

REINHOLD ENVIRONMENTAL[®]



2025 Reinhold/PCUG Round Table Presentation

Hosted by AEP and Buckeye Power

in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

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Operational Flexibility, Efficiency, & Emissions Optimization



Jacob Tuttle, Ph.D.

Taber International, LLC. - President & CTO

Reinhold Environmental PCUG

June 23 – 24, 2025 | Columbus, OH

Solution Experience



Taber International

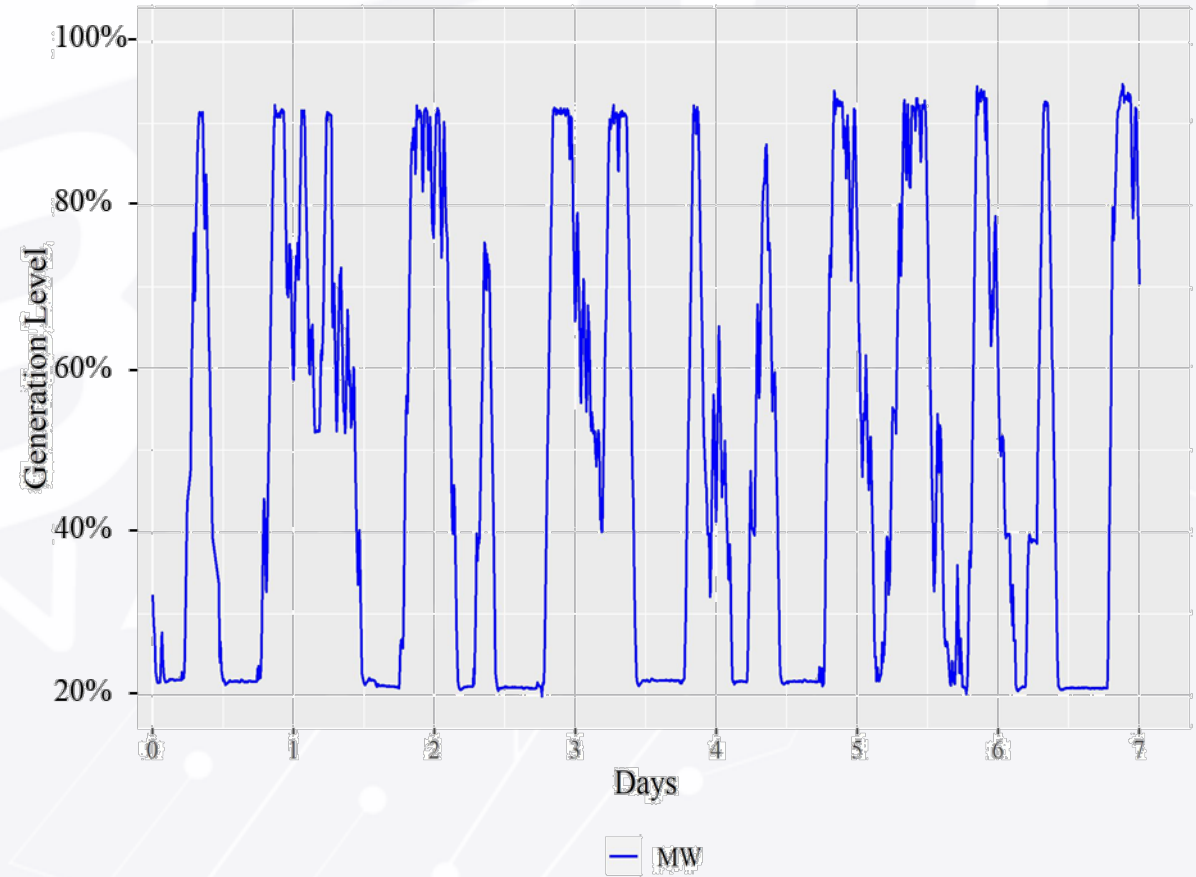
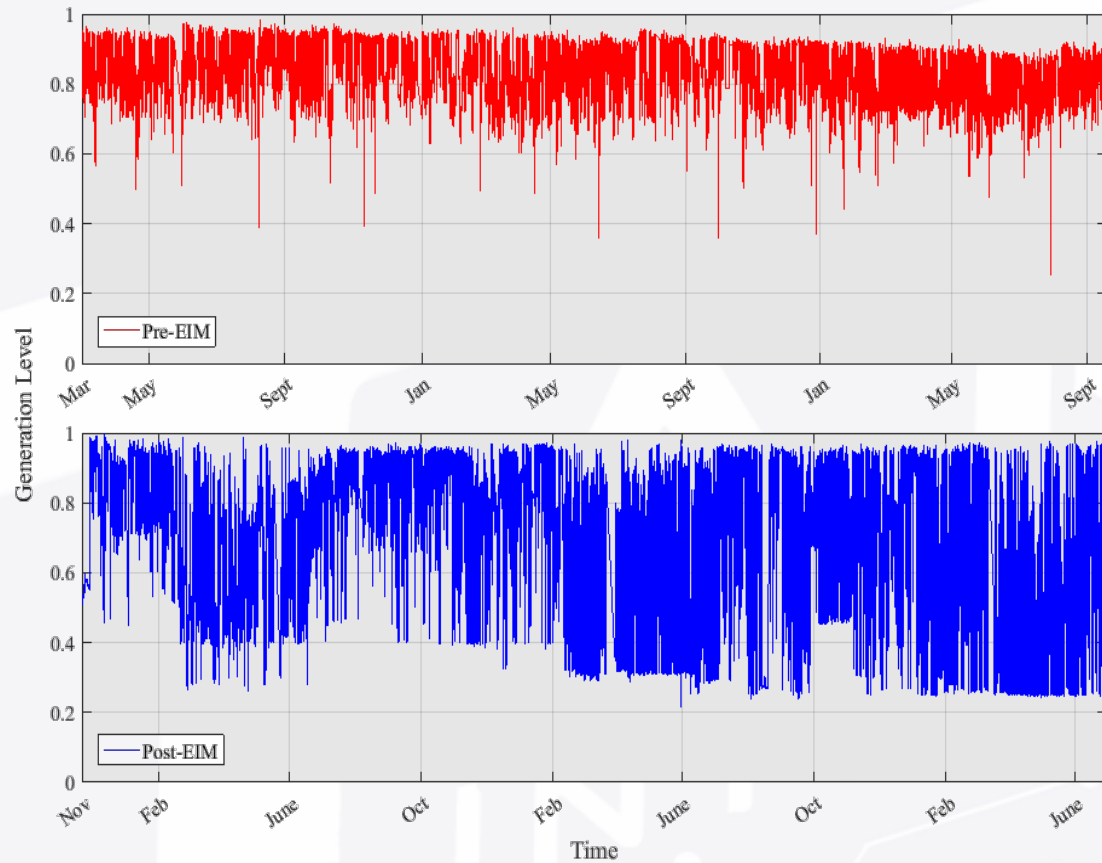
- **19+ years** of operation deploying cutting-edge technology and fully customized optimization solutions for power generation on units from **across Southeast Asia, Europe, South America, Australia, and the United States.**
- Have worked on **all major boiler makes and designs of various sizes** (as large as 900 MW units) assisting with **achieving stable operation as low as 10% MCR without major hardware installations**



Griffin Open Systems

- **Objectives and priorities within systems can readily evolve** to meet the changing energy landscape
- **100% of installations are engaged and in-use**, many are self-sustaining, requiring only minimal attention Develops and maintains The Griffin AI Toolkit™ software platform, a graphical programming environment for process optimization, used by Taber to implement optimization applications
- **An open system framework, providing transparency and clarity** to solutions and an intuitive and easy-to-use platform designed for engineers and operators to quickly and simply automate the mundane and optimize the complex, realizing significant process advantages

Variable & Flexible Load Profile



Variable electricity generation and grid load demands are becoming more and more common-place, requiring existing generators to operate in unforeseen ways, far from original design intentions

How to Achieve This Level of Flexibility?

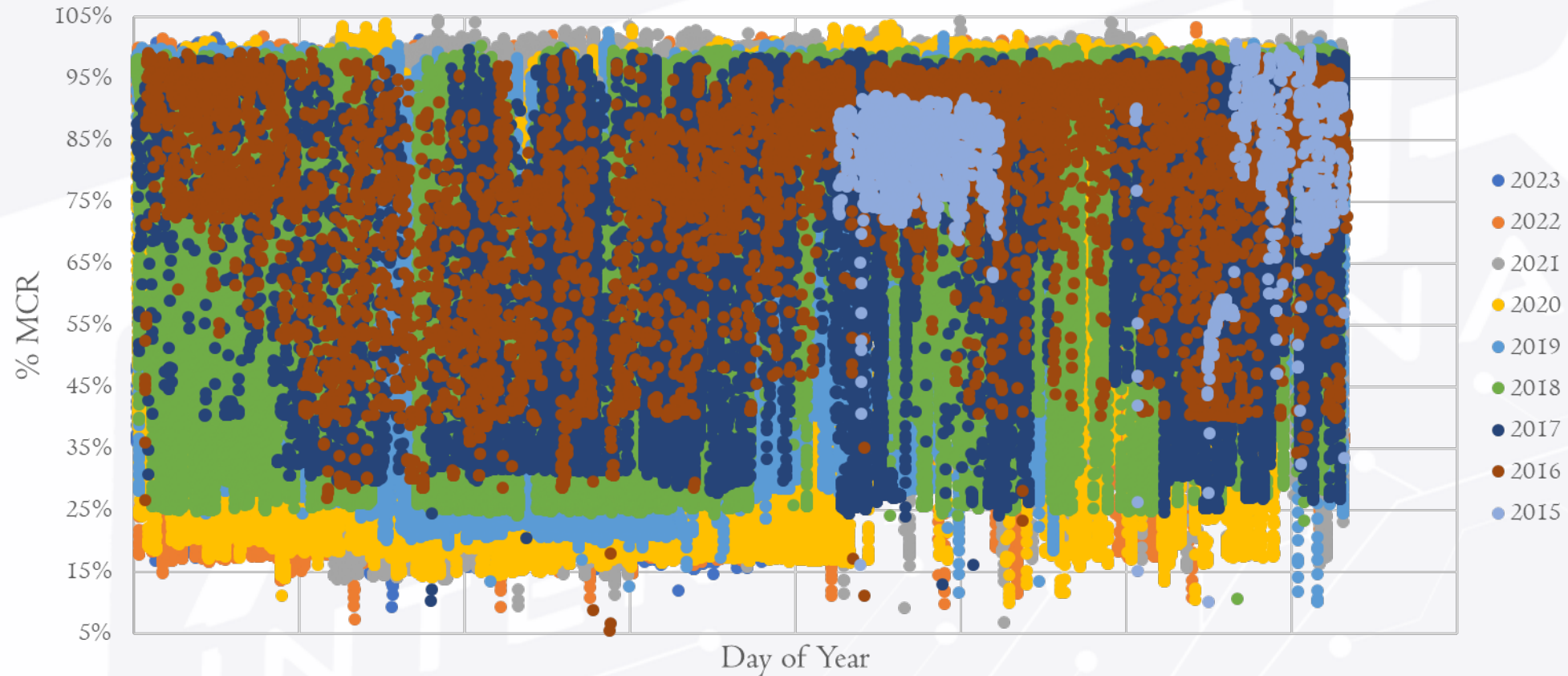
HARDWARE IMPROVEMENTS

- Major projects
- Capital-Intensive
- Long ROI
- Must address integration with existing equipment
- Required control improvements
- Once in place, fixed capability

CONTROL & OPERATIONAL IMPROVEMENTS

- Relatively Smaller Projects
- Minimal Capital
- Short ROI
- Works within existing infrastructure
- Continually adapting

Opportunities through Control Improvements

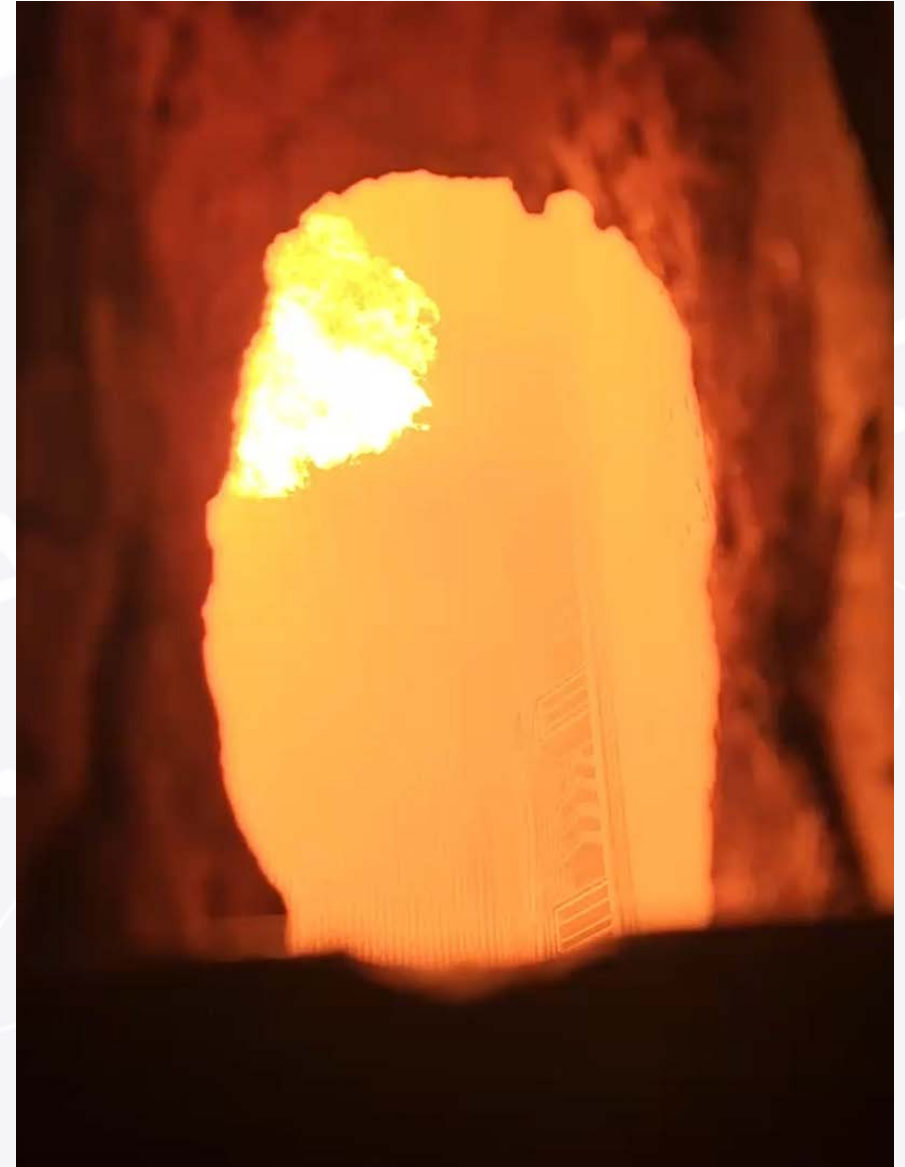


Many equipments installed for baseload operation can reliably perform as low as 25% load, and achieve ramp rates as high as 2.5% MCR/min.

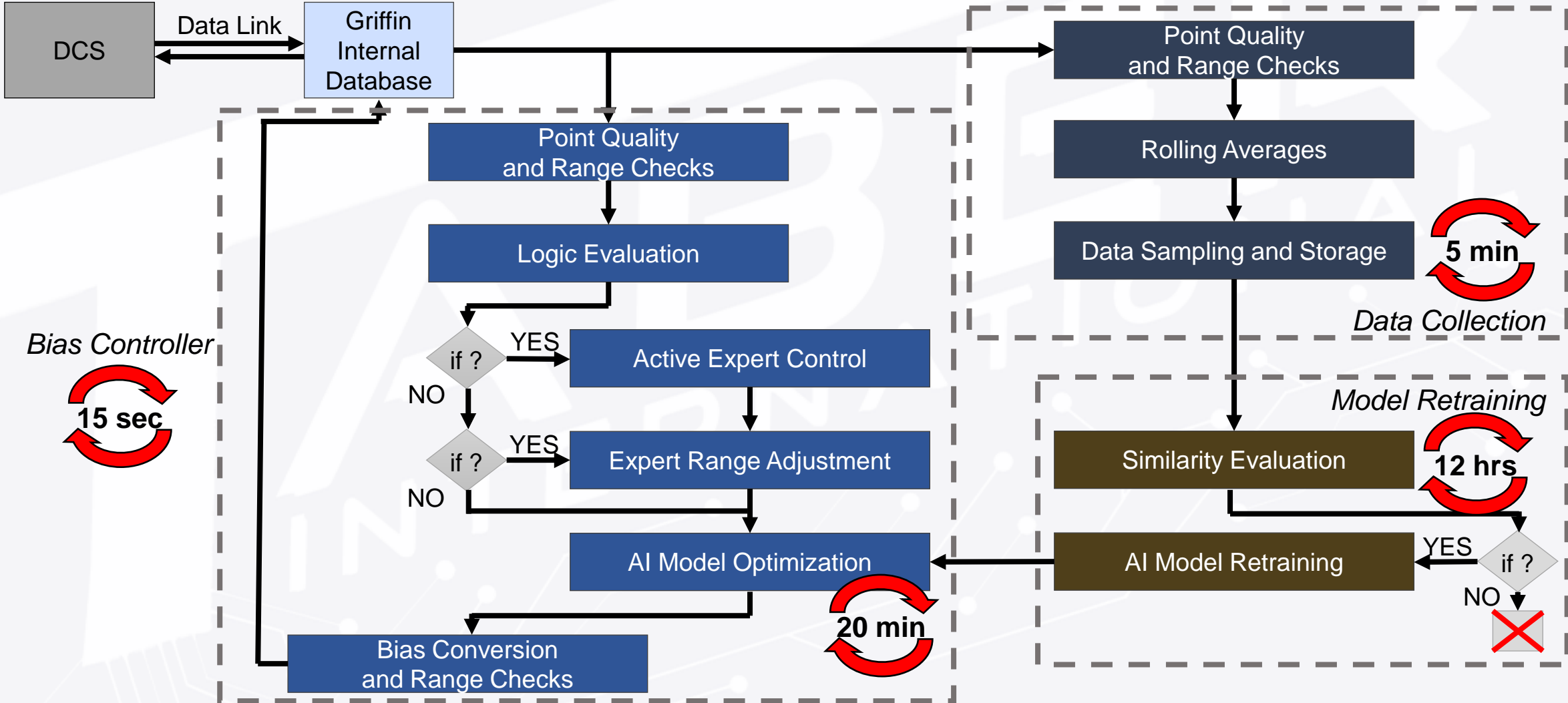
Operation at 25% load and ramping at 2.5% MCR/min is sufficient to meet most flexibility demands of the existing power grid.

Flexible Operation Considerations

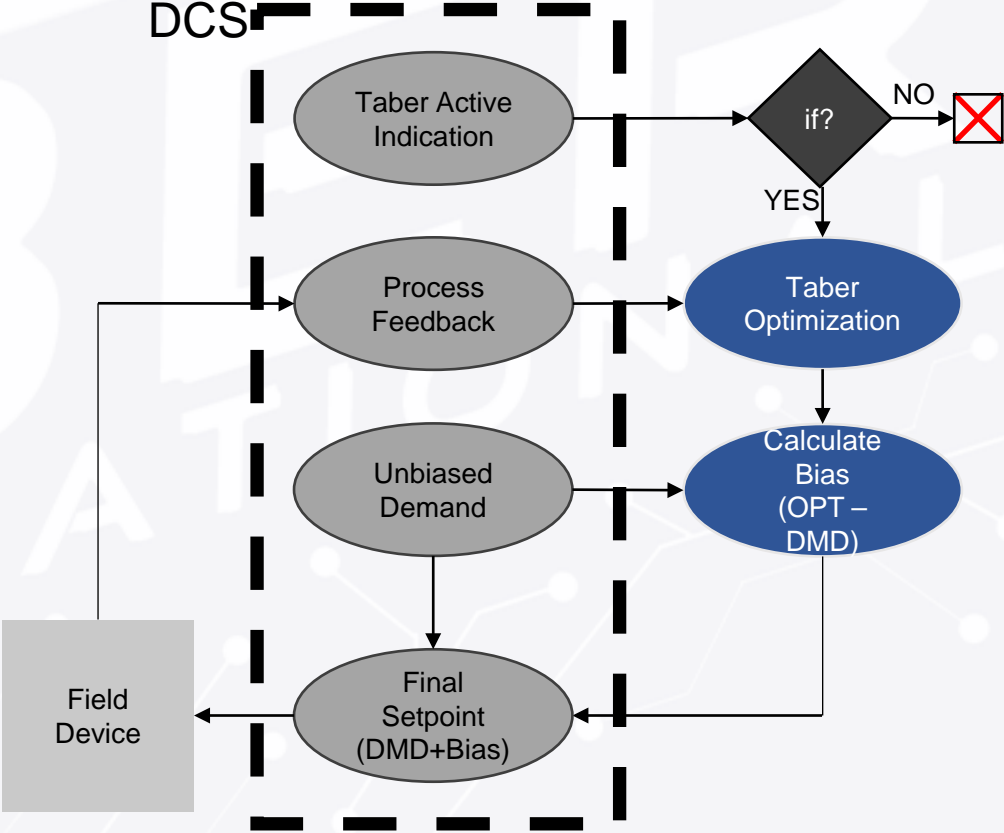
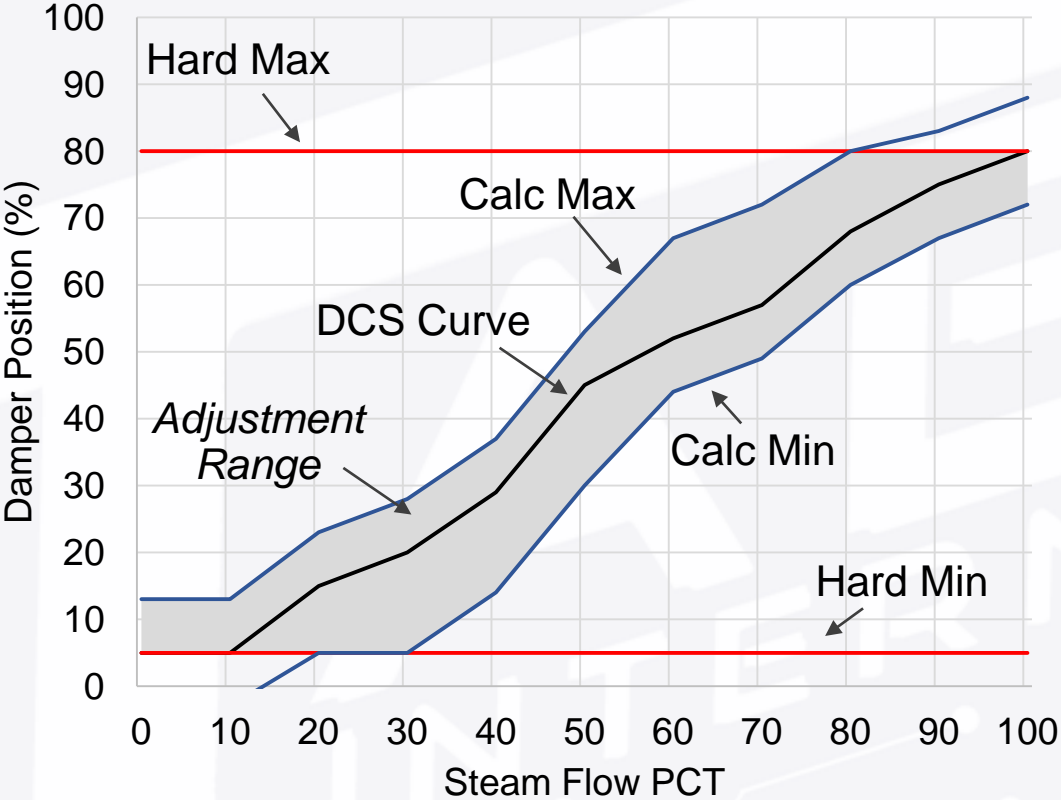
- Steam Temperature Control & Stability
- Flame/Combustion Stability
- Windbox Pressure / Flame Burn-Back
- Total Air Flow Minimum
- Turbine Thermal Cycles
- Turbine Water Induction
- Pulverizer Explosive Range (Coal)
- Emission Impacts



Taber's Combustion Optimization System (COS)

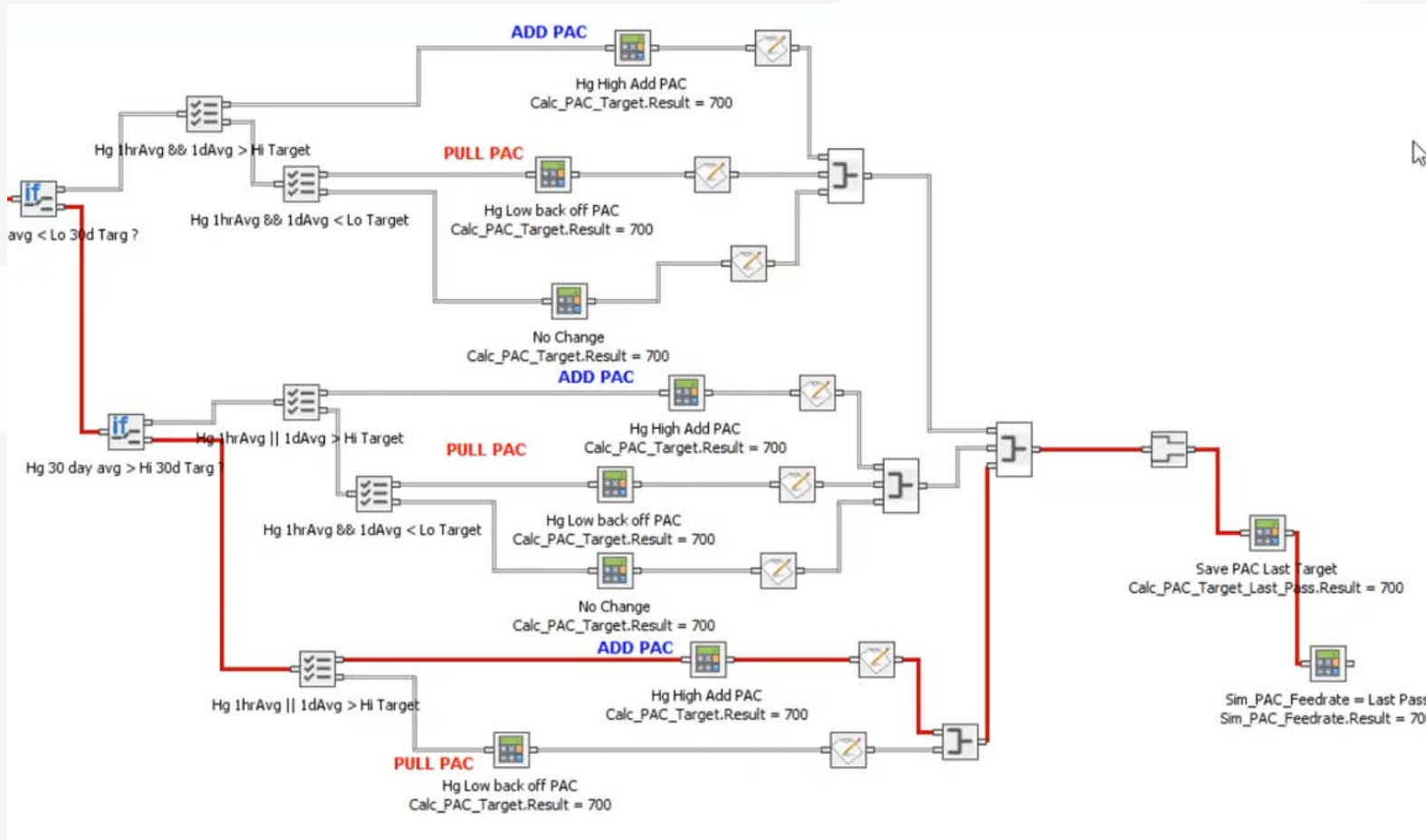


Methodology – Closed-loop Bias Control



In the realm of mission-critical robust systems, where the replacement of controls is unwanted, a bias control methodology is deployed. This approach not only preserves the integrity of the existing systems, but also seamlessly integrates enhanced functionality.

Knowledge Capture



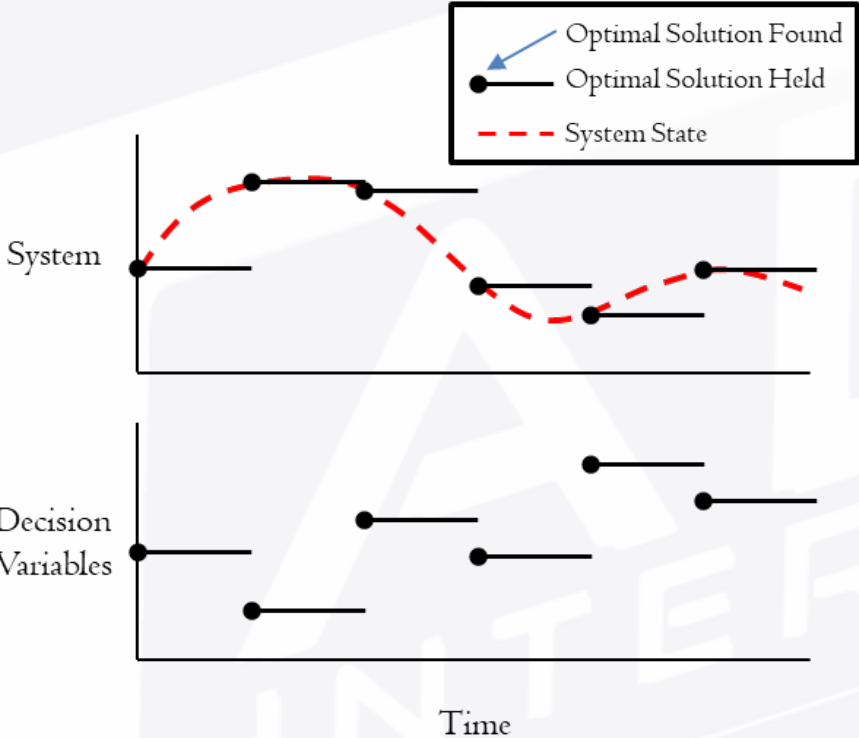
“Knowledge Capture” is the process of codifying operator experience, so that the control system can take those same actions automatically.

Taber’s systems developed in the Griffin AI Toolkit platform provide unparalleled ease and simplicity for accomplishing this.

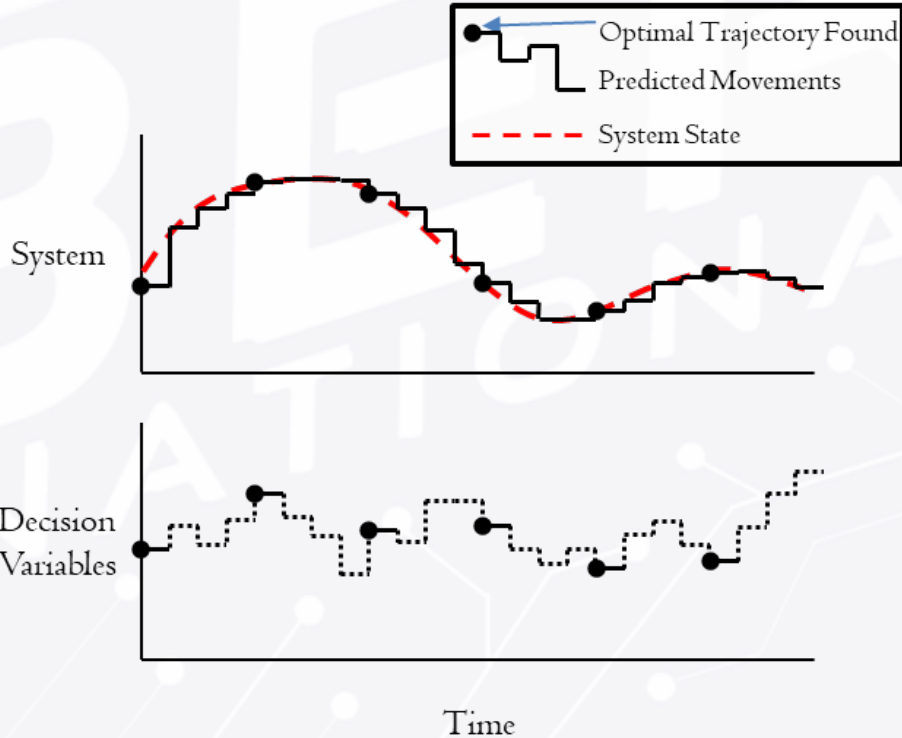


Optimized Trajectory Planning

Real-time Optimization (RTO)



Model Predictive Control (MPC)

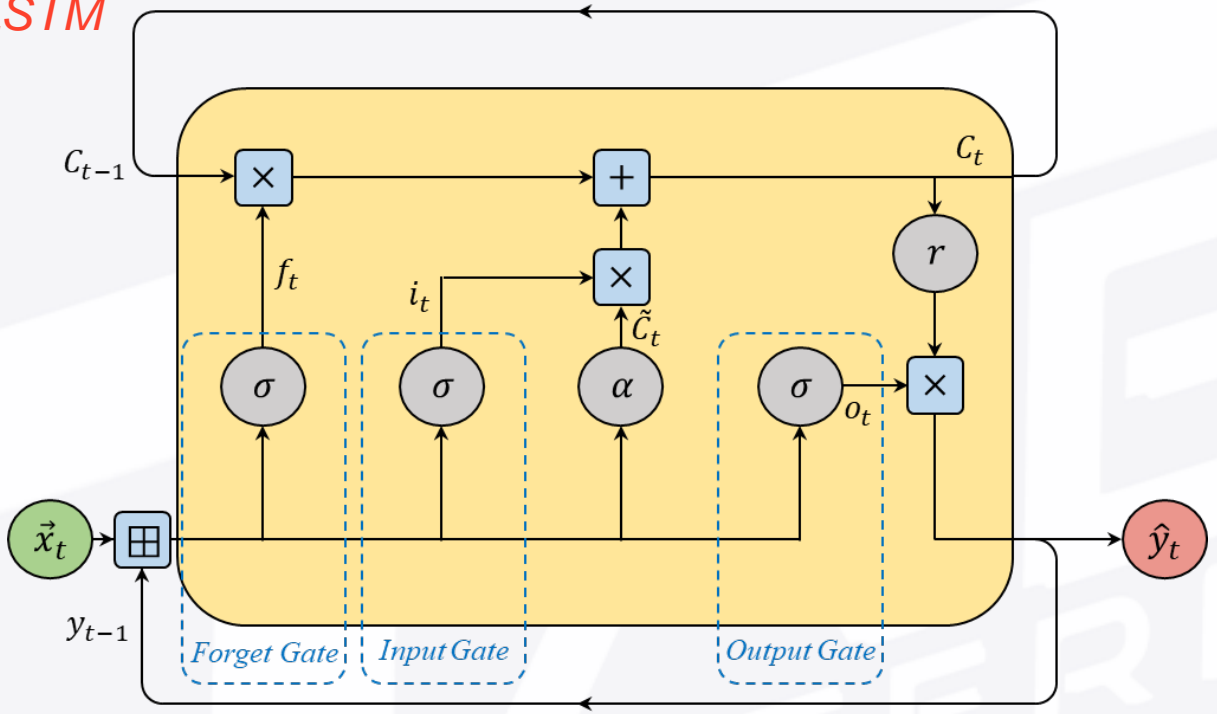


With dynamic data-driven models, true model predictive control can be realized. For a defined target system state path (generation level over time) the optimizer can effectively plan a series of control movements to ensure the system stays in optimal operation throughout the system's movements and ramps.

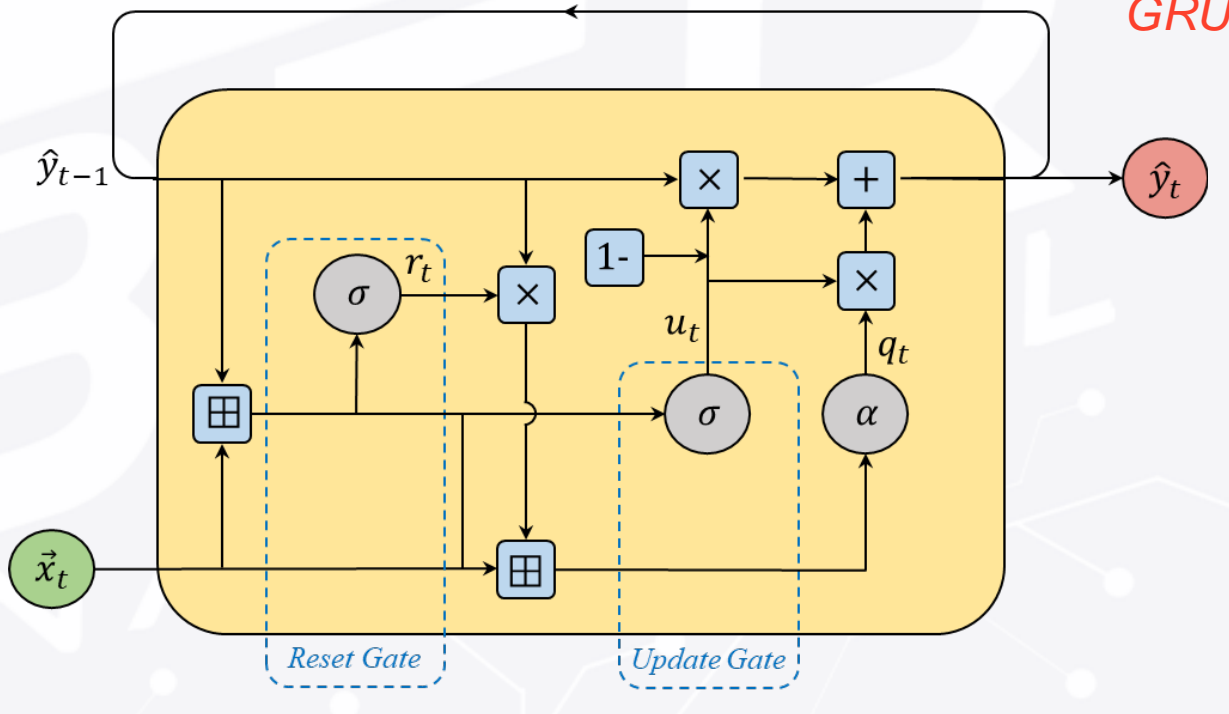


Dynamic Model Types & Characteristics

LSTM



GRU

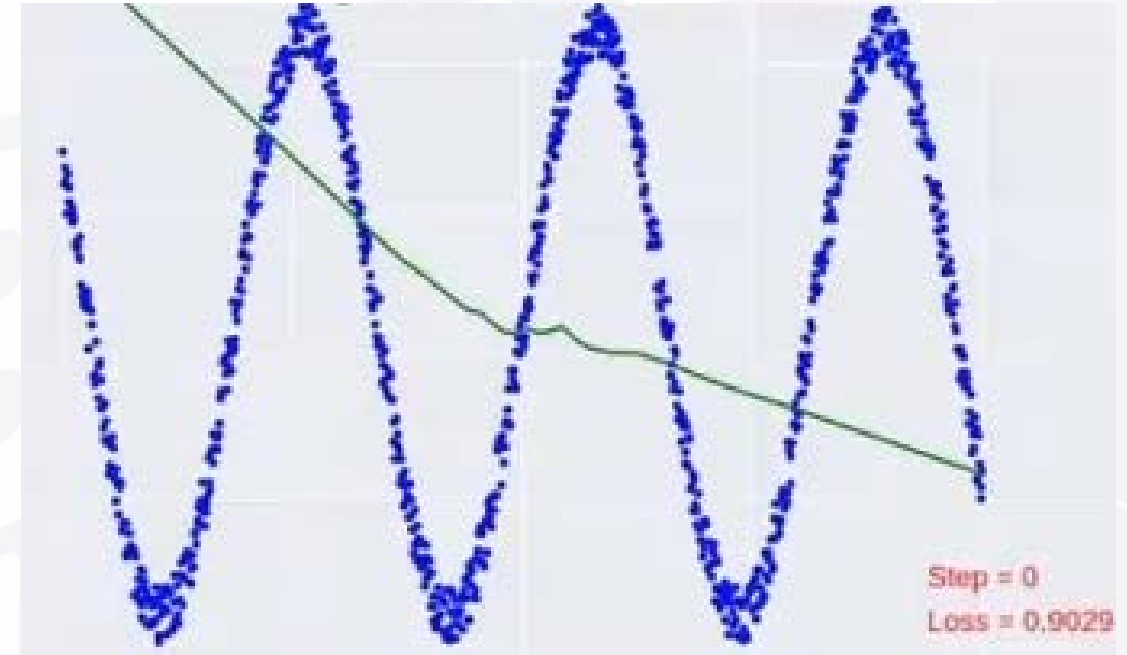
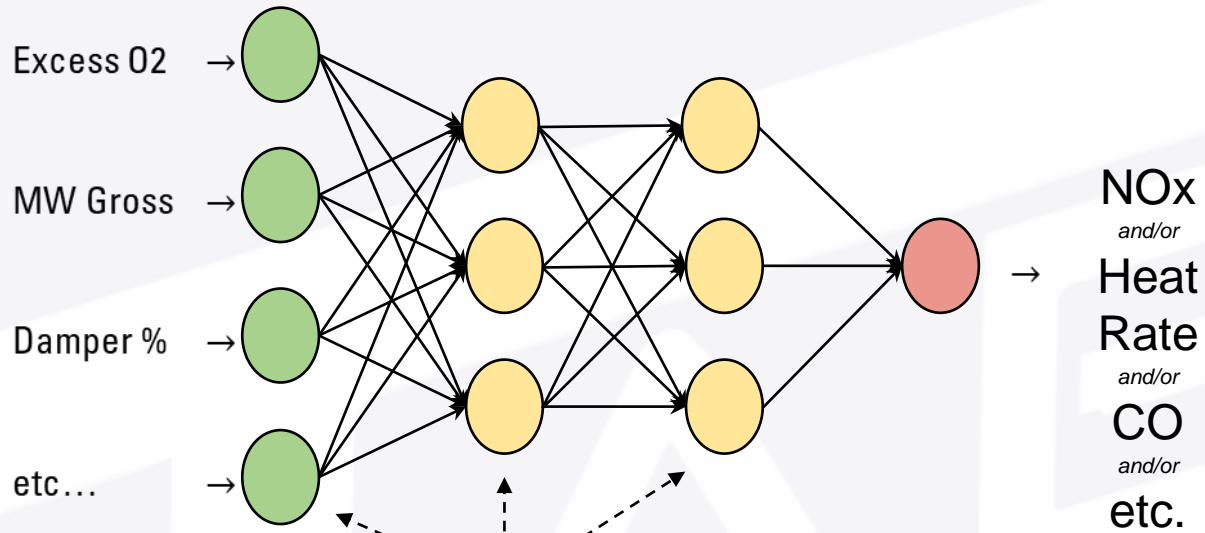


$$\alpha = \alpha \left(\sum_j w_j v_j \right) \quad r = r \left(\sum_j w_j v_j \right) \quad \sigma = \sigma \left(\sum_j w_j v_j \right) \quad \boxplus = \text{Concatenate Vectors}$$

The LSTM and GRU networks internally utilize a series of gates to control how memory is maintained within the model. This gives them an enhanced ability to “remember” over long periods of time, as well as to reset their memory when conditions are appropriate.

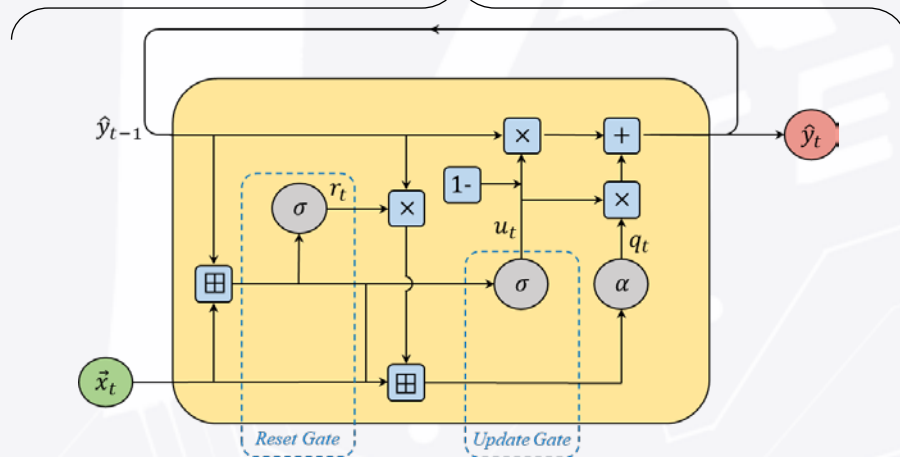


Model Building & Learning Process

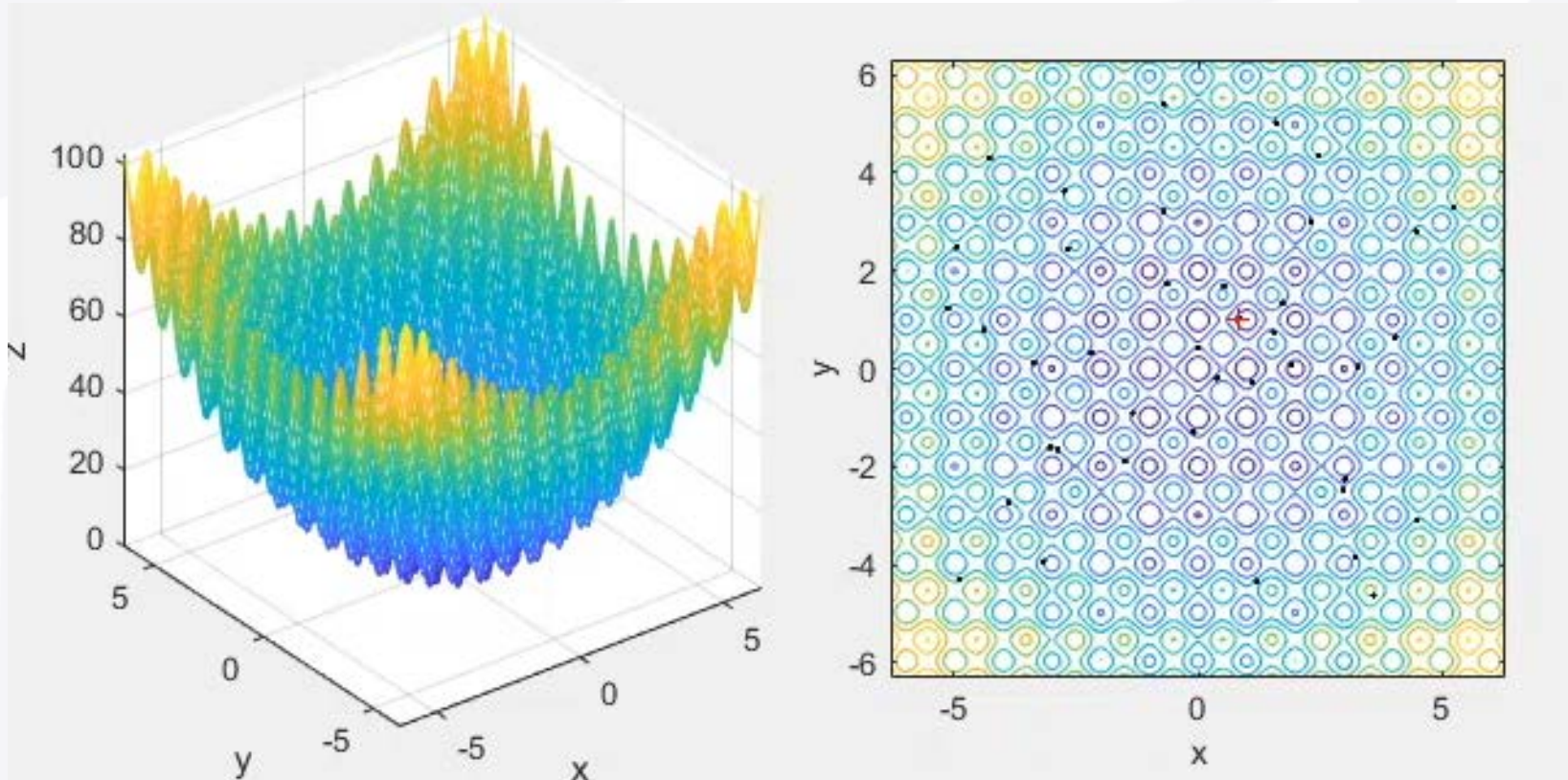


<https://medium.com/@benjamin.phillips22/simple-regression-with-neural-networks-in-pytorch-313f06910379>

Neural network models are essentially maps between readily available system parameters and the expected output of running the system this way. Using collected historical operational data, specialized neural networks are trained to recognize the dynamic relationships in time between all the input parameters (dampers, load, excess O2, etc.) and the desired output (Heat Rate, NOx, etc.). This is an iterative process, meaning the models improve themselves over time.

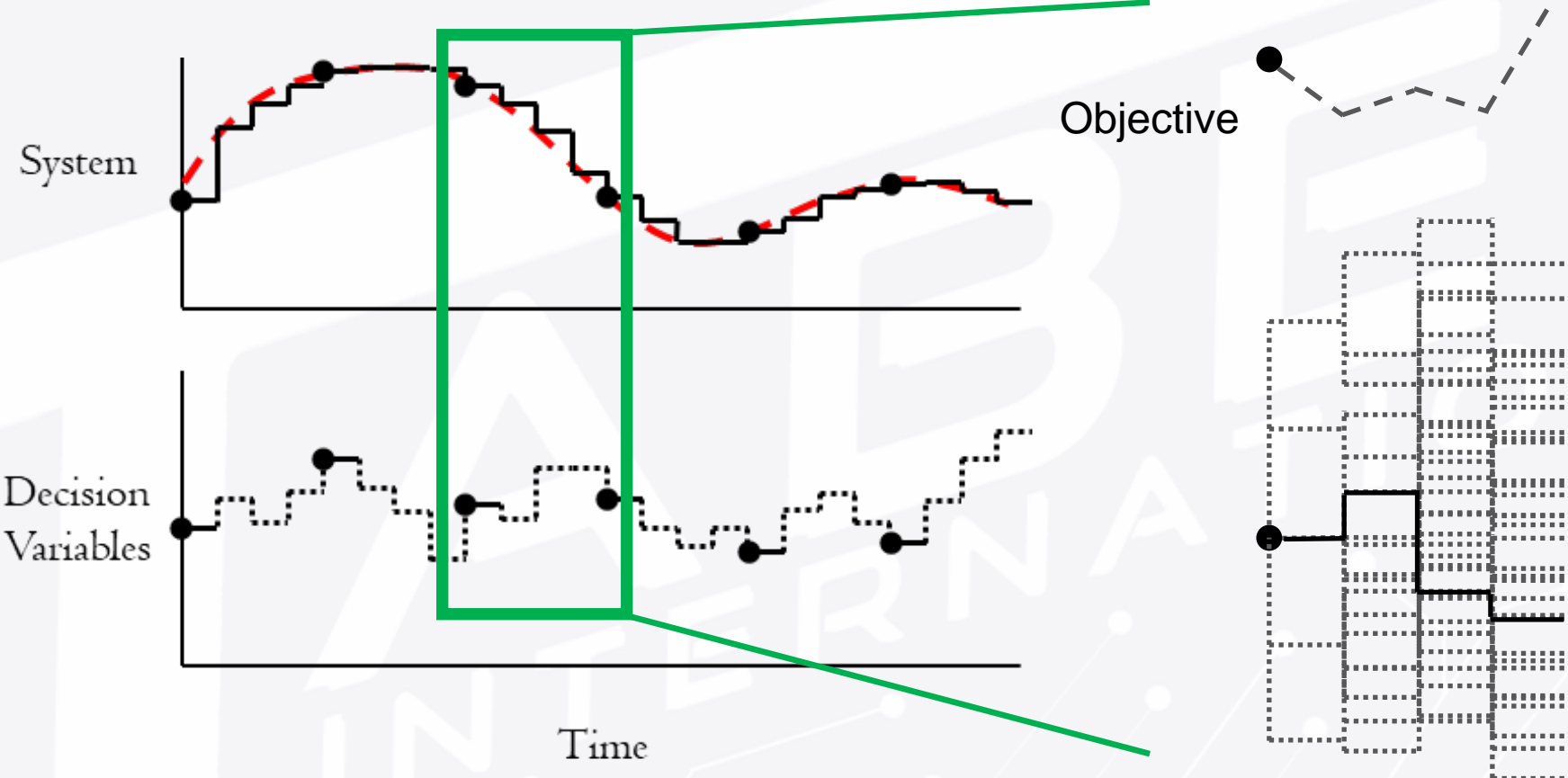


Particle Swarm Optimization



Particle Swarm Optimization (PSO) essentially investigates a million “what-if” scenarios of potential configurations of the unit given the current and expected conditions, and slowly evolves these scenarios toward the current best, searching for optimality. Biases are calculated from these results and are written to the DCS.

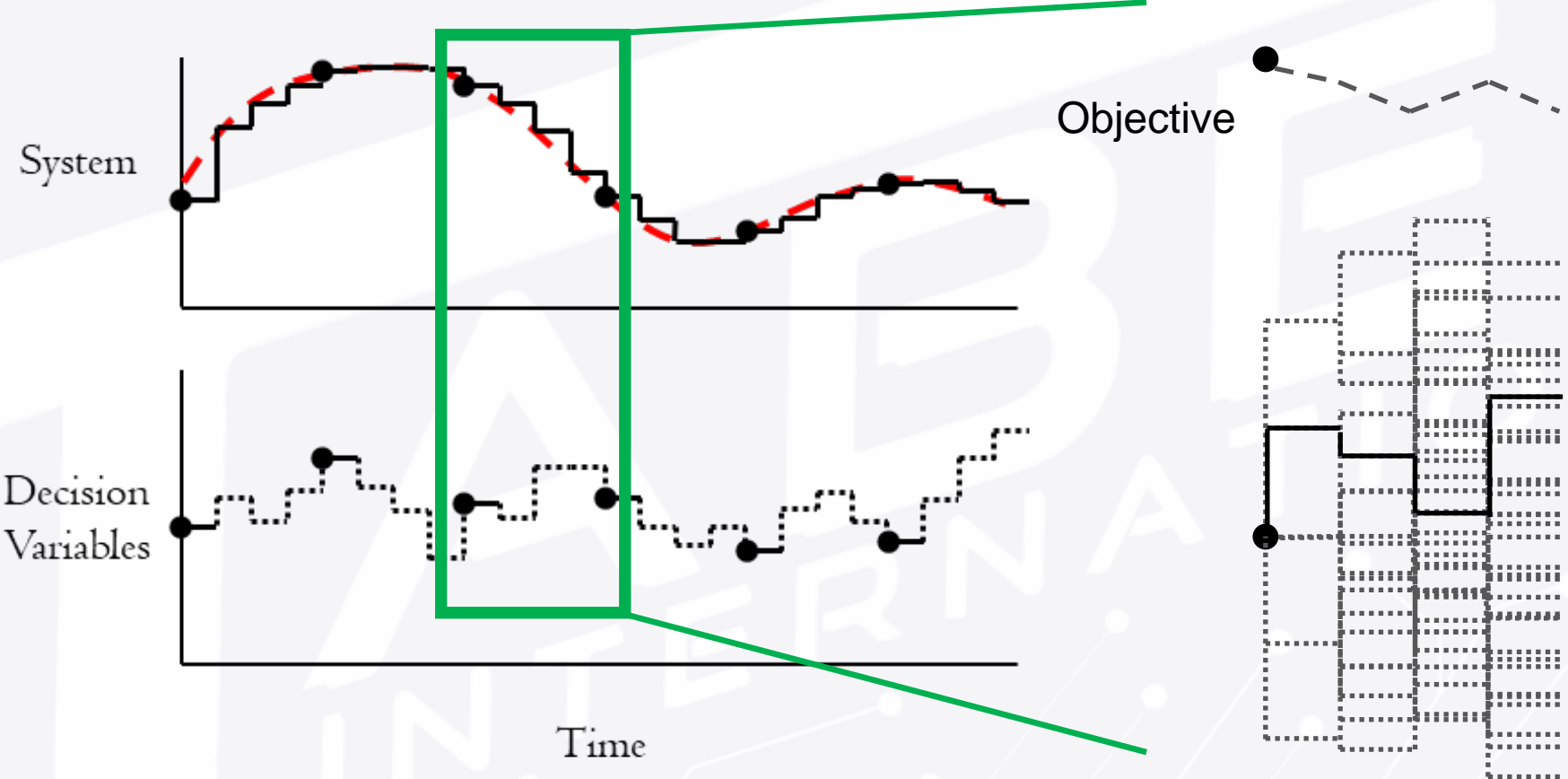
Multi-Step Particle Swarm Optimization



For dynamic optimization and trajectory planning, the problem is much more complex, and multiple steps in time must be optimized, and the effects in time of each step accounted for in determining the true minimum solution of the entire time horizon. As such, the better forecast of actual future demands that is available, the more effective dynamic optimization can be.



Multi-Step Particle Swarm Optimization



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Real-time Adaptation to Coal Quality Changes

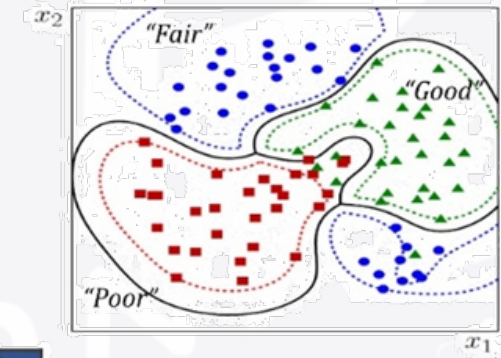
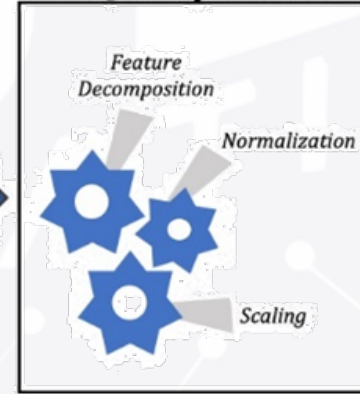
At many sites, coal quality can be highly variable and rarely consistent. Taber provides a means to identify the characteristics of as-fired coal in real-time to respond and adapt to these impacts.

- Real-time DCS measurements
- Coal quality modeled & predicted in real-time
- Adapt combustion and sootblowing practices in response to coal characteristics

Live Operational Data

Feeder Speeds
Mill Amps
Hot Air Damper Position
Unit Load
etc.

Coal Quality Estimator

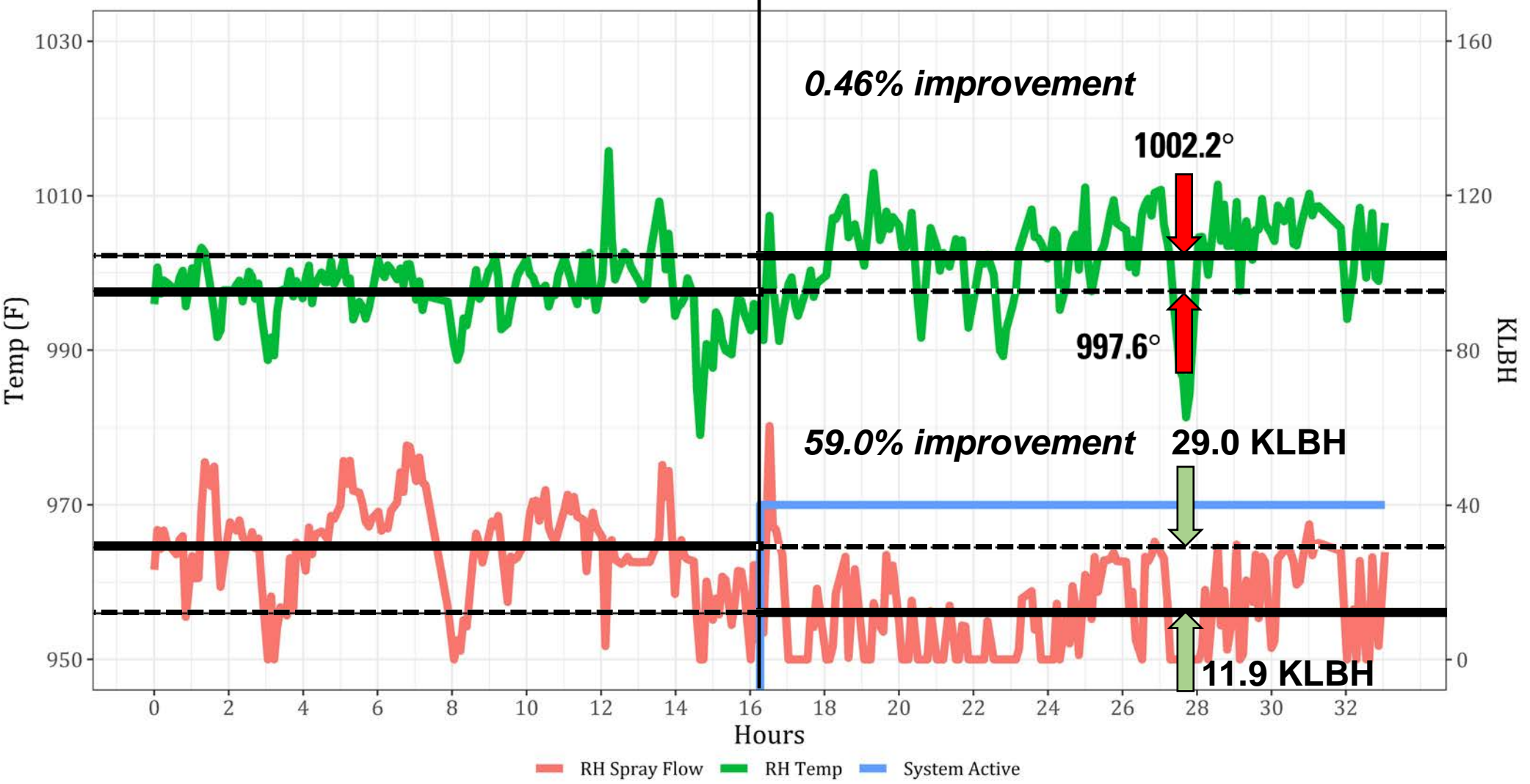


HHV	= 23260 kJ/kg
Ash-%	= 28.6%
Moisture-%	= 16.1%
Sulphur-%	= 4.3%

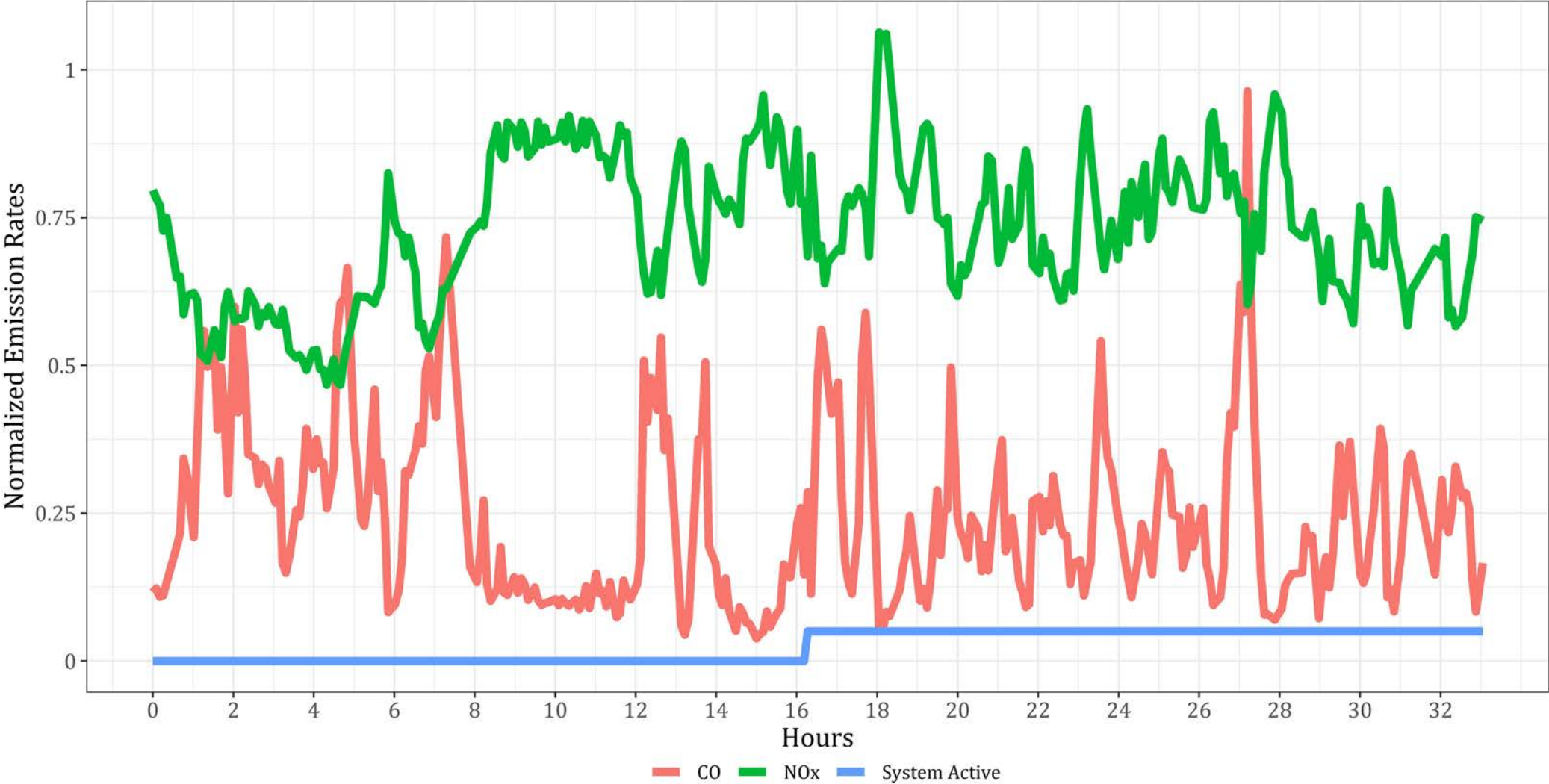
Heat Rate Optimization Event



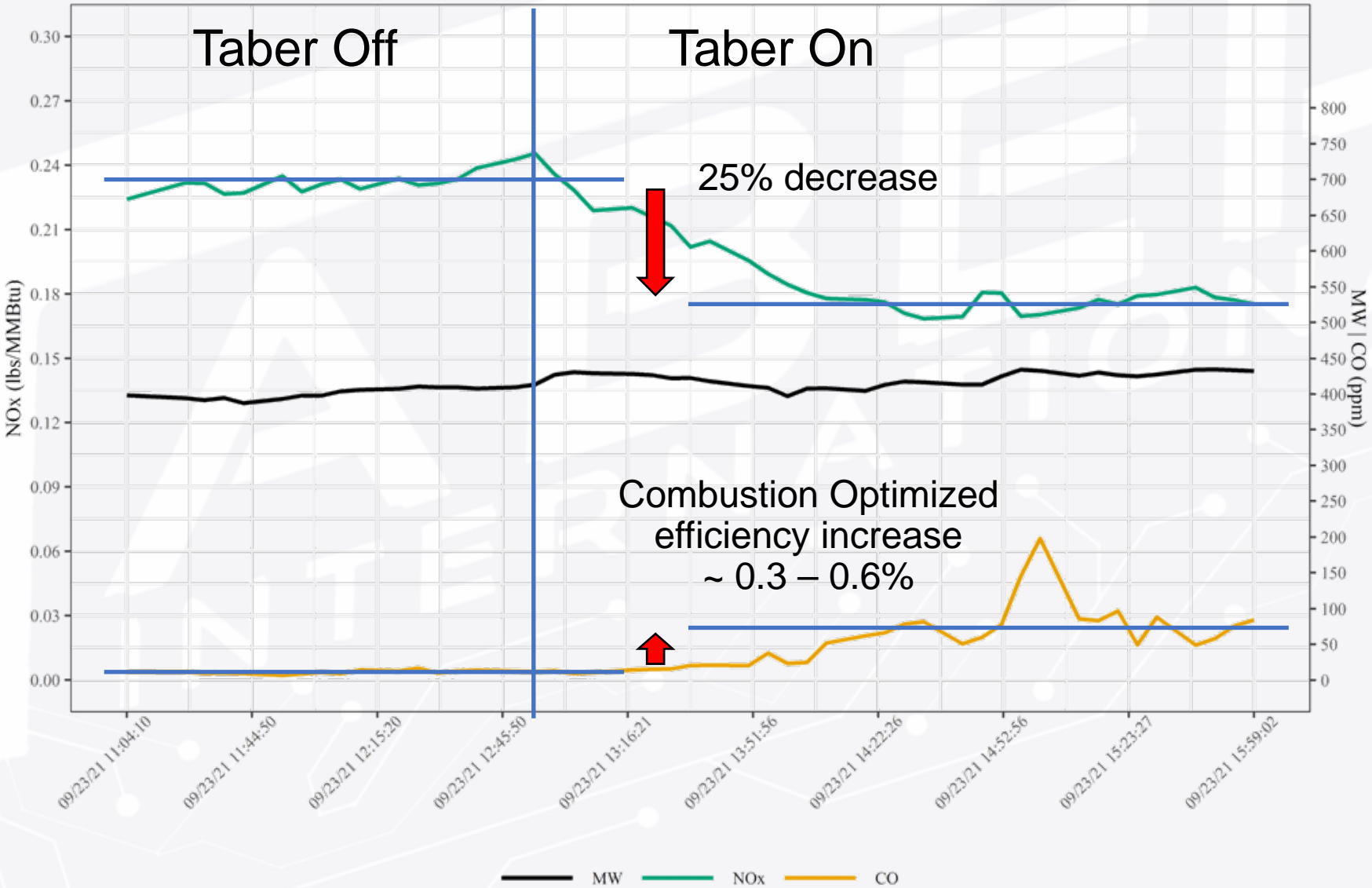
Reheat Steam Temperature Effect



Emissions Effect



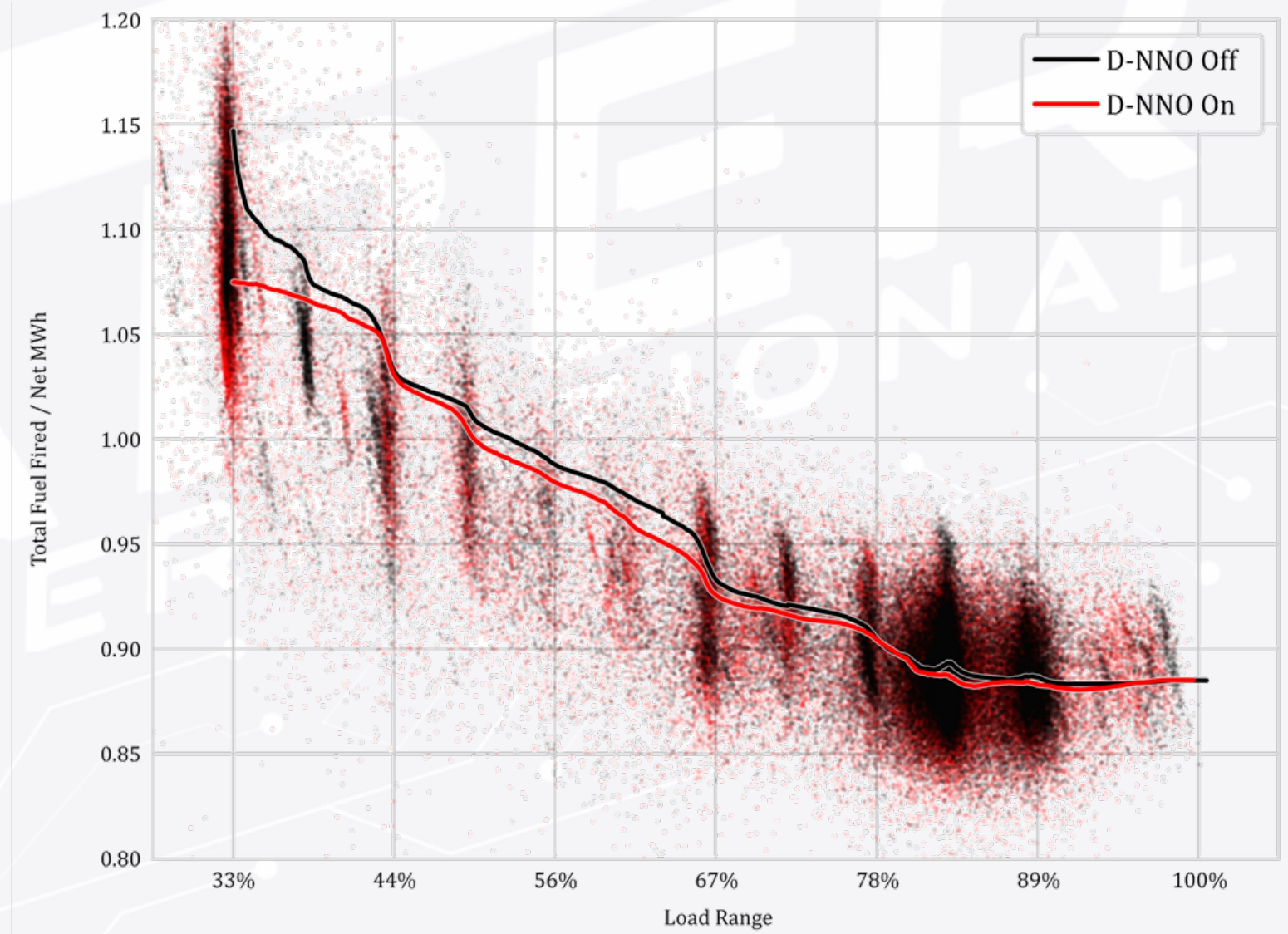
Emissions – On/Off Test



Heat Rate Optimization Consistency

The resulting effects of this system operating in closed-loop control for 2-years show consistent improvement operating efficiency improvement through use of the system.

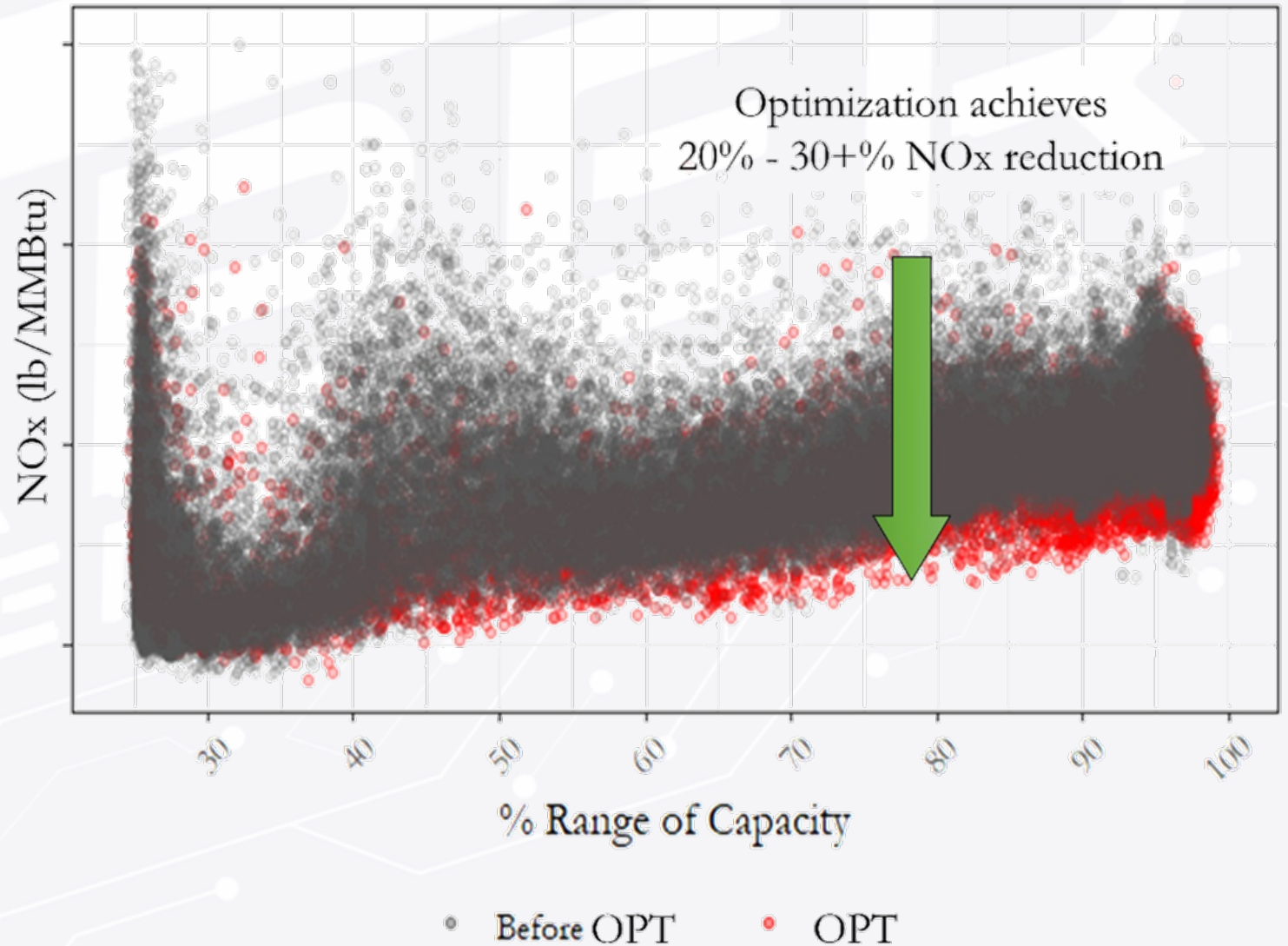
- 2% average operating efficiency improvement
- Improvements observed across the load range, 20% - 100% MCR
- Accomplished using only control improvements and operating practice adjustments



Emission Rate Optimization Consistency

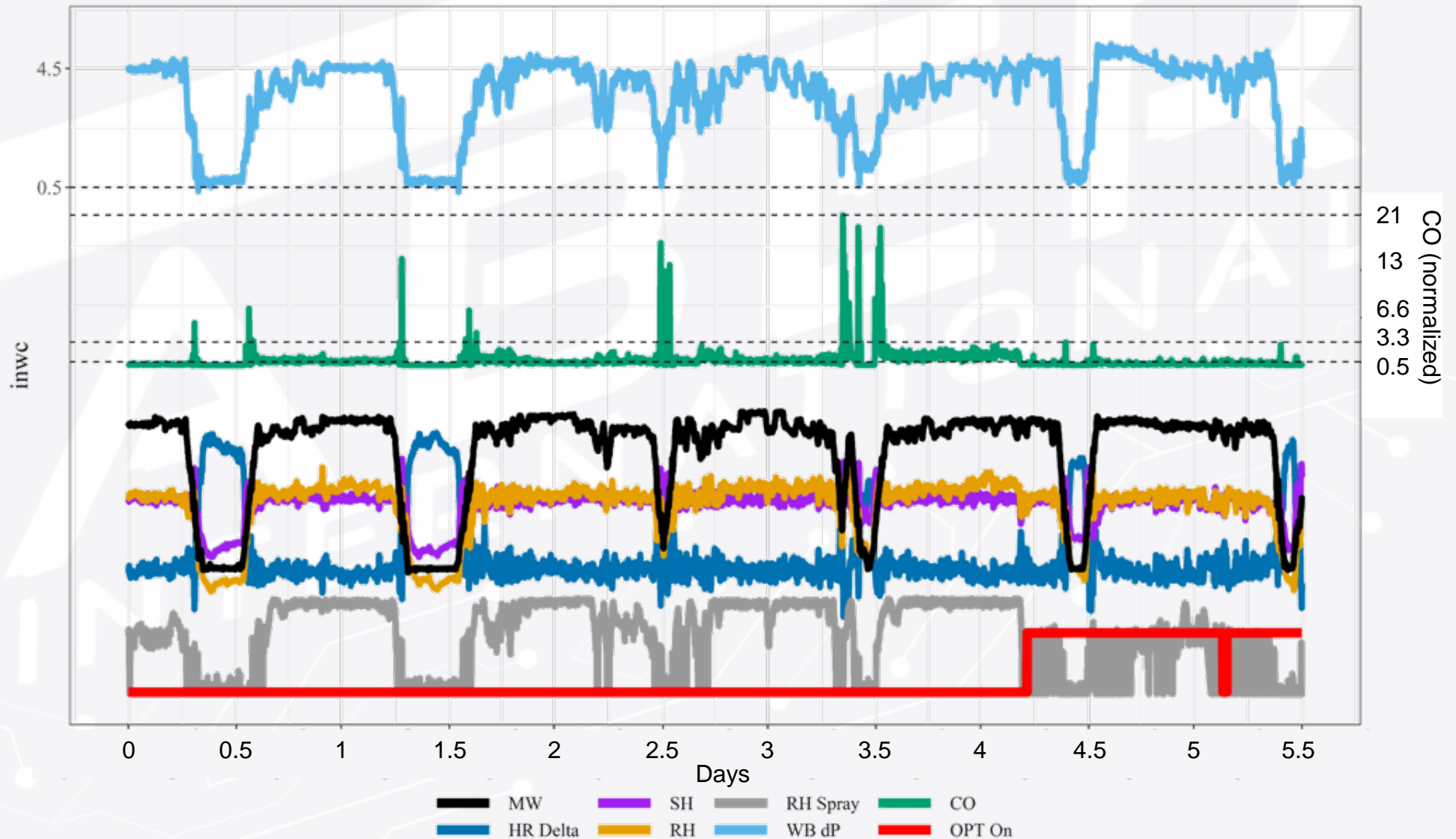
These efficiency improvements are achieved simultaneously with improvements in emission rate, particularly NO_x.

- 20% - 30% NO_x reduction
- Previously unseen low NO_x emission rates realized by optimization
- Greater consistency of lower emission rates versus no optimization



Low Load & Ramping Behavior

Demonstrated ability to better control WB_dP at low load (avoid going too low), significantly improved CO control, similar to improved heat rate indicators, and better temperature setpoint realization during ramping and afterward.



Proven Flexibility Optimization

Improving steam temperature control across the load range improves turbine thermal cycling effects, and avoids other potential water induction damage.

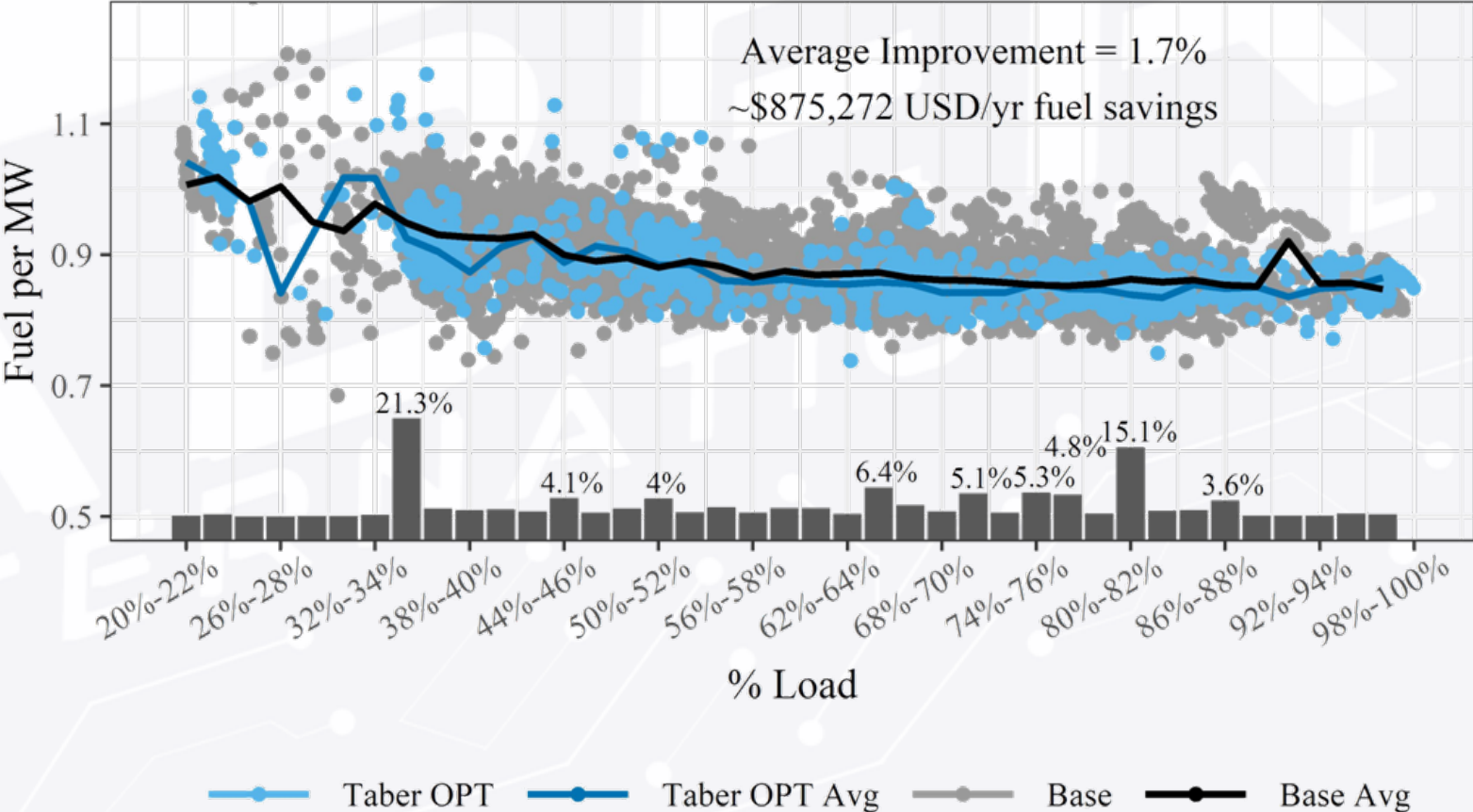
Reduced steam temperature variation and stability improvements across the load range have been observed.

Taber control realizes nearly 27% more temperature stability and 35% better setpoint attainment, avoiding many under- and over-temperature events



Overall Improved System Flexibility and Performance

The culmination of advanced, dynamic AI systems and optimization with expert knowledge capture and automated responses is a robust system capable of enhanced flexible operation and stability, meeting the challenging demands of the future energy grid reliably and cleanly.



Project Testimonials

[We] started load cycling and low load operation back in the 2016-17-time frame. Our current load range capability is from 15% minimum MDC to 100% maximum MDC.

Flexibility is our current reality and maintaining stability during load ramps takes continuous monitoring and adjustments. The inherent problems associated with load ramping and cycling (pressure swings, temperature swings, and low total air flow at lower loads) have been minimized to certain extent, by the optimizer.

In our system load ramps are almost never continuous. There may be 2-3 interruptions or pauses in the total ramp. For example, an afternoon peak load ramp may be from 15% MDC to 80% MDC with a 15-minute pause at 40% and the same at 60%. At each of these pauses is where we have seen the worst pressure and temp swings. **The optimizer can anticipate these excursions and utilize the sprays and/or burner tilts to minimize the effects of the event.**

I think one of the best indicators of this application is operator acceptance. Anyone who has worked at a power plant and has anything to do with operations knows “without operator by-in” the program will fail. **Here our operators have seen positive results and are willing to work to make it better, which makes their life better.**

– Asst. Operations Manger, Coal-Fired Power Plant, Western United States

Project Testimonials

“[Taber’s] KSB enabled us to break away from sequence blowing [and] got rid of 25+ operator-based sequences that were overkill. Blowers run more as needed now, with roughly 20-30% aux steam savings. We’ve been able to tune KSB rules and holds on blowers such that our units are as efficient and as clean as needed for baseload, as well as being inefficient and as dirty as needed to keep exit temps up at low loads for best ESP and SCR operation, the latter of which has made for **better flexibility and turndown.**”

– *Doug Sturm, Sr. Engineer, CGS Operations*

“Our previous system was sequence based [over which] Griffin is a huge improvement, and it is maintaining [unit] cleanliness very well. We’ve had a few short boiler outages on our unit where Griffin is installed. I make it a point to check the reheater for slag when the unit is off. I haven’t seen any issues. Before Griffin, I was walking the unit down easily once a week, sometimes more. Usually we asked Operations to blow certain lances, which required verification and a physical check to make sure it achieved the level of cleanliness that we wanted. Sometimes I would change sequences to get the boiler clean...which usually required a week or so to [do]. Before Griffin, boiler cleanliness consumed 30% of my day. Now with Griffin, I don’t do any of the tweaking anymore. Griffin does it for us.

As pleased as I am with Griffin, what amazed me most was how smoothly and effectively Griffin was rolled out. It was almost seamless and very professionally done. I’ve never been involved, at any place I’ve ever worked, where a change of this magnitude was rolled out so smoothly and seamlessly across multiple shifts.”

– *Ben Hanneken, Engineering, Labadie Energy Center*



Conclusions

- Providing grid stability and sufficient generation is a complicated problem and is only becoming more complex with greater penetrations of variable generation sources.
- With control and operating modifications, the existing thermal fleet is likely capable to act as the balancing agent, and there is great value in their flexible and variable operation.
- Specialized machine learning models which incorporate and learn system dynamics can be more effective in optimizing systems in the midst of transients and dynamic operation than traditional approaches or static optimization.
- Operational improvements to both efficiency (heat rate) and emission rates have been demonstrated both in single events and over extended periods of time.
- Instructing operators and engineers on flexible operation best-practices is critical to achieving unit reliability and overall flexibility. By automating many portion of this process, greater consistency and robustness is achieved.
- As a more integrated approach is realized where upcoming events can be better prepared for and the future load demands predicted with more accuracy, further benefits and gains can be expected through dynamic optimization and trajectory planning.



TOTAL PLANT INNOVATION

COMBUSTION OPTIMIZATION

FLEXIBILITY & RAMPING

MODEL PREDICTIVE CONTROL

ELECTRONIC LOGGING
& REPORTING

PREDICTIVE MAINTENANCE

PERFORMANCE MONITORING
& DASHBOARDS

VIRTUAL SENSORS



*OPTIMIZE THE COMPLEX,
AUTOMATE THE MUNDANE*

Thank You



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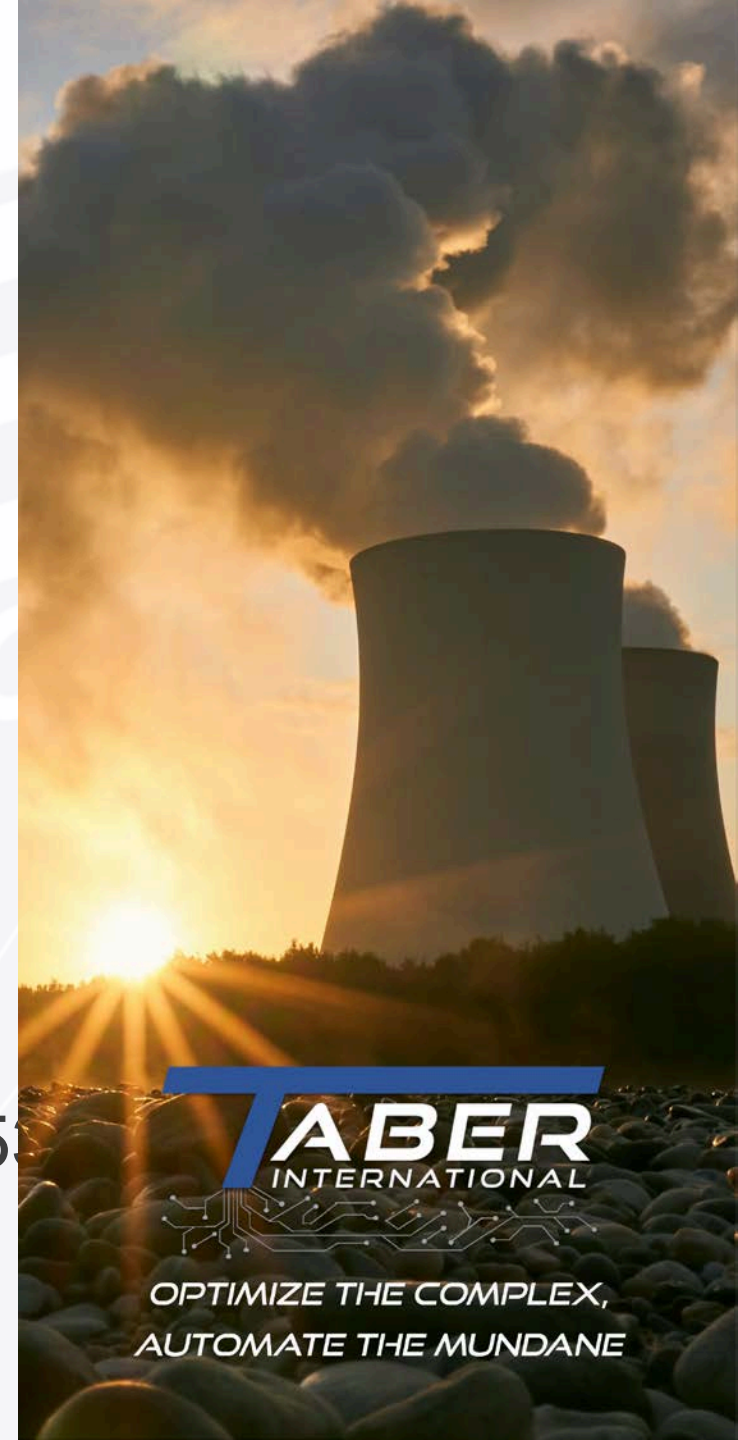


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*OPTIMIZE THE COMPLEX,
AUTOMATE THE MUNDANE*