989 TWh—came from oil.

Overall, global electricity generation in 2011 produced 4.9 gigatonnes of carbon dioxide—that's 39 percent of the world's carbon emissions. Coal-fired power, which produces two-fifths of the world's electricity, accounts for more than 80 percent of the power sector's emissions of carbon dioxide.

With rising demand for electricity, the number of new power plants being built also keeps growing. Most of these continue to be either coal- or gas-fired plants, although wind farms are projected to come in a close third between now and 2035.

In its 2012 World Energy Outlook, the International Energy Agency (IEA) projects that global electricity generation could rise to between 31,748 TWh and 40,364 TWh by 2035, depending upon the energy policies adopted between now and then. The fossil fuel share of that total could be anywhere from 10,487 TWh to 26,829 TWh.

Not surprisingly, most of the growth in the world's electricity demand—more than 80 percent—is expected to come from development in non-OECD countries. China alone is forecast to account for 38 percent of the world's demand growth between now and 2035, with India amounting to another 13 percent.

While the supply of renewable power around the world is growing, coal is likely to remain the dominant fuel source for electricity for many years to come. It is less expensive than many other fuels, globally abundant and, especially compared to natural gas, relatively easy to transport in large quantities and over long distances.

For this reason, the remainder of this report will focus on efficiency strategies for coal-fired power plants... although the solutions can be applied to any type of power plant. ■

Generating power... and waste

No power plant—not even the most advanced wind or solar farm—will ever be 100-percent efficient. But thermal plants that burn coal or natural gas to drive steam generators don't come anywhere close to converting all the energy input into electricity output.

It's estimated that, for every 100 units of fossil fuel converted into electricity, 60 units are lost through inefficient generation and waste heat, while another 10 units are lost through inefficient transmission and distribution, and 10 units are lost through inefficient grounding at end users.

Clearly, there are large opportunities in finding ways to improve generation efficiency and reducing waste heat.

That's especially the case for coal-fired generation, which has seen little improvement in efficiency over the past several decades. Averaged globally, the efficiency of coal power has risen from 33.5 percent in 1971 to just 35.1 percent in 2007. With the right improvements, that could be brought up to 50 percent.

Much of the energy lost in coal-fired power plants is dissipated as waste heat. The best fix for this is to convert a traditional plant into a combined-heat-and-power (CHP) plant. While CHP isn't viable in many areas—customers need to be relatively close to the plant to make use of the heat, and warm-climate regions don't generally need supplemental heat—the strategy can dramatically drive up a power plant's efficiency.

Vattenfall's Nordjylland CHP power plant in Denmark, for instance, has earned a reputation as "one of the world's most efficient coal-fired power plants." It's reported to use up to 91 percent of the energy contained in the coal it burns.

Coal-fired power can also be made more efficient through the use of advanced ultra-supercricital and integrated combined cycle (IGCC) designs. Currently, however, only a small percentage of the world's power plants use either CHP or advanced design technologies. That leaves vast potential for technologies that can make existing plants more efficient. ■

Taking a power plant's 'pulse'

Recent years have brought big advances in sensor and measurement technologies, and these are being increasingly deployed in everything from home smart-energy meters to systems for monitoring stresses and fatigue on bridges. Such technologies are also making it possible to closely measure and manage the many complex components of a power plant.

Coupled with ever-more powerful computers and intelligent software, these innovations can be used to 'fine-tune' a power plant's efficiency like never before.

Information technology can help to improve power plant efficiency in a number of ways. On an industry-wide basis, measuring, monitoring and analysing plant data—everything from coal pulveriser settings to heat transfer patterns—can help to identify what makes some power plants more efficient than others. Those insights can then be used to establish best practices for the sector in general.

At the individual power plant level, IT can be used to help optimise combustion processes, boiler operations and production costs. Software and services to help with these have been in use for some time, but opportunities remain to expand and improve upon these.

For example, combustion optimisation software—first implemented mostly to reduce nitrogen oxide emissions—increasingly offers new capabilities, such as reducing the need to use natural gas to help with coal firing or enabling the addition of combustion sensors to improve heat rates. This kind of software can provide either real-time intelligence or dynamic modelling for better predictive capabilities.

A more hands-on analysis in the form of production cost optimisation can also help to improve power plant efficiency. In this approach, an appraisal team might visit a site to gather a variety of data, then analyses that information to generate recommendations for reducing heat rates and improving plant performance. After the recommended improvements are made, another analysis is conducted to assess the effectiveness of those changes and identify additional ways to improve operations even further.

Generating electricity efficiently and cost effectively today requires a balancing act with numerous, complex variables: fuel consumption per kilowatt-hour, NOx emissions regulations, cost per million BTU, carbon dioxide emissions costs, soot production, boiler temperature control and much more. Smarter monitoring, analytics and management technologies make it possible to optimise those far more easily than human operators can. ■

How IT efficiency works

Optimisation software
Optimisation software works by using measurements from various parts of a power plant to dynamically manage performance as conditions that can affect efficiency change. This provides a finer level of control than can human operators, who typically make manual adjustments as needed to stay within an acceptable performance range.

Integrated optimisation goes even further by using different "modules" to dynamically manage multiple connected systems in a power plant: for example, combustion, sootblowing and selective catalytic reduction operations.

Optimisation technology is often modelled on how human neural networks work. This enables modules to "learn" how the various systems in a power plant interact. In other words, the software can deliver a certain level of artificial intelligence to manage power plant operations more effectively.

Depending on a plant operator's preferences, optimisation can be deployed in either a closed-loop or advisory mode. In a closed-loop setting, the power plant is automatically controlled in real time. In an advisory mode, the technology provides information to a human operator, who then decides what actions to take.

Production cost optimisation
Production cost optimisation (PCO) is often aimed at improving a power plant's heat rate, which describes how much heat is needed to generate one kilowatt-hour of electricity. The lower the heat rate, the lower the plant's fuel use and expense.

PCO works by analysing plant data, on-site observations and in-person interviews to identify ways to improve performance. A test project run by the Electric Power Research Institute, for example, involved the following steps:

1. Analyse one month of historical performance data from the power plant to establish a baseline for the facility's heat rate;
2. Conduct an on-site appraisal with the help of heat rate experts. The site visit includes interviews with key people to identify how they report and manage problems with plant performance, as well as an assessment of plant equipment condition;
3. Deliver preliminary findings and recommendations for improvement before leaving the plant;
4. Analyse data and information from the on-site appraisal and complete a report with recommendations for improvements. The prioritised recommendations include cost estimates and projected benefits;
5. Conduct a followup analysis after the improvements are completed to measure performance and any resulting reductions in heat rate.

Asset management software
Asset management software can provide a somewhat more holistic approach towards improving power plant efficiency.

Plant operators use such software to gain an organisation-wide view of assets and processes: budgets, operating costs, maintenance schedules, system status and more.

While aimed more at company-wide efficiency rather than pure energy efficiency, asset management software can help reduce losses by ensuring power plant components are checked, cleaned and maintained according to schedule. Keeping parts in good working order can prevent breakdowns, extend the life of components and ensure they work as intended for optimal efficiency. ■

Power plant IT in action

Baldwin Energy Complex
As part of its Clean Coal Power Initiative, the US Department of Energy (DOE) in 2004 launched a demonstration project to test performance optimisation at a power plant in Illinois. Completed in 2007, the test showed that optimisation technology was able to reduce NOx emissions by 12 to 14 percent, increase available megawatt-hours by 1.5 percent and improve the plant's heat rate by 0.7 percent. The DOE noted in its final report, published in 2012, on the demonstration that the heat rate improvement could have likely been higher, but plant personnel made NOx reductions a higher priority.

The demonstration at the Baldwin Energy Complex, which has three 600-megawatt coal-fired units, tested five modules from NeuCo. The modules were designed to optimise overall performance, equipment maintenance, combustion, furnace-selective catalytic reduction interactions and sootblowing.

"The five plant optimisation products developed and demonstrated during the course of the project have the potential to provide operational, economic, and environmental benefits for many types of power plant boilers," the final DOE report stated. "These systems operate with existing control equipment and sensors thus minimising system installation cost. In addition, installation does not require substantial plant downtime."

NeuCo indicated that a typical US fossil fuel-fired power plant could see the optimisation technology pay for itself in less than one year. The DOE added, "The actual benefits realized and payback period required may vary depending on the circumstances at specific power plants. The performance benefits, low cost, and inherent flexibility of the technology have generated significant interest within the fossil fuel-fired electrical generation industry."

EPRI
As of 2011, the EPRI's PCO project had completed assessments of 15 power plant sites, and received data for followup analysis from five plants that had made PCO-recommended improvements.

Four of the five power plants reported significant improvements in heat rates following the assessments and subsequent upgrades. The improvements ranged from 300 to 600 BTU per KWh.

"This level of improvement represents 3 to 5 percent of a plant's annual fuel bill and demonstrates that making heat rate an integral part of maintenance and operations activities can yield real and lasting financial savings," wrote Sam Korellis, senior project manager for EPRI's Combustion Performance and NOx Control Program.

(The fifth power plant reported an increased, rather than reduced, heat rate. The EPRI attributed that "in part, to increased cycling and extended operation at lower loads.")

Korellis noted that, for a typical 500-megawatt power plant burning bituminous coal at the cost of $2 per mBTU, "a mere 1 percent heat rate reduction will save about $700,000 in annual fuel costs."

The improvement strategies recommended by the EPRI following its assessments included routine testing, sootblowing optimisation and heat rate awareness training with more readily available heat rate data for staff.

Fortum
The European energy company Fortum implemented IBM's Maximo Asset Management

Power plant IT in action

software as part of its ongoing sustainability efforts. The software helped the business centralise its process knowledge and gain an integrated, transparent view of its assets.

In addition to improving workplace safety and optimising maintenance plans, the asset management software has helped Fortum continuously monitor all power plant components. That has enabled better predictive maintenance, which has increased system reliability and availability.

In the long term, the company also expects that improved asset management will help it reduce operating costs by some 30 percent.

"With our standardised operating concepts, we ensure that power plants can generate energy reliably and efficiently, and provide optimum performance," said Björn Sude, mobilisation manager for Fortum Service Deutschland. ■

Who's who in optimisation

Following are brief profiles of some of the IT-based optimisation solutions currently being marketed to the power sector:

ABB
ABB's Optimize Predict & Control software uses multi-variable model predictive control (MPC) for combustion optimisation and management of other power plant processes. It claims plants using its technology have reduced NOx emissions by 8 to 40 percent while generating "tens of GWh per year of additional electrical energy with the same fuel consumption."

Babcock & Wilcox
Flame Doctor is a portable hardware and software system that B&W uses in its combustion tuning services. Featuring a graphical user interface and module for diagnostics, the software uses analytics to identify flame patterns and problems with combustion. B&W currently offers Flame Doctor as a value-added service, but it is working with the EPRI on possibly installing permanent systems at some utilities.

Emerson Process Management
Emerson's SmartProcess Energy Management software uses real-time, closed-loop control to "balance steam systems, manage electrical demand swings and upsets, identify opportunities to buy and sell power, improve efficiency, and run an entire industrial utility at the lowest cost automatically." Emerson also offers SmartProcess Boiler for combustion control.

GE
GE's Kn3 software is designed to model, optimise and control boiler operations to increase efficiency and/or reduce emissions. GE claims the software can help the average coal-fired power plant cut NOx emissions by 10 percent and reduce fuel costs for gas-fired plants by 0.5 percent.

IBM
IBM's Maximo Asset Management software helps power plant operators centralise their process knowledge and gain an integrated, transparent view of assets. While not directly aimed at the generation sector, the software can ensure better maintenance schedules and thus improve efficiency, according to IBM.

Invensys
Invensys says its Connoisseur software provides a unique approach towards optimisation by combining neural network strategies with model predictive control. It claims the application can reduce NOx levels by 10 to 30 percent and improve heat rates by up to 1.5 percent.

Metso
Metso's DNA FBB Combustion Manager is designed to improve power plant efficiency and minimise emissions. It uses fuzzy logic to help keep selected process variables within acceptable limits and is, according to Metso, "especially suitable for fluidized bed boilers firing fuels such as sludge, wood waste, bark and low-grade brown coal."

NeuCo
NeuCo's ProcessLink software platform uses multiple modelling and optimisation strategies to provide real-time support for decision-making. The software integrates a suite of solutions for power plant operations: BoilerOpt, CombustionOpt, MaintenanceOpt, PerformanceOpt and SootOpt.

Rockwell Automation
Rockwell's Software CEM (for "continuous emissions monitoring") uses existing process sensor data to model processes in real time and generate accurate emissions predictions. This enables power plant operators to maintain

Who's who in optimisation

uptime even during sensor failures, which prevents fines for non-compliance.

Siemens
Siemens' SPPA-P3000 Process Optimization is software that performs continuous monitoring, analysis and optimisation of power plant components and processes. It includes support for optimising combustion, fuel costs, sootblowing, temperatures and more, as well as for reducing emissions. ■

What's next

Increasingly, optimisation software and analysis are being used to manage and control not just one aspect of efficiency—for example, NOx emissions—but to improve overall power plant efficiency, fuel use and costs.

These offer an opportunity to help make inefficient power plants in in both developed and developing economies more efficient and cleaner with a quick payback time.

The benefit would go beyond saving costs for the operator to reducing fuel consumption and carbon emissions while enabling reliable electricity supplies (and, as a result, ongoing economic development).

As they become increasingly sophisticated and cost-effective, optimisation solutions could help overcome a key obstacle to improved power plant efficiency in countries where, for instance, coal is cheap or heavily subsidised.

Considering that renewables and nuclear power aren't expected to replace fossil fuel power anytime soon, and that the world's power plant fleet remains likely to be dominated by sub-critical (less advanced, less efficient) coal plants for decades to come, optimisation software is likely to play an important, and long-term, role in minimising emissions from fossil-fuel-generated electricity and controlling energy infrastructure costs for both operators and end-users. ■

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Opportunities

While older, less efficient coal-, gas- and even oil-fired power plants can be found around the world, some regions are more likely than others to emerge as the top markets for optimisation IT. Among these are:

- Countries with a heavy reliance of coal-fired electricity that are facing strict climate-change and emissions reduction goals;
- Coal-dependent countries with plans to reduce fossil-fuel subsidies for the power sector;
- Developing economies rapidly building new fossil-fuel-fired power plants to meet fast-growing demand;
- Fast-growing countries that are heavily dependent on inefficient fossil-fuel power.

China clearly meets the first and third conditions, while Australia—which became a belated signatory to the Kyoto Protocol in 2008—is a prime candidate for optimisation IT under condition one.

Saudi Arabia, whose power generation today is still largely reliant on burning oil, has a strong incentive (condition number four) to invest in optimisation technologies as it works to provide reliable power to a fast-growing population while also trying to control domestic oil consumption to ensure adequate oil supplies for export. Coal-dependent and fast-growing India could also be a candidate under condition four, but currently does not have as strong a motivation as Saudi Arabia.

Reducing fossil-fuel subsidies (condition two) has been strongly advocated by organisations like the International Energy Agency. However, many subsidy-heavy countries have yet to commit to such changes. This is an area that bears watching in future to identify potential new opportunities for optimisation IT. ■

Conclusion

Continued advances in sensor technology, analytics, artificial intelligence and "big data" computing will in coming years keep creating new opportunities to expand efficiency-aimed measurement, monitoring and control technologies in power plants.

Such technologies, in addition, will be more needed than ever as we move into a cost- and emissions-constrained, fossil-fuel-dominated future.

The ongoing integration of intermittent renewables into the world's power grids, and the increasing stresses on infrastructure caused by climate change, will also demand smarter, more reliable management of electricity supplies.

For all of these reasons, IT innovations for optimising power generation are likely to enjoy a healthy global market for many years to come. ■

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