The Trough of Despair – Where AI Hype Meets Reality in Power Generation and How to Navigate Through It

Summary

In the years since Artificial Intelligence (AI) first became a hot topic at power industry conferences, expectations have peaked with miraculous claims of optimizing plant availability and efficiency, reducing maintenance costs, smarter decision-making and lowering emissions. However, a growing gap is apparent between the claims surrounding AI in the energy sector and the reality in terms of practical, scalable outcomes. While AI offers vast potential for enhancing power plant performance, demonstrated return on investments remains limited by technical, operational and commercial challenges.

This paper explores the realistic opportunities AI presents to improve power plant performance, examining its true potential, existing use cases, and limitations that need to be addressed to enable widespread adoption and value.

---

1. Introduction

In an era of rapid digital transformation, the power generation industry is under immense pressure to modernize operations. As market competition and energy demand increase, so does the industry's need to increase reliability, capacity and efficiency. AI has been heralded by many as the key to unlocking these improvements. However, as with any technological revolution, the initial excitement around AI has led to unrealistic expectations and notable disappointments. This white paper discusses practical applications of AI in the power sector, weighing hype against tangible benefits that can realistically be expected today and in the near future.

---

2. Initial AI Excitement and Claims in Power Generation

The potential benefits of AI in power plants stem from its ability to process vast amounts of data, recognize patterns, and generate insights that would otherwise go unrealized. Over the past few years, this potential has led to industry publications, conferences and advertisements being filled with excitement and anticipation. Common claims of AI features and benefits in this context include:

2.1 Enhanced Production and Efficiency

AI-powered systems and services are often promoted as capable of optimizing plant operations in real time. For example, machine learning (ML) algorithms can analyze operational data, forecast demand, and automatically adjust equipment settings to maximize efficiency. Potential benefits include maximizing output and reducing energy waste, leading to improved plant heat rates and reduced operational costs.

2.2 Predictive Maintenance

One of the most cited use cases for AI in power plants is predictive maintenance. Claims are common that AI algorithms can process sensor data to predict when equipment might fail, allowing operators to perform maintenance before costly failures occur. Expected reliability benefits include reducing unplanned outages, extending equipment lifespan, and minimizing maintenance costs.

2.3 Reduced Emissions

AI is also advertised as capable of minimizing environmental impact. Through better control of combustion processes, fuel mixing, and flue gas treatment, AI systems may help reduce emissions of greenhouse gas, NOx, and SOx. This prospect is particularly attractive to operators of coal or natural gas-fired power plants, where compliance with increasingly stringent emission regulations is critical.

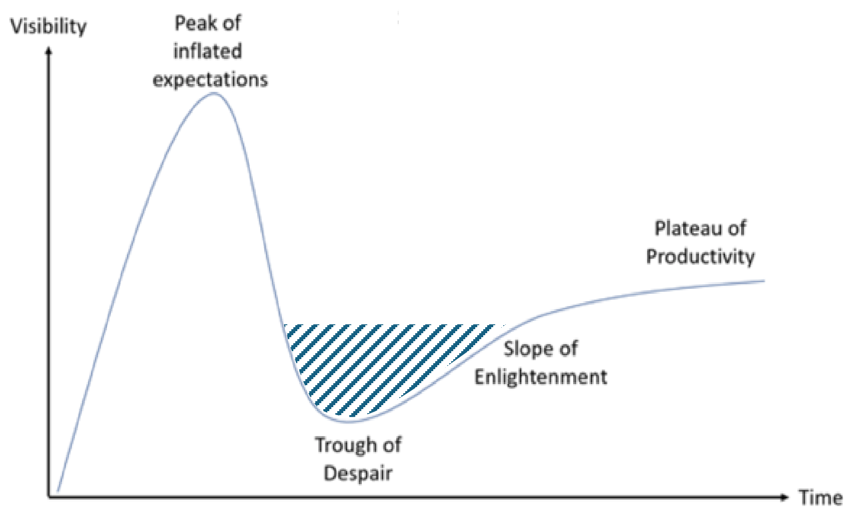
2.4 Autonomous Control Systems

Advertisements, publications and conferences also reflect excited anticipation for the prospect of fully autonomous power plants. With AI managing everything from dispatch and load balancing to energy storage, power plants could theoretically operate with minimal human intervention, thereby reducing the likelihood of human error and continuously optimizing performance in real time as energy demand fluctuates.

---

3. The Trough of Despair

A common phase in the adoption of emerging technologies is the "trough of despair" part of the Gartner Hype Cycle framework[1]. This phase occurs when the initial surge of inflated expectations inevitably leads to disappointing results. In the context of AI in power generation, many vendors, asset owners, and operators are currently navigating this phase as initial expectations of efficiency gains, autonomous operations, and reductions in maintenance costs have proven more challenging and costly to achieve than anticipated.



Navigating through the trough of despair requires focus on realistic, incremental improvements and investing in infrastructure and human capital to ensure long-term benefits. To achieve the promise of AI in power generation, the following specific challenges and limitations are now being tackled:

3.1 Data Quality and Availability

For AI systems to deliver meaningful insights, they require large amounts of consistent, high-quality data. Many power plants, particularly older ones, either lack the necessary data infrastructure or have incomplete or inconsistent data sets. Plant instrumentation data can be inaccurate or misleading for many reasons, including calibration drift, instrument malfunction, temperature excursion (e.g., freezing), or incorrect historian configuration. Several methods may

---

[1] The **Gartner Hype Cycle** is a graphical presentation developed by the technology firm Gartner to represent the maturity, adoption, and social application of specific technologies.

be used to assure data quality, including automated quality checks, smoothing filters, or statistical methods.

Data quality issues can mislead AI models, causing false alarms and other inaccurate predictions about equipment health or energy output. The resources necessary to address these data quality vulnerabilities are significant and were largely unrecognized in earlier phases of the AI adoption process.

3.2 Concept Drift

Concept drift is a significant challenge in power plants, where the operating environment and conditions can change over time. For example, the efficiency of a gas turbine may gradually decrease due to wear and tear, or new regulations may require changes in operating practices, leading to shifts in data patterns. Similarly, seasonal variations, such as higher demand for cooling during summer or heating during winter, can cause changes in the patterns of energy production and consumption.

AI models trained on historical data might assume that these patterns remain constant over time. However, when concept drift occurs, the model's predictions can become inaccurate, leading to suboptimal decisions, such as unnecessary maintenance or incorrect load balancing. To address concept drift, models must be regularly updated with new data to learn the latest patterns. Approaches include periodically retraining models or using algorithms that adapt to changing conditions. However, detecting concept drift in real time and deciding when to update models remains a complex challenge.

3.3 Extrapolation Error

Extrapolation error is a critical issue when AI models that use machine learning are used to predict conditions beyond the range of available data. For instance, if a model is trained on power output data from a turbine operating under normal conditions, it may not accurately predict performance during extreme conditions, such as a sudden increase in power demand or an emergency shutdown scenario.

Power plant operations often require predicting scenarios that have not been encountered before, such as extreme weather conditions impacting power generation or equipment operating beyond its typical limits. Models that rely on extrapolation can make incorrect assumptions, leading to significant errors. For example, a model might assume that power output will continue to increase linearly with fuel input, not accounting for the efficiency loss or safety limits that occur at higher levels. To minimize extrapolation errors, it is important to use models that incorporate a deep understanding of the physical limitations and operational constraints of the power plant equipment. However, accurately modeling these complex systems is challenging and requires extensive domain knowledge.

3.4 Integration with Legacy Systems

The benefits of AI technology have the greatest potential when plants have modernized systems yielding large, sufficient amounts of high-quality data. AI often struggles to show value when dealing with legacy infrastructure found in many aging power plants. Retrofitting AI systems into older plants can be complex and costly, and the returns may be either too little and/or too late to justify the investment.

3.5 Workforce Challenges

AI implementation in power plants requires a workforce that is prepared to trust AI technology and participate in its adoption. In practice, however, the energy sector has traditionally been slow to adopt new technologies, and there is often a shortage of staff with the necessary incentives and resources in terms of time and knowledge. Upskilling existing staff or hiring new talent can be both time-consuming and expensive, further complicating AI's return on investment.

3.5 Implementation, Operation and Maintenance Costs

In addition to the cost of addressing challenges noted above, AI technology implementation requires substantial investment to build, operate and maintain. AI models, which can number in the dozens or even hundreds at a utility-scale power plant, need to be individually designed, built, and tested before deployment. After deployment, each model typically operates continuously and requires high-speed computing resources to function and personnel to monitor, troubleshoot, and maintain. Again, the extent of these costs was not always considered in early projections of AI technology value.

---

4. Current Use Cases and Success Stories

Despite the challenges noted above, AI is delivering real results in several areas of power generation. A few noteworthy use cases include:

4.1 Anomaly Detection and Diagnostics

AI technology, primarily machine learning (ML), is now used at power plants to detect and diagnose anomalies in commercially successful engagements. Solving the problems of concept drift and extrapolation error was necessary to achieve this outcome, as well as careful data quality evaluation and selection of processes to monitor based on economic value. Actual benefits include continuous, reliable performance evaluation with real-time quantitative information that facilitates diagnosis and rapid, high-quality decisions.

4.2 Performance Optimization

At combined cycle plants, ML is used to quantify and optimize the effect of system configuration changes and operating/maintenance procedures in real time. Examples include changes to firing curves, compressor blade cleaning in combustion turbines, and superheat or reheat temperature in boilers. In the renewable energy sector, AI is being used to optimize the performance of wind turbines by analyzing wind patterns and turbine data to adjust the angle of the blades in real time to maximize power generation.

4.3 Performance Forecasting

Nearly all (95%) of domestic US power generation is bought and sold through day-ahead merchant markets such as PJM, MISO, and ERCOT[2]. Each facility offering power into these markets is required to submit a forecast of generating capacity on an hourly basis for the following day (daily declaration). AI technology is now used to achieve unprecedented accuracy in forecasts of generating

[2] Reference source: https://www.nga.org/electricity-markets/

capacity and fuel demand. Plant characteristics are modeled daily to optimize accuracy based on actual performance data in various configurations specified by the asset operator. Benefits include reducing losses due to forecast errors, increasing accuracy of fuel demand forecasts to optimize energy management decisions, and eliminating manual activities to calculate, check, and distribute daily declarations.

---

5. The Path Forward: Balancing Expectations with Reality

To maximize the potential of AI in power generation, industry stakeholders need to strike a balance between aspiration and practicality. The following recommendations can help bridge the gap between hype and reality:

- **Incremental Implementation**: Rather than pursuing full-scale AI solutions, power plants should focus on incremental improvements, starting with high-value processes in which AI can deliver proven value in areas such as anomaly detection, diagnostics, performance optimization, and forecasting.
- **Data Infrastructure Investments**: Upgrading data collection and processing infrastructure is critical for AI adoption. This includes installing reliable instrumentation, controls, data acquisition, and historian systems.
- **Workforce Development**: Familiarizing key decision makers with AI technologies will be essential for long-term success. A workforce with domain expertise that is prepared to trust AI technology and participate in its adoption is crucial to unlocking AI's full potential.
- **Partnerships with Tech Providers**: Collaborating with AI and tech companies that have experience in the energy sector can accelerate the learning curve and lead to more effective AI deployment.

---

6. Conclusion

AI offers transformative potential for improving power generation plant performance, but its application is not without significant challenges. While some use cases demonstrate that AI can deliver real benefits in efficiency, maintenance, and emissions reduction, the industry must temper its expectations and approach AI implementation with a focus on gradual, sustainable progress. By investing in data infrastructure, workforce training, and strategic partnerships, power generation companies can begin to realize the promise of AI without falling victim to the hype.

About the Author
Stewart Nicholson is President and founder of Primex Process Specialists, Inc., a professional services firm specializing in generation asset optimization services. Building on thirty years' experience in process optimization, Stewart's mission is to further develop and deploy Primex's suite of advanced forecasting, anomaly detection, and diagnostic services. Stewart is a seasoned executive, patent holder, Professional Engineer, ASME published author, and contributing author of Machine Learning and Data Science in the Power Generation Industry (ISBN 9780128197424). For more information, visit www.primexprocess.com.