Deployed Digital Factories

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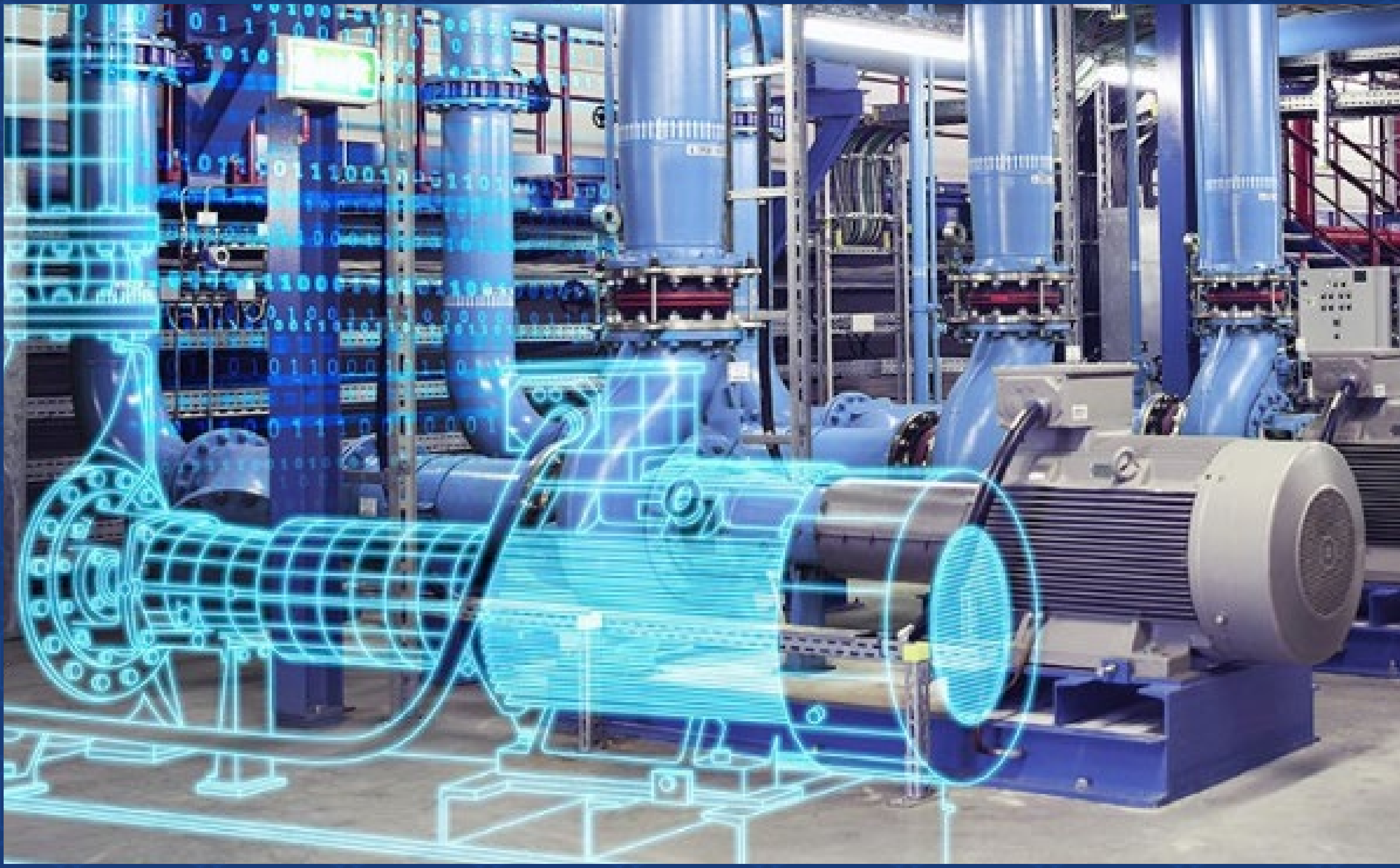

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Deployed Digital Factories Introduction

Taber International, LLC is a systems integration firm dedicated to performance improvement for a wide range of process industries. Taber focuses on the uses of software to turn data that is often disparate, scattered, and needing transformation into usable and actionable data for process personnel. This paper covers success stories for simpler dashboard implementations through more complex digital factory implementations.

One of the true linchpins of Industry 4.0 and the transformation to smart manufacturing and smart industry is the "digital factory". The term "digital factory" has taken on many meanings over the past decade, but in general, it represents a digital representation of aspects of a physical factory or process, comprising mathematical models, stored operational data, data visualization and analytics, control system simulators, and other components. When all the various components are brought together the digital factory appropriately replicates the physical factory. This becomes a valuable asset to a company for improving the understanding of the system and accelerating improvements to the factory's performance and operation.

It seems to go without saying, but a key difference between the digital factory and the physical factory is that the digital factory doesn't generate a product or service; it is simply there to represent and reflect it and potentially provide actionable data to modify the actual factory process. Due to this, a **successful digital factory doesn't necessarily have to include or represent every minute detail of the physical factory or process, nor does it need to have every facet of production in place to start providing benefits**. This opens up a world of possibilities and dramatically lowers the barrier to entry to starting the digital factory journey. This leads to potentially an easily scalable and lower risk path than building the physical factory. This incremental approach also leads to a much quicker realization of benefits from the digitalization process.

Ready to put our solution to work? Get in touch with us today.

For future white papers and notices when new videos for the digital factory become available, please register your name, company, and email on the contact us page of the Griffin Open Systems website. You may also request the free version of the Griffin Dashboard Toolkit.

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Building and Scaling a Digital Factory

Those starting (or continuing) the Digital Factory Journey can start by answering just one question:

"What one, specific aspect or component of the process is priority?"

The response to this question will guide the entire effort and set the structure for what the emerging digital factory will look like. For example, if the response is "Real-time output performance & quality," the digital factory will be made of operational data, data analytics, manufacturing data analytics, and detailed visualizations to bring to life the variations in output performance & quality. Or if the response is "improvement to Equipment X in Zone Y," the digital factory will include a mathematical model of Equipment X to represent its function, data to characterize the upstream and downstream conditions which influence this equipment, then apply optimization to improve its function within the process.

Approaching the Digital Factory Journey in this way is the most straightforward and results-oriented approach, and what's even better is that this can be done multiple times to further enhance the total approach. When the first priority item has been incorporated, the question can be asked again to focus on the next area that needs attention. As this process continues, over time a highly sophisticated and multi-faceted system is developed where each component of the system is directly addressing high-priority areas of the system and directly generating results and providing benefit.

The remainder of this article will describe details of this process in action to better demonstrate how asking the question "What one, specific aspect or component of the process is a priority?" has resulted in companies and processes achieving significant benefits.

Equipment Health & Maintenance Case Study

One of our clients provides equipment health and maintenance monitoring to clients to help them maximize the performance of their equipment and reduce downtime. Their process involves compiling information from a number of sources, including measurements made on the equipment directly, its function within the process, the work order and maintenance platform, results from specialized monitoring analytics, and technician comments. This group asked the question,

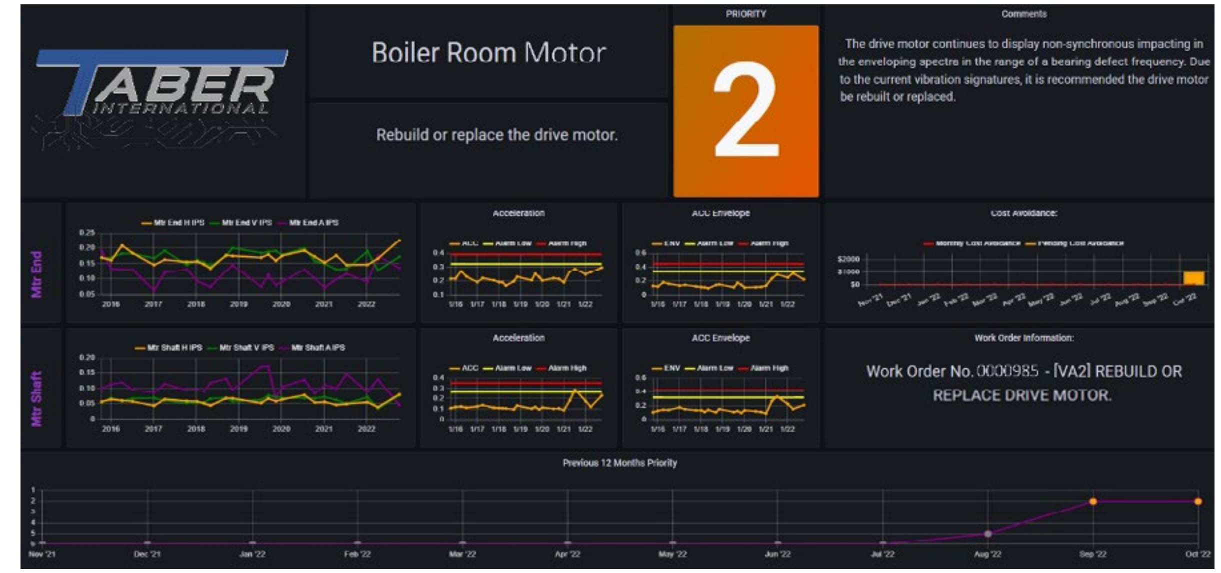
"What one, specific aspect or component of the process is priority?"

and the answer they arrived at was

"Transparency of factors contributing to equipment health."

To start the Digital Factory Journey, all of the disparate information and data sources needed to be brought together within a single platform, and then an effective means of representing this information in an intuitive and centralized way needed to be developed. For representation, a fully customized equipment-level dashboard would be constructed to show users the contributing factors to behavior as well as other important information, and the dashboard could then be navigated by a user to access any equipment of interest across the process. To accomplish the necessary data aggregation and serve the dashboard, a flexible and adaptable host platform was selected, The Griffin AI Toolkit®. This platform allowed for multiple connections to various system databases and data structures to be accessed in real-time and this information was made available for visualization.

The data as accessed came in multiple formats and structures and readiness for use. Within the Griffin host platform, the various data streams representing all equipment site-wide were aggregated and processed to properly organize individual equipment. Then these were displayed as time series and integrated into maintenance records, technician comments, and other findings to build a more comprehensive and readily available look into each piece of equipment. Further, some of the raw information needed further processing to determine exactly how to be represented. For example, cost information is provided indicating the potential impacts of not performing identified equipment maintenance. However, whether this is a pending cost, or if the cost has been avoided and effectively saved depends on the trend of equipment priority ratings. A specialized characterization and identification procedure was developed within the platform to analyze the past priority observations and appropriately correlate these to grouping costs as pending or avoided. Other manufacturing data analytics such as determination of limits thresholds for measurements made on the equipment were also incorporated within the dashboard generation application, and ultimately an adaptive, live dashboard was developed for each piece of equipment belonging to the subject process.



This client's "digital factory" has a high-level machine health focus and very succinctly provides users with multiple forms of up-to-date information concerning the status of any equipment of interest highlighting those needing attention and maintenance, and potential bottom-line impacts.

This process of dashboarding and data aggregation results in less time spent processing data and more time on root cause analysis, while providing a new toolset to succinctly display data to end users in a form they find useful.

Process Performance Optimization Case Study

Thermal electricity generation is a complex process involving the conversion of chemical and mechanical energy into electrical energy through a series of processes with different approaches and objectives. Further, the handling of process outputs such as waste heat and combustion products must also be addressed by adding even more processes to the system as a whole. This highly interconnected and complex process still falls within the range of the digital factory, and the starting point for the journey remains the same.

"What one, specific aspect or component of the process is a priority?"

to which multiple answers are usually relevant

"Decrease emission rates to operate more sustainably."

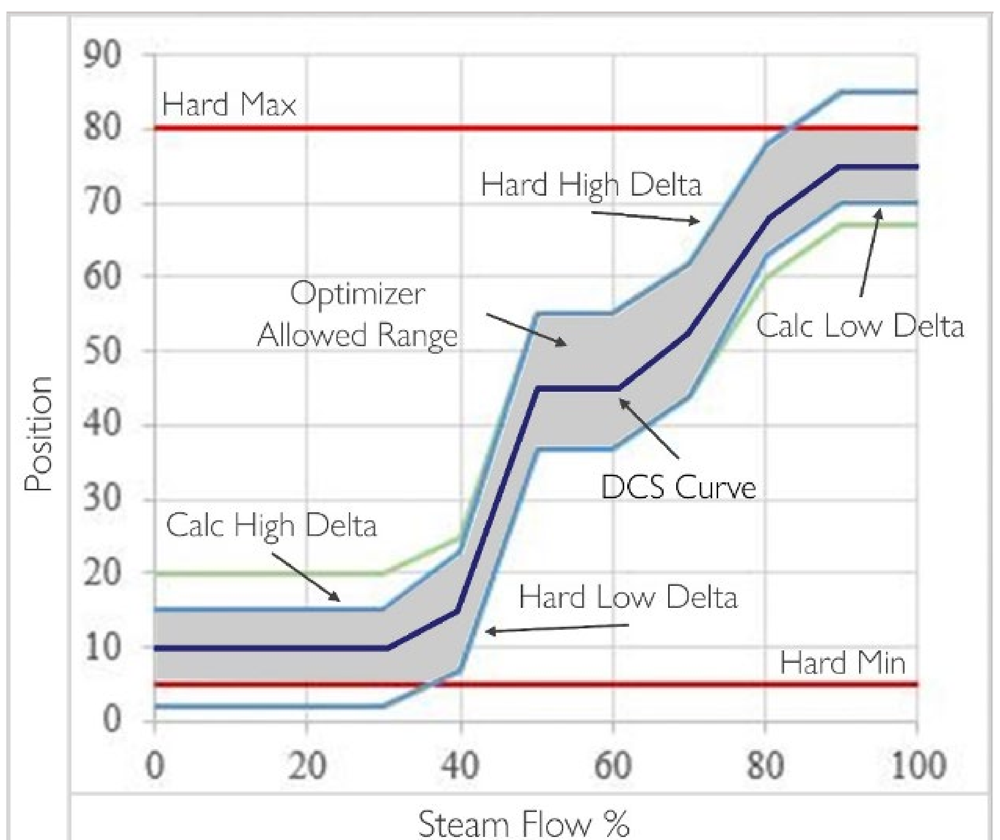
"Improve efficiency to reduce costs to rate-payers."

"Avoid process upsets to improve equipment health and longevity." etc.

Numerous successful digital factory implementations have been developed in this area. The process has remained similar, choose just one of the priority answers to start and incorporate this into the digital representation.

Sustainable operation is a high priority of all electrical generators, and coal-fired power plants have made tremendous strides in this direction. They must be flexible to achieve demand balancing for the electrical grid, and digitalization has been proven to aid in improving sustainable operations. This process involves hundreds of inputs and multiple subprocesses that the digital factory must include, and with the operation being highly variable, the digital factory must be capable of automatic adaptation in response to these variances. The combustion process can be made to run optimally (e.g., minimized emissions) by properly balancing the many input factors that drive it.

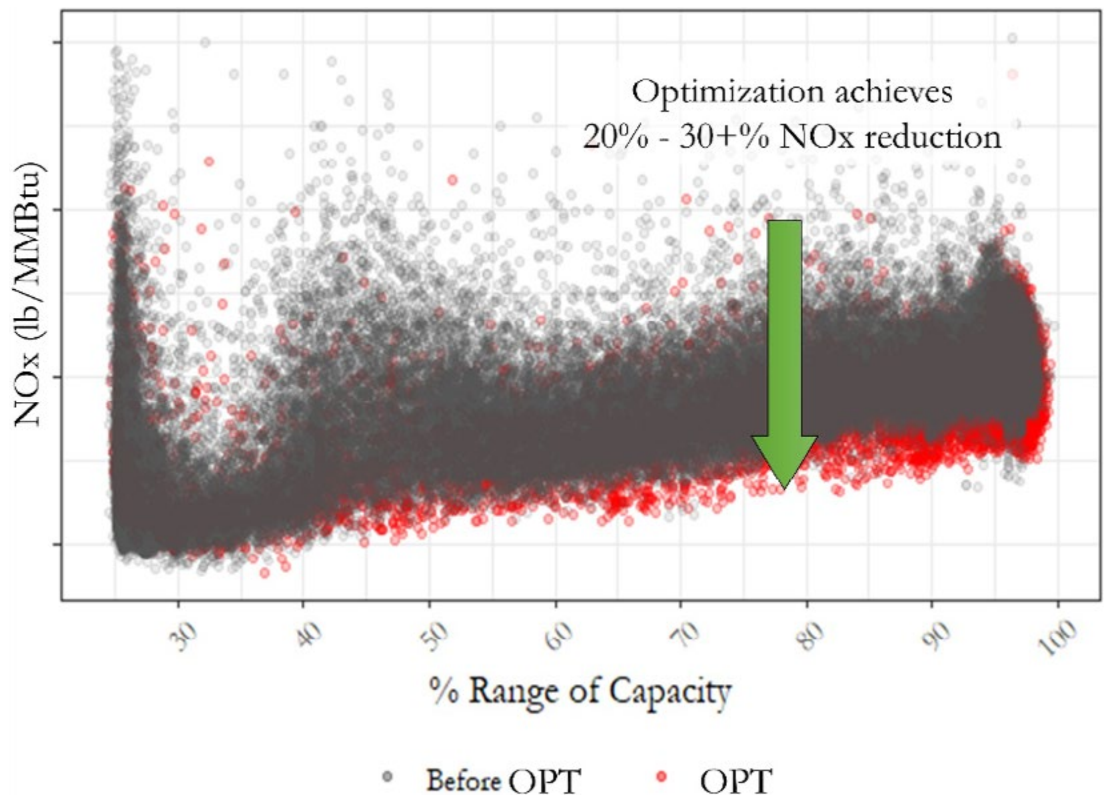
Starting again with The Griffin AI Toolkit® as the host platform, the hundreds of process indications and live data inputs are incorporated into the optimization application. This process operates under many constraints, and these must be understood by the digital system, which is done by recreating the many constraints and limitations within the system's computation and evaluation. These constraints include remaining within appropriate operating limits of system equipment such as temperature and pressures, ensuring the combustion process has adequate airflow to complete combustion, and maintaining steam flow rate at design temperature and pressure to drive the turbine and turn the electric generator for power production. All of these constraints are made visible to the digital application, and the optimization procedure must work within these bounds.



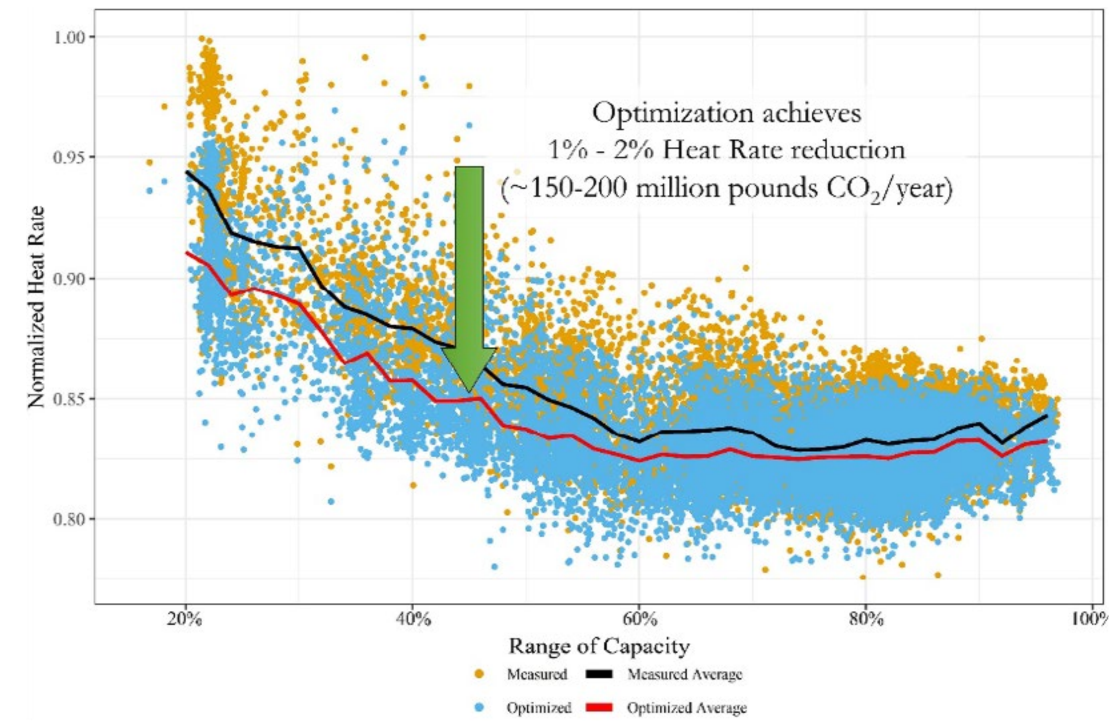
Once the bounds are established, the extensive experience of site operators and engineers is directly leveraged to develop expert rules and logic to drive optimization system responses (i.e. knowledge capture). This represents a unique aspect of this digital factory implementation: **the digitalization of site experience and best practices, eliminating the loss of knowledge as experience retires**. Operators with 40+ years of experience know the systems they've worked on throughout their careers better than anybody, and by transcribing their knowledge into automated procedures that the optimization system carries out automatically so that the knowledge can go on serving and improving the system long after they've retired, and is available for subsequent operators to learn from. For example, an experienced operator knows that in their unique system, the combination of high temperatures observed in one particular area of the process AND relatively low excess oxygen (O2) in 2 of 4 measurement probes can be resolved by lowering the tilt angle of ONLY the lower level of overfire air dampers. This response can be easily automated within the custom optimization application by identifying those trigger conditions and defining the response to be enacted when they're active, subject to other process constraints and limitations.

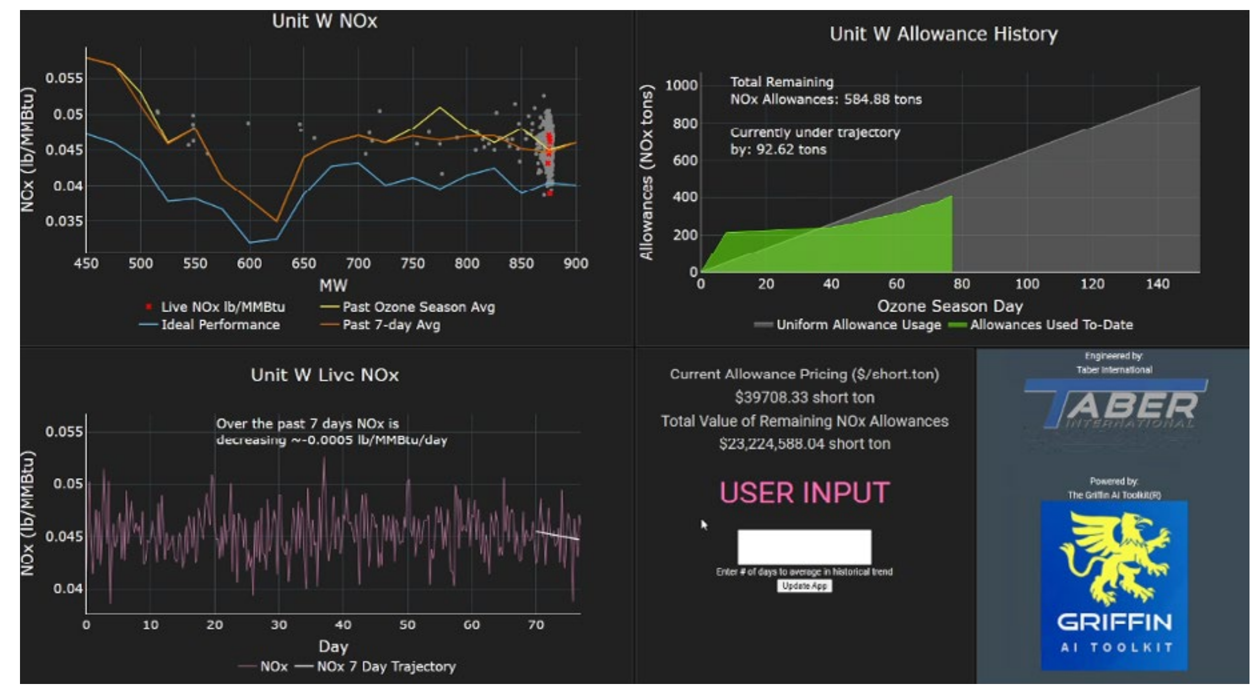
Going beyond direct response and expert rules and logic, the complexity of the process necessitates the use of artificial intelligence (AI) to understand and rapidly process copious amounts of information in the changing environment. Using neural networks, support vector regression, and reinforcement learning models, years of historical operation can be used to digitally represent the specific nuances and details of the subject system. These AI models are then coupled to optimization procedures like particle swarm optimization (PSO), ant colony optimization (ACO), genetic algorithm (GA), and gradient-based optimization as appropriate to the process and system to continually achieve process objectives.

By coupling processes, best practices with AI, and optimization, a unique, hybrid optimization system is realized using this digital factory. The system is both adaptive and robust, responding to individual circumstances as merited by the process itself through the digital factory platform. This is successfully integrated into a closed-loop structure (i.e., is done automatically) with bias values sent to fine-tune the control system setting. This allows operators to focus on other system priorities, leaving emission minimization and sustainability to be constantly achieved by the digital factory optimization system.



With the emission reduction component of the digital factory in place, extending this to the other "What's the priority?" response is straightforward and streamlined. This starts a process to integrate what are often called 'islands of automation' or control strategies. Using the same input and historical information, operating efficiency and CO2 improvements are achieved. This is extended further by expanding the reach of the system to not only the combustion process, but to supporting areas such as cooling tower operation for reduced power and water consumption, soot blower operation improving unit cleanliness, steam usage, and energy transfer; and post-combustion equipment like Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) systems as required by the recently revised EPA "Good Neighbor Plan".





The step-wise or incremental digital factory implementation approach allows for each successive step gains to be added to those already achieved, fully realizing lean manufacturing and optimized operation of these systems. The results are fewer emissions, better efficiency, and better overall control. One additional key benefit is the reduction of time spent by operators and engineers to deal with repeat problems and alarms which are now preemptively addressed.

Full Process Simulation & Optimization Case Study

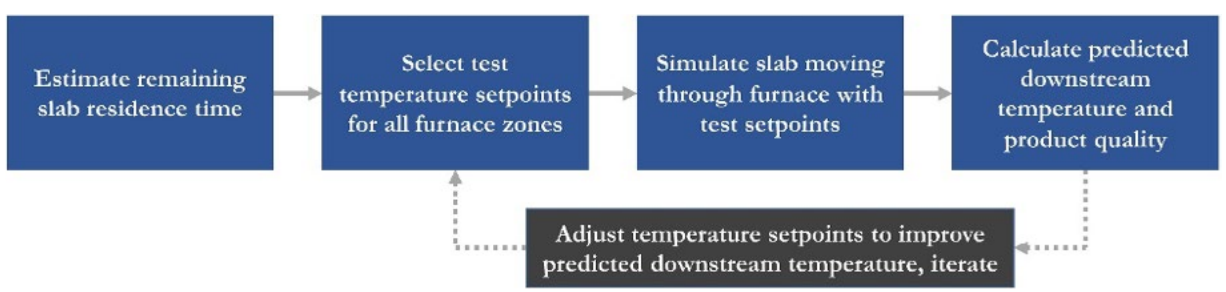
We've seen how the digital factory has been used to better visualize and understand the systems and how it's been applied to directly improve the live performance of a system. Now let's focus on an application that fully simulates the process and makes system adjustments based on simulation results. For this we'll look at a Reheat Steel Mill that processes large slabs of steel, heats them to nearly 2000°F, and rolls them into coils of thin sheet metal for production. This site yet again started with the question,

"What one, specific aspect or component of the process is the priority?"

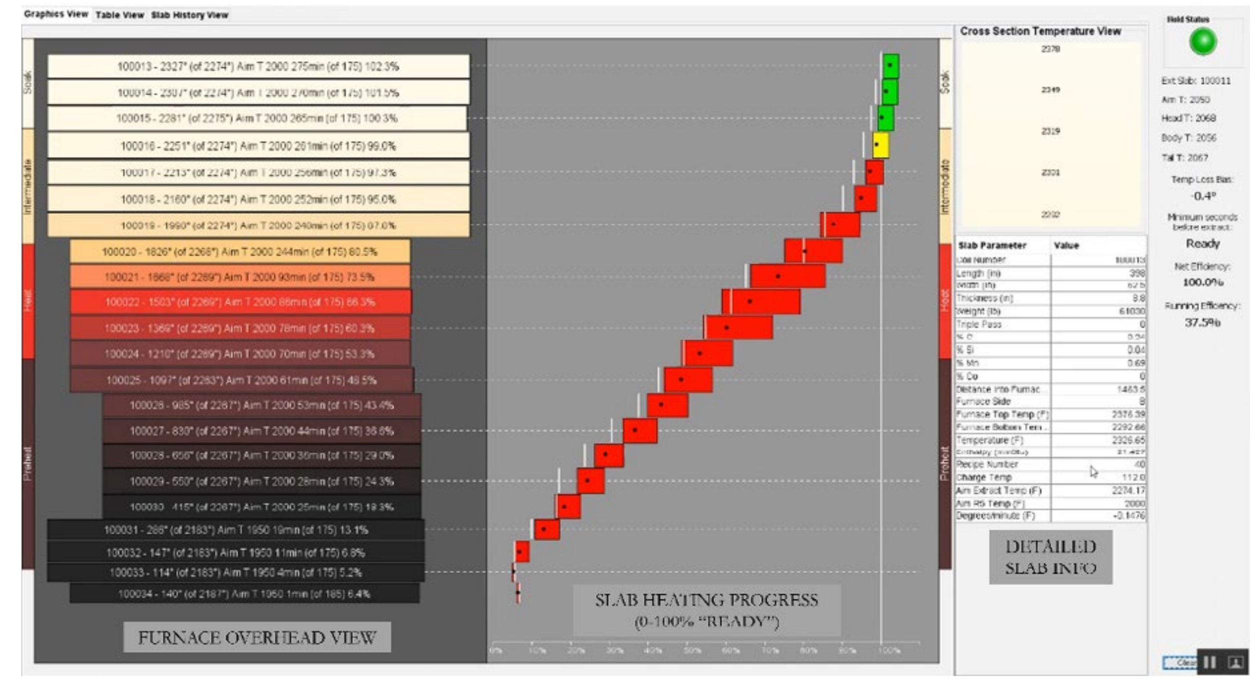
and responded with the answer

"Downstream product quality."

Critical to product quality is the temperature of the steel slabs far beyond the heating portion of the process. Since it is so far downstream, the temperature can't be directly measured and used for immediate process adjustment. This required a simulation of the "life" of the steel slab to be created such that the immediate conditions of the reheat mill could be correlated to the downstream temperature that indicates product quality. This approach incorporates a model predictive controller (MPC) architecture but with the necessary modifications to extend the process objective to the future measurement and utilize current system conditions simply as constraints.



The simulation model created to accomplish this ultimately required a hybrid modeling approach where theory and first-principles modeling (e.g., heat transfer and other transport equations) accomplished the simulation of slab "life" through the furnace and the downstream processing. Data-driven neural network modeling was used to adapt the process for immediate conditions and to correct the theoretical temperature prediction based on historical observations. To further improve the effectiveness of the digital factory implementation in improving system performance, the live conditions and simulation results were compiled into a live digital twin display of the furnace environment, showing slab conditions and predicted results.



The furnace simulator graphic assists operators with recognizing the conditions of individual products within the system, while the hybrid first-principles and AI MPC procedure continually adjust firing conditions to ensure that each slab extracted from the furnace is sufficiently heated to achieve optimal downstream temperature. By optimizing firing, fuel usage is significantly decreased (6 – 12%) while oxidation rates of the steel (wasted material) are minimized and the production rate of a high-quality product is maximized, with reject product being essentially eliminated.

Conclusion

Many new and existing technologies are being applied to industry and process control, and when deployed appropriately, they provide significant opportunities for improving systems. The Digital Factory has been explored and discussed by many, and we've been able to successfully demonstrate that when this approach is used in an incremental, "step-by-step" manner, multiple benefits can be realized at numerous points throughout the process. Realizing a "Digital Factory" doesn't have to be done all at once, and by focusing on the highest priority area, deploying to address this priority, and then repeating the process, improvements, and gains can be rapidly achieved and compounded upon to realize the model, lean manufacturing and system environment controls engineers and system operators are striving for.