



Continuous Performance Improvement in Power Generation Optimization in Action

Authors: Don Labbe, Consulting Engineer-Advanced Controls, Invensys
Lew Gordon, Consulting Engineer, Invensys

What's Inside:

1. The Challenge
2. Typical Optimization Process
3. Four Steps to Performance Improvement
4. Optimizing Heat Rate Controls
5. Soot Blower Optimization
6. Overfire Air Optimization
7. Cooling Tower Optimization
8. Conclusion
9. References

Continuous Performance Improvement in Power Generation

Optimization in Action

1. The Challenge

In today's environment, power plant managers continuously face new challenges and requirements. Even a short list includes the need for higher efficiency, lower emissions, greater fuel flexibility, higher availability, lower operating costs and a faster dispatch rate.

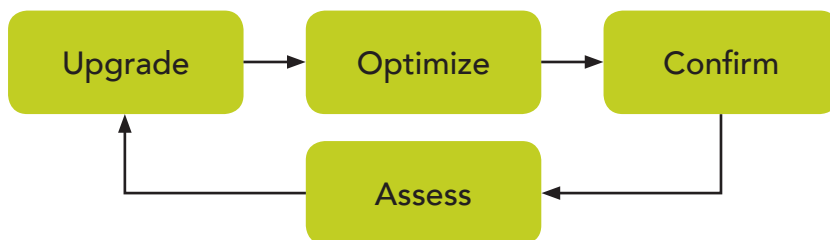
To meet these challenges, plant staff are continuously designing and installing equipment upgrades. The good news, however, is that these upgrades also create new opportunities for achieving performance and profitability improvements through advanced control.

Optimizing Control Systems can extract the maximum performance benefits from equipment upgrades, while respecting the plant operating constraints. Significant economic benefits can be gained through:

- Direct fuel savings
- Higher efficiency (lower heat rate)
- Lower CO₂ and NO_x emissions
- Improved ramp capability for dispatch
- Integration with alternative fuels
- Lower overhead operating costs

Experience has demonstrated ROI periods as short as a few months for power plant optimization systems.

Each plant has unique constraints that are obstacles to achieving and sustaining these benefits. This paper describes a series of plant equipment upgrades and coordinated optimization systems at South Mississippi Electric Power Association (SMEPA) R. D. Morrow Station over a six-year period.



2. Typical Optimization Process

The key to success is always a combination of:

- Ongoing cooperation and partnership between end user and optimization vendor
- A flexible and capable optimization tool set
- Optimization expertise
- A commitment to continuous performance improvement



What is Optimization?

Optimization is an overused term that has many varying connotations. In this white paper the intended meaning is "extracting the maximum benefits from a system while respecting the operational constraints of the equipment."

Continuous Performance Improvement in Power Generation

Optimization in Action

3. Four Steps to Performance Improvement

At the R. D. Morrow Station, a series of four evolutionary and interdependent efforts have yielded significant performance and economic improvements. These improvements include:

- Optimizing upgraded Units 1 and 2 DCS (Distributed Control System) heat rate controls to gain fuel savings, CO₂ reductions and lower NO_x emissions
- Optimizing upgraded soot blower controls for additional fuel savings and lower CO₂ emissions
- Optimizing upgraded overfire air handling system to further reduce NO_x emissions
- Optimizing controls for a rebuilt cooling tower for additional fuel savings and lower CO₂ emissions

4. Optimizing Heat Rate Controls

Upgrade: A general upgrade of the DCS controls for the Units 1 and 2 boiler controls

Objectives: The objective of the first optimization systems was heat rate improvement, CO₂ reduction and lower NO_x emissions. A second objective was the implementation of a soot blower advisory system.

Approach: This effort used optimizing Model Predictive Control (MPC) to achieve the following objectives:

- Balance east and west boiler superheat and reheat steam temperatures to increase the average temperature while maintaining the higher side temperature at set point
- Extract more energy from the flue gas by achieving lower flue gas temperature, balancing furnace air distribution and lowering overall air flow
- Balance side-to-side ball mill outlet conditions
- Improve ball mill balance and grinding performance for improved coal fineness and lower unburned carbon (LOI)

Benefits: The optimization systems met these objectives and provided additional benefits of improved unit ramp rate and increased maximum load generation. One major challenge was the wide variability in coal quality that hindered normal plant operation, particularly for lower grade coal. The optimization system improved unit performance for these low grade coals permitting faster dispatch rates and higher load generating capacity.

An extensive heat rate test comparing operation with and without the optimization system in service was conducted at the conclusion of the project with heat rate improvements approaching 1%. The success on the first unit led to rapid commissioning of the second unit which achieved similar benefits.

5. Soot Blower Optimization

Upgrade: New soot blower controls in the DCS replaced the original stand-alone relay and timer-based soot blowing system.

Objectives: The soot blower advisory system implemented in the first project required the operator to manually execute the actions suggested by the advisor and provide feedback on the system to acknowledge the action. The objective of this optimization effort was to implement an automated, "smart" soot blower system that would:

- Minimize the system demands placed on the operator
- Increase the net average steam temperatures to the HP and IP turbines, thereby increasing cycle efficiency
- Avoid any negative impact on thermal performance arising from improper soot blowing procedures
- Maintain the reheat steam temperature at or above the load based target



Four Key Projects

1. **Optimizing Heat Rate Controls**
Upgrade DCS controls with MPC
2. **Soot Blower Optimization**
Balance steam temperatures
3. **Overfire Air Optimization**
Modulating air dampers
4. **Cooling Tower Optimization**
Rebuild and modernize

Continuous Performance Improvement in Power Generation

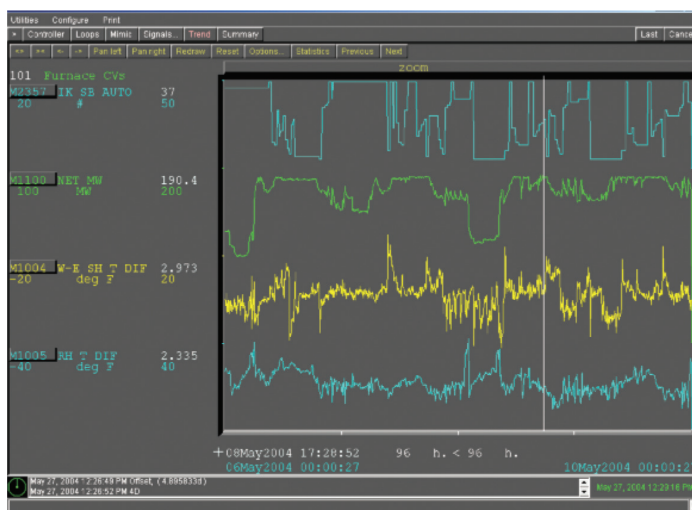
Optimization in Action

Approach: The boiler control system applies the highest side temperature as the measurement input to the steam temperature controls. Balancing side-to-side superheat and reheat steam temperatures minimizes the temperature difference and raises the average temperature to the turbines.

To balance these temperatures the optimizer applied a mix of two appropriate technologies, including:

- Smart logic system to evaluate key performance measurements, unit fouling conditions and equipment status
- Programmable sequence blocks to implement timers and permissives

Benefits: Soot blowers perform the essential task of removing deposits on the furnace walls and tubes that can significantly imbalance energy distribution. Consequently, activating appropriate soot blowers can improve thermal performance while avoiding serious adverse affects on thermal performance that can last for several hours.



Soot Blower Impact on Side-to-Side Superheat and Reheat Temperature Differences (see diagram, left)

This system reduced the mean west/east superheat and reheat temperature differences to 2.5F and 3.4F over the observation period, as shown in the two lower trends. Generally, there was a marked increase in the average superheat and reheat temperatures, yielding higher unit efficiency.

6. Overfire Air Optimization

Upgrade: New damper drives provided secondary air regulation to each burner while maintaining full overfire air flow capacity above each burner. New DCS controls modulated these secondary air dampers. This provided the means to adjust secondary air distribution in the furnace and achieve greater effectiveness of the overfire air.

Objectives: The objective of this effort was further reductions in NO_x emissions.

Approach: The optimization system applied dynamic multivariable control and neural net models of the newly modified secondary air dampers effects on the measured furnace parameters. These parameters included furnace O₂ distribution, stack NO_x and CO and steam temperatures.

The multivariable control system also included new virtual sensors representing key burner zone parameters. These virtual sensors track the load, coal mill shifts and fuel quality changes. Constraints on these virtual sensors limited the secondary air damper modulation to a range that is effective in achieving NO_x reduction while ensuring satisfactory furnace conditions.

Benefits: The system sustained NO_x reductions of approximately 10% across the load range. The system also achieved the additional benefit of increased heat rate improvement through the balance of O₂ distribution. Since the control system applied the lowest side O₂ measurement in the O₂ controller, a side-to-side difference increased the average O₂ through the furnace. Balancing the O₂ distribution further lowered the average O₂ and thereby reducing furnace dry gas losses.

Continuous Performance Improvement in Power Generation

Optimization in Action

7. Cooling Tower Optimization

Upgrade: This upgrade rebuilt the two cooling towers providing the cooling water for the units. New fiberglass members replaced the prior wooden structure with a new water distribution system using four circulating pumps, retaining the sixteen 2-speed cooling fans.

Objectives: The temperature and flow rate of the cooling water influence condenser performance, steam turbine exhaust pressure and turbine power generation. Maximum cooling minimizes water temperature and turbine exhaust pressure and maximizes the turbine load generation from the available steam flow. However, maximizing cooling also exponentially increases the auxiliary load on the unit, significantly lowering the net load generation available for the grid.

The objective of this effort was to balance the amount of cooling versus the associated auxiliary load to maximize net load generation.

Approach: The relationships of the performance of the cooling tower and the turbine efficiency are all highly non-linear and vary with ambient conditions. Due to the complexity of the optimization problem and because the cooling tower fans and circulating water pumps are on a stand-alone hard wired control system, the solution took the form of a cooling tower advisory system within the NOx and heat rate optimization system.

This optimization system balances the impact of the increasing number of pumps in service and fan speed on each condenser's backpressure and each turbine's MW production against the incremental power consumption of the pumps and fans to seek the optimum condenser performance.

Benefits: A comparison of a 24-day period in November 2006 under normal operation to November 2007 with the Cooling Tower Optimization system in service indicated an average hourly savings of 1205 KW at a value of ~\$1,120/day in salable power. Assuming an average of 1000 KW benefits year round, the optimization system can be expected to provide over \$330,000 in additional annual revenue.

8. Conclusion

A series of equipment upgrade projects at the SMEPA R.D. Morrow Station have been coupled with optimization systems to gain performance benefits in the form of fuel savings, reduced emissions, increased net power generation and improved dispatch capability. The combination of a flexible and capable toolset, application expertise and the power of continuous improvement is now providing continuous and significant performance benefits to the station.

9. References

- 1.) D. Labbe, D. Roberts, J. Brown, Equipment Upgrades and Phased Optimization Enhance Unit Performance, 18th Annual Joint ISA POWID/EPRI Controls & Instrumentation Conference, Phoenix, AZ, June 2008.
- 2.) D. Roberts, L. Gordon & D. Labbe, Optimizing Heat Rate with Model Predictive Control on Riley Turbo-Furnace Units, 12th Annual Joint ISA POWID/EPRI Controls & Instrumentation Conference, San Diego, CA, June 2002.



Invensys Operations Management • 5601 Granite Parkway III, #1000, Plano, TX 75024 • Tel: (469) 365-6400 • Fax: (469) 365-6401 • iom.invensys.com

Invensys, the Invensys logo, ArchestrA, Avantis, Eurotherm, Foxboro, IMServ, InFusion, SimSci-Esscor, Skelta, Triconex, and Wonderware are trademarks of Invensys plc, its subsidiaries or affiliates. All other brands and product names may be the trademarks or service marks of their representative owners.

© 2011 Invensys Systems, Inc. All rights reserved. No part of the material protected by this copyright may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, broadcasting, or by any information storage and retrieval system, without permission in writing from Invensys Systems, Inc.

Rel. 03/11 PN I-PW-0112