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Five strategies for sustainable, resilient and efficient thermal power generation

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Executive summary:

Power plant operators are continually seeking ways to improve their facility's output, now more than ever at a time when reliability and resiliency of the power supply is an overriding concern. This paper describes five strategies to help power utilities face the new economic challenges as well as to operate more sustainably:

- Strategy 1: Integrated engineering and asset information management
- Strategy 2: Integrated simulation and learning through the asset lifecycle
- Strategy 3: Integrated Electrical Instrumentation & Control (EI&C) project execution
- Strategy 4: Integrated asset performance management
- Strategy 5: Making power generation more sustainable

Introduction

The economics of power generation have been upended over the past several years. Whether building a new power plant or operating an existing fleet, utilities and power producers face increasing challenges. Renewable energy continues to take market share from fossil fuels, most notably coal, whose use remains in decline across the U.S., Europe, and elsewhere. Countries such as India and China remain reliant on coal for much of their generation, but new coal plants must be designed with advanced emissions reduction technology to meet enhanced pollution standards. Combined cycle natural gas-fired plants also must be more efficient, using new technology to produce reliable power while keeping operations and maintenance costs in check. Electricity producers more than ever must utilize technological advances and cost-saving methods to remain viable in a highly competitive landscape.

This paper describes the following five strategies to help power utilities face the new economic challenges as well as to operate more sustainably:

- **Strategy 1:** Integrated engineering and asset information management
- **Strategy 2:** Integrated simulation and learning through the asset lifecycle
- **Strategy 3:** Integrated Electrical Instrumentation and Control (EI&C) project execution
- **Strategy 4:** Integrated asset performance management
- **Strategy 5:** Making power generation more sustainable

The benefits of implementing these five (5) strategies are:

- **Improve engineering efficiency:** Increase efficiency of engineering, design, and construction to remain competitive and profitable, while driving out avoidable waste, risk, and rework. Integrated data-centric applications enable engineers to collaborate more effectively across project disciplines and locations. Eliminate rework with the ability to detect errors during the design stage, leading to 20% improvements in engineering efficiency.
- **Maximize capital and project efficiency:** The unification of instrumentation, control, and safety systems along with electrical management systems into a digital environment enables innovation and mitigates capital project investment risks, reducing overall project capital costs by up to 15%.
- **Increase fleet-wide reliability and performance:** The combination of assets with connected devices, and most importantly, the data captured for each of these assets, introduces the need for technology solutions to harmonize disparate data, as well as provide a single view into maintenance needs, downtime predictions, and scheduling of proactive maintenance. The increased reliability translates to one-sixth fewer unplanned shutdowns.
- **Edge-to-enterprise visibility:** In many facilities today, constantly changing asset data is hard to find because it is saved in non-standard formats on stand-alone applications. It is not instantly available when you need to make a quick decision, making it difficult to measure completeness, consistency, and accuracy. The solution is a network of connected data that allows faster, easier and contextualized visibility by anyone, anywhere, on any device, at any time.
- **Empower the operation workforce:** Reducing time-to-competency has become a major issue to sustaining productivity. Also, a change in the generation mix from coal fired to natural gas and renewables requires an agile workforce that can be trained to safely operate with transitioning power generation. A continuous improvement process requires more integrated training that is key to workforce empowerment and retention, resulting in 50% reduction in training costs and 7X more knowledge retention.

- **Increased sustainability:** Power plant optimization from design through operation requires lower resource usage, as well as lower byproduct waste. (ash and GHG gases). Producing more with less can reduce carbon footprint by 7 to 12%.
- **Cybersecurity:** Power plant owners and operators are rightfully sensitive to cybersecurity vulnerability. As the number of connected devices increases, the risk to maintaining secure operations also increases. The rationale for industrial modernization must include mitigating cybersecurity risks, in addition to adhering to new compliance measures, changes in capabilities and equipping an evolving workforce demography. Software and hardware providers must adhere to strict cybersecurity compliance procedures during the development and installation of a solution. Once installed, the cybersecurity system must be monitored and maintained to keep pace with evolving technologies to safeguard against threats.

Strategy 1: Integrated engineering and asset information management

Challenge:

Traditionally, asset models of the power plant are developed during the design phase but are not maintained through its lifecycle. EPCs (Engineering, Procurement, and Construction companies) work with comprehensive data for the plant, but the development of asset models created during design often are not updated during construction. This leads to gaps in understanding the plant assets, less effective operator training, and reduced engineering efficiency.

Disconnects can exist between process and discipline engineering, while design iteration loops between these groups at key milestones are unsynchronized. Separate personnel, databases, and work methodology contribute to mistakes, rework, delays, and cost overruns. In a worst-case scenario, such errors can result in under-sized equipment being discovered during start-up or over-sized equipment that results in higher OPEX costs.

Solution:

A customizable, multi-discipline design tool to aid in the construction of the power plant mitigates these costly errors. The key to building the power plant of the future is an end-to-end integration of conceptual, planning, and detailed design into an environment that handles all process simulation and engineering from one single data hub with bi-directional information flow. This approach also enables the creation of an asset digital twin of the plant – a three-dimensional model of the physical plant equipment that can be utilized throughout the plant's life cycle for design, training, maintenance, expansion, and more.

This digital twin must include process and electrical distribution equipment, to unify the engineering data across the entire lifecycle, and it must serve as a foundation to provide augmented, virtual, and mixed reality experiences for the users. The single database platform allows for data to be entered once, and used repeatedly saving valuable time, reducing human error, and improving engineering efficiency.

Using the example of a variable speed drive, traditional specifications might include dimensions, heat loss, instruction manuals, and terminations. The asset digital twin includes this information and a 3D model of the drive along with details like standard configurations and a consistent asset performance management framework. In addition, the modeling of this equipment can be enhanced by embedding function blocks for process simulations, power utilization data for electrical system simulation, and more.

Benefits

Unifying the engineering and asset information has profound and sustainable benefits. Project delivery time is shortened, engineering efficiency is enhanced, and construction costs are reduced. Managing changes, multi-discipline collaboration, and project document creation (e.g., piping and instrument diagrams, process flow diagrams, load lists, dimensional layouts) can be automated to reduce design errors and improve workflow efficiencies. By using an integrated engineering approach, EPCs and plant owners can expect better end-to-end collaboration and project control. Typically, improvements of 20% in engineering efficiency and 5% reduction in Total Investment Cost (TIC) are possible in the engineering and design phase alone.

Strategy 2: Integrated simulation and learning through the asset lifecycle

Challenge:

To be most effective, the simulation must include both process and electrical power to embody the design of the plant and to simulate responses to changes in process and equipment conditions, malfunctions, and business directives. Integrating the three principal domains that have historically been distinct creates new value:

- 3D designs of the asset
- Fundamental physics and chemistry of the process
- Performance of electrical system infrastructure

Solution:

Integrated simulation enables virtual studies of process start up and shutdown, control scheme design, controls checkout, operator training, asset performance monitoring, and real-time optimization. By adding reliable predictive capabilities over a wide range of design and operating parameters, the simulation becomes a vital digital asset and essential tool during the life of the facility.

The behavioral simulation starts in the conceptual design phase to provide a macro view of the design options. As the plant design matures, the model expands to include general asset intelligence for the plant. During the detailed design phase, the simulation platform uses the engineering database to streamline work, while enabling continuous testing of the power and process design.

Engineering design becomes more agile as changes to the model are tested. The behavioral digital twin simulator can be redeployed for operator training, saving both time and money.

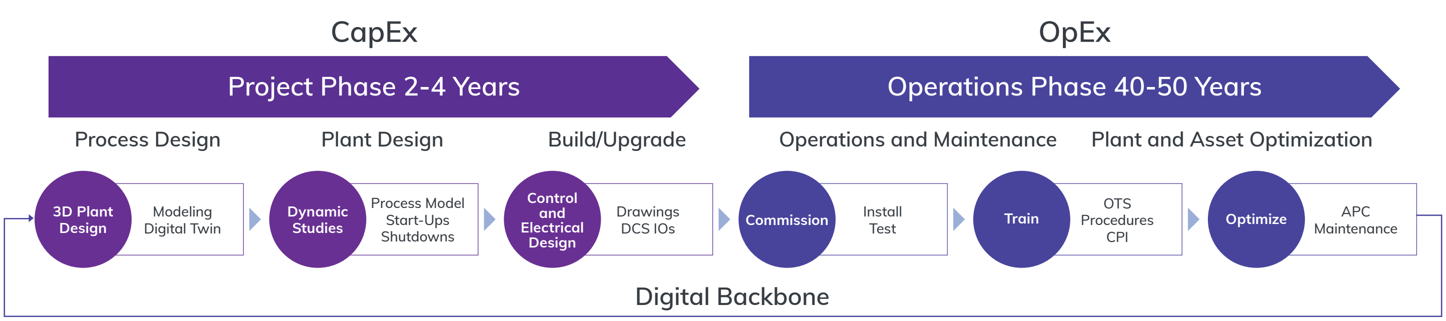
The digital twin keeps evolving to reflect the same processes and control logic as in the corresponding plant systems. First principles models, including rigorous thermodynamic, electrical and fluid flow calculations, bring a superior level of robustness and accuracy to dynamic process simulation at your plant. The process models must be integrated with other important plant applications, such as DCS and PLC control system emulators, to drive operator training systems.

Benefits

The model created during the design phase is leveraged during plant start-up and functions as a unified platform, eliminating the need to rebuild models. It is possible to train operators, evaluate unit performance against the model, monitor asset operation, and provide real-time optimization. Together, this increases energy and process efficiency to improve business performance.

As depicted in the figure below, the digital twin delivers value throughout the lifecycle of the plant, reducing CAPEX during the project phase and OPEX during operations.

The high-fidelity dynamic simulation plant model reflects the operations and control responses of the actual plant. This leads to model-based decision-making, ensuring better process reliability, higher energy efficiency, and more sustainable operations, while minimizing risk for EPCs and plant owners alike.



Strategy 3: Integrated electrical and instrumentation project execution

Challenges:

The evolving trend of new thermal power generation developers include private investors and/or local municipalities where project implementation schedule is tight adding further risk on the project success. The role of Main Automation Contractor and Main Electrical Contractor emerged in the early 2000s to deliver complex solutions on-time and on-budget for capital project execution. These two disciplines have historically been managed separately, as were the methods that guided their design and construction work. This introduced added expense, time and risk to project completion.

Solution:

De-risking the project execution by minimizing the number of interfaces is becoming more and more important as a result of the growing complexity of projects. A new approach to project execution uses a Main Automation and Electrical Partner (MAEP) to simplify the project management process for the EPC and owner. The MAEP is responsible for unifying both process automation, electrical distribution, and energy management control systems. By working closely with the EPC firm around a broader design scope for the project, the MAEP enables better coordination and integration of systems, reducing risk throughout the project and particularly during commissioning.

Integrated automation and electrical systems can be designed and constructed at the MAEP facilities. This enables optimized overall sizing and completion of integrated testing prior to shipment to the site.

Another feature of this solution is the ability to continuously test the system during the design and configuration stages through virtualization in a cloud environment. The combination of methodology and technology has the potential to substantially reduce changes and minimize risk to the critical path, reducing time to operations. The MAEP leverages the technologies and methodologies described in this paper to build on the power of the digital twin to plan, design, and optimize the process and electrical infrastructure for an entire facility.

Benefits:

As a result of implementing the methods described in this paper, the combined MAEP can mitigate those sources of risk during project execution. Having the planning, design, and commissioning overseen by a single project management office, under the responsibility of the MAEP, serves to reduce surprises during the project execution. Uncertainties are reduced as process conditions, process automation systems, and the supporting power distribution facilities are aligned and optimized by the MAEP using the tools and methods described herein. The full MAEP approach can achieve CAPEX reduction and improve schedules by up to 15%.

Strategy 4: Integrated asset performance management

Challenges:

Operators are increasingly expected to optimize power plant performance and improve return on capital employed while ensuring safety and reliability. It is difficult to identify root causes between seemingly disconnected events that can impact the performance of common assets or systems. For instance, an operator may implement process changes that overstress rotating or electrical equipment, causing unplanned downtime and increased maintenance costs. Failures could also be caused by control loop instability issues that lead to unnecessary equipment wear. Without an integrated asset performance management system, it is more difficult to analyze and eliminate the root cause of the equipment issues.

Solution:

Asset performance management collects data about how equipment is performing and provides the tools and applications that enable the best use of assets to safely achieve operational goals at minimum cost. Complementing traditional asset management applications, IIoT enables the use of real-time condition-based monitoring, performance monitoring, predictive diagnostics, alarming, and reporting. It also enhances prescriptive up-keep, moving beyond predictive analytics to prescribe recommended next steps for maintenance.

Advanced analytics and digital services enhance these traditional functions in a way that creates new insights in the cause-and- effect relationships between equipment conditions and failure modes. Data is integrated within a single platform where it can be leveraged by data analytics and machine learning technologies to distill important relationships that would otherwise be overlooked. Condition monitoring and predictive analytics can include insight from equipment across multiple systems and generation sites, disciplines and across all asset classes, including a combination of planned and predictive maintenance actions based on the asset risk model.

Operational safety management digitizes the execution of inspection, maintenance, and modification work to improve the safety of power plant operations and compliance with relevant safety regulations. This includes functions such as automating the manual permit processes and automating maintenance workflow.

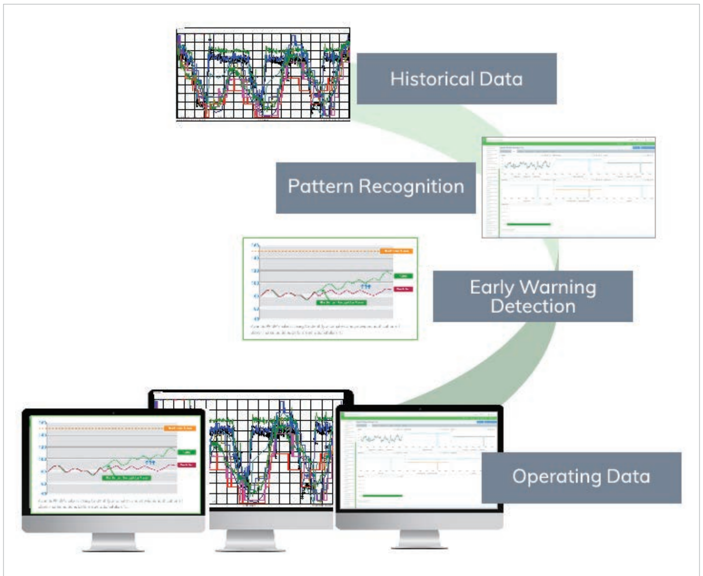
Benefits:

An integrated asset performance management system provides an asset-centric view of operations, enabling engineering and maintenance teams to collaborate and analyze issues that involve multiple equipment classes, as well as multiple generation sites.

The potential savings and operational improvements from an integrated asset performance management solution can include:

- Better management of multiple generation sites (fleet wide maintenance)
- Increased generation efficiency and return on assets
- Increased Mean Time Before Failure (MTBF), avoiding unplanned outage
- Extended equipment life and availability
- Streamlined procurement processes
- Increased labour productivity

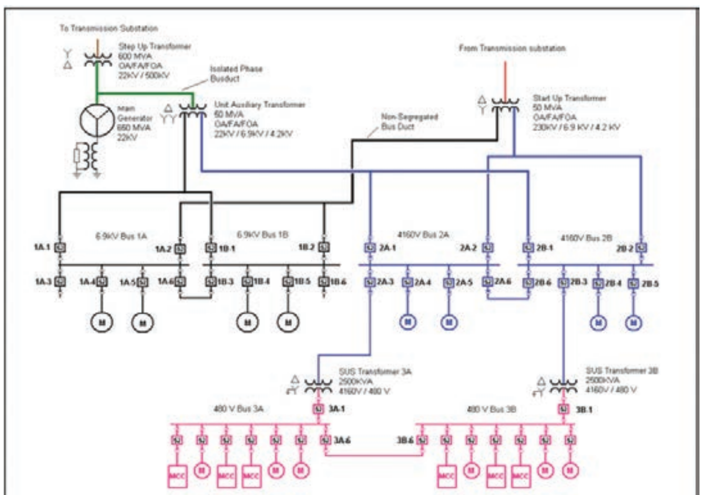
Example of predictive analytics applied to critical equipment architecture



Strategy 5: Process optimization (making power generation more sustainable)

Challenge:

The increasing use of renewable generation and strict emission regulations challenge power utilities to improve their efficiency and lower their carbon footprint. Power plants produce power, but they also require electricity to operate systems such as boiler water pumps and lube oil pumps among others. Approximately 5 to 8% of the power generated is consumed inside the plant. This translates to 25 – 40 MW of auxiliary power for a typical 500MW power generator. Hence, reducing this parasitic load increases the plant efficiency and the owner's revenue. A typical one-line diagram is show below:



POWER PLANT ELECTRICAL DISTRIBUTION ONE - LINE DIAGRAM

Description:

A recent survey found that 95% of energy executives believe that digital transformation is a strategic priority for their business. Utilities and power companies are increasingly adopting cloud computing, data analysis, process optimization, and more to help create or maintain competitive advantages. This move to new digital technologies requires utilities to integrate and connect more of their services.

Solution:

There are several ways to improve plant efficiency, starting with better consumption of a plant's fuel, along with its water, and the reduction of a plant's emissions of pollutants. Reducing a facility's carbon footprint, and lessening its overall impact on the environment, also benefits a plant's economics and should be part of any sustainability program.

Advanced Process Control (APC) uses artificial intelligence and neural networks to help power generators realize maximum value from their existing fossil fuel-powered fleet. The use of a hardware and software agnostic solutions eliminates the need to replace existing equipment in your power plant, lowering your overall cost. Real-time combustion optimization and intelligent soot blowing are prime candidates for APC. However, APC is also used to improve plant ramp rates, optimize steam temperature control, and lower emissions among others.

The use of predictive and prescriptive analytics enables power companies to equip their workforce with more information about a plant's operations and maintenance, both inside and outside the facility. Today, all medium voltage (MV) and most of low voltage (LV) power devices are equipped with extended operational and diagnostic capabilities. In most cases, these advanced capabilities are not utilized, because they are not made available to operators, or they require specialized software or personnel. New field devices (instruments, valves, etc.) in the market have more capabilities that can be integrated into the operation and maintenance systems.

Utilizing the full capabilities of smart field devices enables visibility into asset health, such as a identifying a sticky valve before it becomes blocked or receiving an early warning that a motor's power consumption is abnormally high. This condition-based maintenance allows plant personnel to modify operations or repairs to maximize uptime and power generation.

The electrical distribution system plays a very important part in the safe and reliable operation of a power generating unit. In fact, twenty percent of all hardware instrumentation in a typical power plant's DCS comes from devices that are part of the electrical system.

This adds complexity and cost throughout the engineering, building and commissioning phase of a power plant project. Hardwired Input/Output (IO) needs to be engineered in the source system, the destination system, installed and cabled, tested in both sides and finally commissioned.

Cost efficiencies are realized during the design and commisioning phase, when the electrical distribution system is designed and implemented along with the rest of the plant's control system. Furthermore, equipment malfunctions and trips are easily diagnosed and remedied during plant operation, because the proper process and electrical information is readily available through the DCS.

Benefits:

- Increased plant efficiency by using APC
- Increased failure prevention by better use of connected devices
- Reduced carbon footprint
- Increased efficiency by reducing parasitic loads
- Reduced hardware, cabinet space and cabling

Conclusion

Whether building new generating assets or operating an existing fleet, utilities and power producers must strive to become more efficient and more sustainable. Embarking in a digital transformation offers many benefits. However, the combination of assets with connected devices, and more importantly, the data captured for those assets, brings the need for technology solutions to harmonize disparate data. Operators want an easy-to-understand view into maintenance needs, and scheduling of proactive maintenance, to lessen downtime.

They want to know the current status of operations, and which improvements offer the fastest financial return. Solutions that are software and hardware agnostic and can be implemented without the need to replace existing systems, improving a plant's economics through more efficient use of equipment and personnel are key to this journey.

About the authors

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