Optimizing Efficiency and Profit: Lessons for Combined Cycle Power Plants from Other Industries

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Proactively Managing Assets for Peak Performance

As renewable energy becomes more popular and breaks down previous market barriers, combined cycle power plants face increasing threats to profitable operations. A recent Deloitte article pointed out that renewables have achieved greater price and performance parity on the grid and increasingly, many regions are turning to solar and wind as cost-effective methods of balancing the grid. Wind and solar are driving electricity prices down, placing greater pressure on combined cycle plants to control costs and increase efficiency. [1]

In addition, the demand response programs many utilities have put in place call for plants to ramp in ways their equipment wasn't designed to accommodate. This can place undue strain on components, ultimately contributing to costly breakdowns. While many factors are beyond a plant operator's control, equipment failures don't have to be one of them. New prescriptive analytics technology delivers detailed insight into asset performance and potential problems, allowing those who manage combined cycle power plant operations and maintenance to answer several prevalent questions:

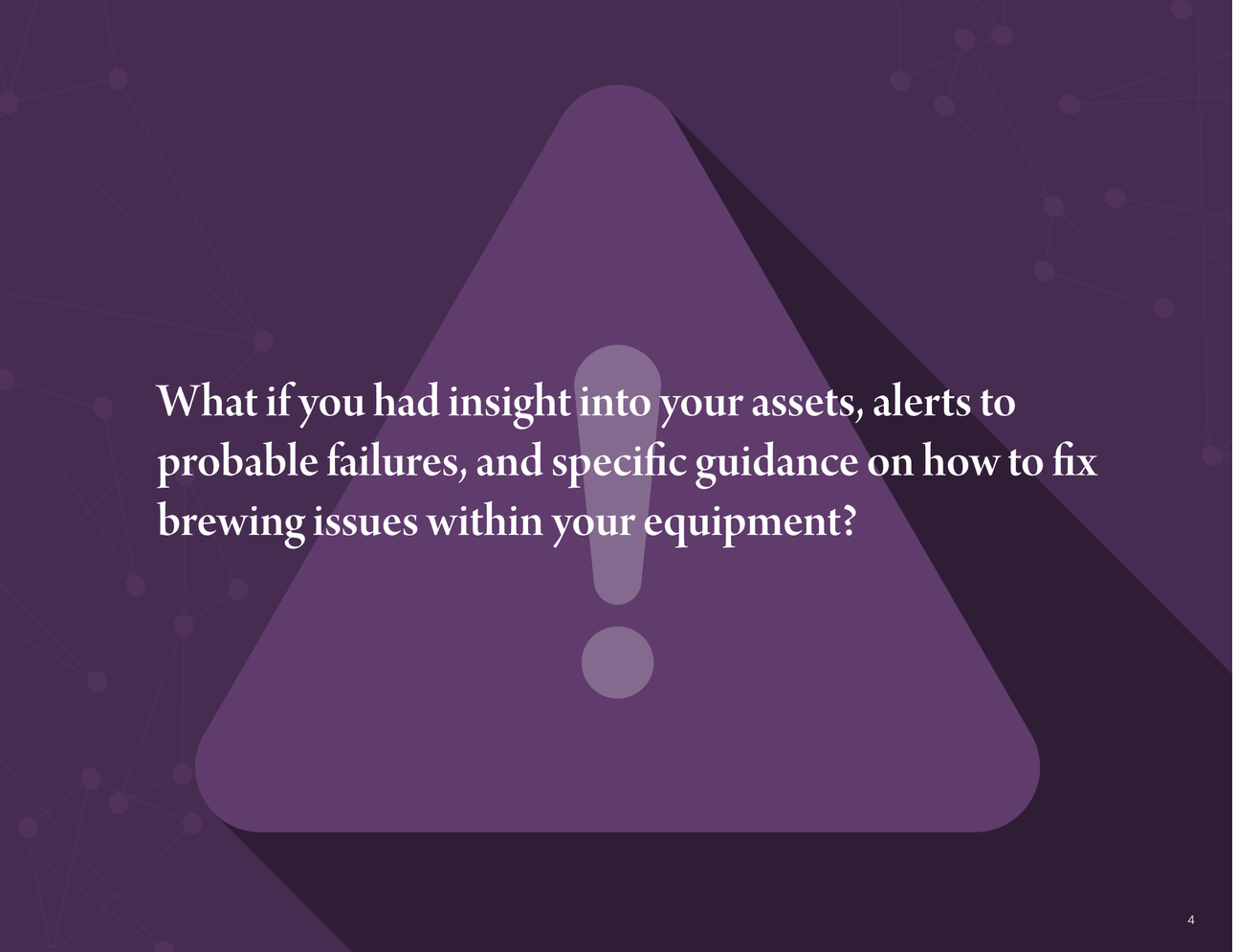
- How do you know you're getting the most life out of your assets?
- Are the recommended starts or hours the OEM suggests aligned to how your asset operates?
- Does the OEM prioritize their profits over your plant operations?

What if you had insight into your assets, alerts to probable failures, and specific guidance on how to fix brewing issues within your equipment? Companies in process-heavy industries, such as petrochemical, oil & gas, pulp & paper, transportation, and mining are using prescriptive analytics to reduce equipment failures and increase profits. Equipment for these industries is expensive to purchase, maintain and operate, yet essential for the business. When this equipment breaks, it means lost productivity and revenue, as well as astronomical repair or replacement costs. Many combined cycle power plants could benefit from adopting the prescriptive analytics tools that are delivering savings in other industries.

Get Precise Recommendations and Guidance with Predictive Analytics

Analytics for rotating machinery — specifically heavy-duty gas turbines — isn't new, from tracking starts and hours on crucial capital parts to measuring vibrations and analyzing oil samples. These tests are great at describing what has already happened and showing damage that has occurred. Unfortunately, they do little to predict or prevent failures. Improving our ability to measure nuances with enhanced sensors and better understanding of the physics affecting an asset is great, but getting ahead of any downtime with advance notification of impending failures is far more valuable to the business.

Rather than normal wear and tear, process deviations or operating excursions cause a large proportion of equipment damage. An ARC View Report on proactive asset management proved that 82 percent of failures are not wear-based and therefore not addressable by standard scheduled maintenance. Data on failure patterns compiled by NASA and the US Navy shows that only 18 percent of failures correlate to calendar time, run time or cycle count.



ARC estimates that the process industries alone suffer $20 billion of annual production losses due to unscheduled downtime: “To reduce such losses, companies are eager to complement existing maintenance strategies with new techniques to further minimize downtime.”

Predictive analytics, with these improved sensors and first-principle algorithms, provide an alert to a potential failure based on how a machine should operate given a specific set of conditions. These conditions, or rules engines, are essentially hard-coded based on system configuration and some general expectation of weather and operation. At one organization, the predictive analytics sometimes worked and provided warnings that an asset was not in perfect health; however, they also provided numerous false positive alerts. More importantly — and perhaps more frustrating — the alerts didn’t provide guidance on how to return the asset to peak performance.

In addition, these rules engines simply run the same test repeatedly, without really learning the machine or its environment over time. The same false positives recur without adjusting the baseline for different conditions. Equations created to monitor new equipment become less reliable as it ages — changes in metallurgy, fuel, operators and environment all have effects that aren’t reflected in the original equation. Few plants take the time to update equations to factor in these variables.

Go From Analyzing Past Failures to Preventing Future Problems

Rather than simply analyzing past asset damage, progressive organizations are tapping into the power of machine learning to identify potential problems far before an asset reaches the point of failure. Recognizing patterns in data, new asset performance management (APM) systems identify small changes that can signal larger problems and send alerts before an incident occurs. Acting on these alerts allows plants to dramatically reduce or eliminate unplanned shutdowns and production losses.

Using inline, real-time analysis of the patterns of normal and failure behaviors of equipment and machines, the next generation of APM solutions accurately portray asset lifecycle and asset reliability and focus on the early root cause of degradation, rather than later-stage detection of damage. The system identifies unique signatures related to a specific piece of equipment and a cause of failure, prescribing precise maintenance actions based on the indicators detected and historical data. With this methodology over a period of roughly 2 ½ weeks, the latest prescriptive analytics tools can create new insights and recommendations quickly, which plant operators can act upon to avoid catastrophes.

This approach has delivered recent success in speed, scale and savings with several assets including compressors, pumps and engines. Combined cycle power plants could realize similar benefits to other industries that rely on complex, costly capital equipment:

How Other Industries Are Benefiting from APM

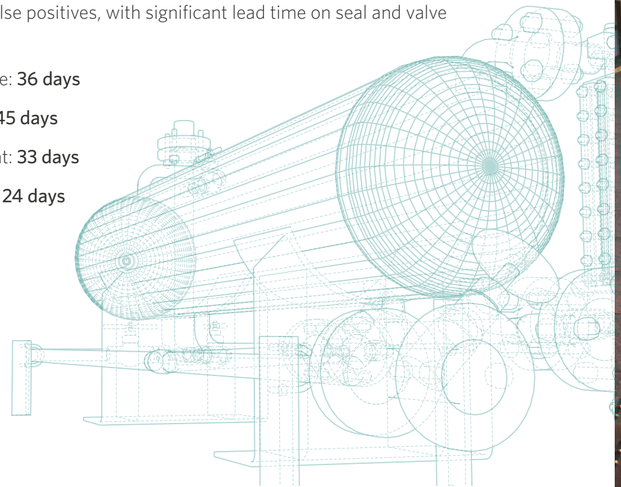
One of the world's largest **polyethylene and polypropylene producers** had several unplanned shutdowns due to failed hyper compressors that impacted the entire chemical complex. Two failure modes became the focus of the project: problems with the high-pressure packing and central valve. The packing was developing leaks, but with an unexpected pattern and progression. Repair teams hypothesized that the failure was associated with startup and shutdown. The central valve problem was a case of the poppet valves grinding into their seats. After some period, the valve head degraded to the point where it was sucked into the discharge orifice, causing catastrophic failure in milliseconds. Repairs were expensive, and production losses were typically 5 to 10 times greater than the repair costs. After deploying a new APM solution, in just a few weeks, plant operators received 27 days of advanced warning for central valve failure and 48 days of notice for the high-pressure packing. With the solution's ongoing benefits, the plant's staff was able to eliminate unplanned downtime, reduce asset damage and remediate asset downtime problems in a business-optimal way.

A different **facility** processing 15.6 million metric tons of liquefied natural gas a year faced multiple catastrophic failures that resulted in an economic loss of roughly $40MM USD. Various third-party inspections and retrofits did not resolve the problem. Using low-touch machine learning along with roughly 100 tags from the equipment and 500 upstream process tags, a new prescriptive analytics program created and refined anomaly and failure agents in only 9 days. While the site staff assumed a compressor issue, the solution focused on the entire plant — agents and a sensor ranking report pointed to a problem with the heat exchanger. Thirty-seven sensors in the mixed refrigerant system upstream were rated highest on the report and identified as the root cause. This alert was raised 51 days before potential leaks and failures at the heat exchanger that would have resulted in material mixing, significant downtime, shocking repair costs and, most importantly, potential disastrous injury.

One **rail transport company** used machine learning to prevent catastrophic engine failures. Through analysis of archived lube oil samples, the software discovered both normal behavioral patterns and exact failure patterns, and then successfully transferred that data to autonomous agents monitoring some 600 locomotives. Within just four months, machine learning identified 10 pending failures and prescribed corrective action, which amounted to over $10 million in saved costs. Scaling the solution to more than 4,000 locomotives across the company system preemptively detected failures on another 96 engines, resulting in additional major savings.

More relevant to the power industry, a 300,000-barrel-per-day **refinery** and their 600MW integrated gasification combined cycle **power generation plant** wanted to improve uptime and decrease maintenance costs. Within a few weeks, the APM solution analyzed 52 million sensor values, including condition data and process data, and cross-referenced the work order history for the plant assets, including 340 prior work orders. Monitoring agents created from this data accurately identified specific failure modes, without false positives, with significant lead time on seal and valve repairs including:

- High valve temperature: **36 days**
- Oil seal replacement: **45 days**
- Pump seal replacement: **33 days**
- Gas seal replacement: **24 days**



Increase Productivity and Profit

Prescriptive analytics help plants become more competitive in today's power generation market rife with changing operations and off-take agreement dynamics. Owners and operators want extended operating ranges, faster starts, quicker ramp-rates, trip avoidance, and higher efficiency at lower minimum NOx compliant output. Today, the focus has clearly shifted to a peak economic efficiency rather than the full load peak thermal efficiency used as the measuring stick for power plant performance in the past. Power plant flexibility in operations and fuel source is now required, even at the detriment to efficiency in some cases.

After-market hardware solutions for power augmentation, efficiency improvements and flexibility enhancements have increased in the number of players, offerings and adoptions. Chillers, foggers, evaporative coolers, wet compression, improved hot gas path systems, upgraded combustion, and enhanced compressors can all improve a specific aspect of the gas turbine's performance. Many APM solutions providers focus on the asset in isolation without clearly understanding the impacts on the entire power plant's system or process. Each system must be configured based on the specific variables that affect a particular site.

Unless an OEM has designed an entire asset, they lack system-and process-wide understanding. They also drive revenue through part and service sales — as much as the OEM needs to drive customer satisfaction, sometimes recommended solutions may place greater value on the OEM's margins than on plant efficiency and profit. Insight across systems or plants that include equipment from multiple OEMS can be tough to come by, but incredibly valuable in troubleshooting complex systems.

Learning from Other Industries

Combined cycle power plant owners and operators can draw on the wisdom the process and transportation industries have applied to drive greater flexibility and profit from their assets. Adopting prescriptive analytics that take a system-wide view offers visibility into minute changes that indicate degradation well in advance of a critical event. These tools have been successfully used to create data-driven guidance to remove failures, reduce downtime, accurately predict remaining useful life and optimize operations.

The latest APM innovation combines real machine learning and physics-based models to deliver meaningful prescriptive analytics that give a detailed report and recommended action well before a looming event occurs.

Figure 1: Prescriptive Analytic Methodology

Figure 1 lays out the methodology for effective prescriptive analytics in detail and provides relevant direction for what should be done in all assets including the specific expensive component parts. With existing customer data, which includes detailed operational and environmental data, the tool learns and creates Autonomous Agents™ that are tied to anomalies and failures. Once these Agents are tuned and adapted to the precise operation and environment of that specific asset, they report pertinent findings and raise alerts if failures are imminent. Whether it is rotor imbalance, bearing failure, blade cracking, nozzle clogging, boiler tube leaks, or anything else, the system can predict imminent failure, prescribe a solution and optimize the asset to support specific business initiatives.

The Case for Innovation to Improve Operations

Drawing on technology used to serve the petrochemical process industry, monitor freight transportation equipment and protect power generation assets, the latest innovations in machine learning and APM can help plant operators capture more value from capital equipment. Though established industries and organizations can be reluctant to adopt new technologies, digital transformation presents a tremendous opportunity for plants to overcome unprecedented challenges. As combined cycle power plants face an increasingly competitive landscape, operations leaders cannot afford to overlook tools that support greater agility, efficiency and profit.

Prescriptive analytics have delivered cost savings and increased agility to businesses with many parallels to combined cycle power plants — particularly those running assets with similar components in variable environments. It's time to adopt machine learning to gain greater insight into your assets to ensure they operate at peak efficiency to drive revenue and profit.

End Notes/References

[1] **Global Renewable Energy Trends**. Marlene Motyka, Andrew Slaughter and Carolyn Amo. Deloitte. 13 September 2018.

[2] Proactive Asset Management with IIoT and Analytics. Ralph Rio, ARC Advisory Group. 15 January 2016. **https://www.arcweb.com/blog/proactive-asset-management-iiot-analytics**.

[3] AspenTech Automated Machine Learning Solution Enables Organizations to Move Up on the ARC Asset Management Maturity Model. Bob Gill, ARC Advisory Group. 8 March 2018.

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