Demonstration of Integrated Optimization Software at the Baldwin Energy Complex

Demonstration Operations Complete

Participant

NeuCo, Inc.

Additional Team Members

Dynegy Midwest Generation — host

Location

Baldwin, Randolph County, IL (Dynegy Midwest Generation's Baldwin Energy Complex)

Technology

Advanced optimization software, building on NeuCo's ProcessLink® technology

Project Capacity/ Production

1,768 MW

Coal

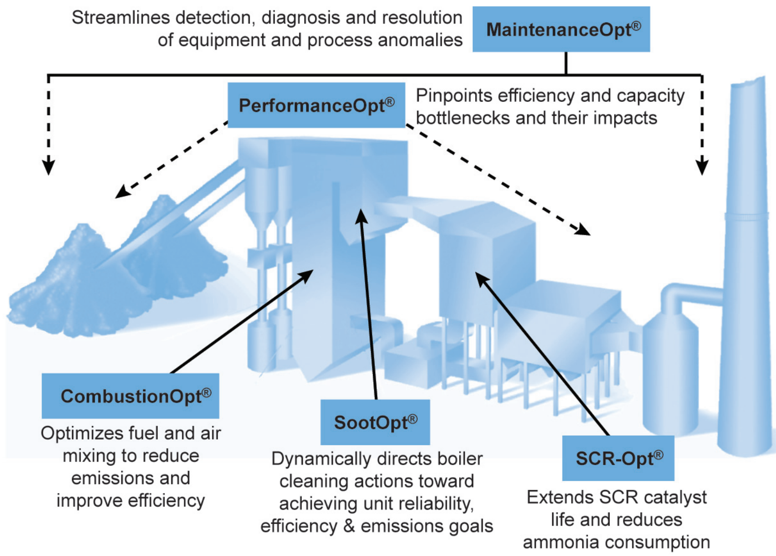
Powder River Basin (PRB) subbituminous

Project Funding

Total	$19,094,733	100%
DOE	8,592,630	45
Participant	10,502,103	55

CCPI-1

Emissions Control			
Mercury	■	NO_x	■
SO_2	■	$PM_{2.5}$	■



Objectives

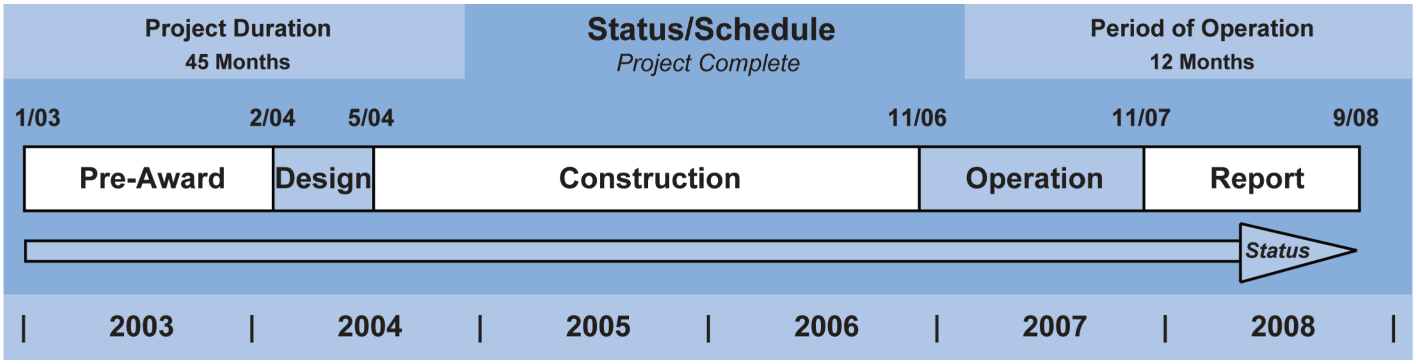
To design and apply individual on-line optimization modules at the Baldwin Energy Complex for combustion, sootblowing, selective catalytic reduction (SCR) operations, overall unit thermal performance, and plant-wide economic optimization; to integrate individual optimization modules through NeuCo's ProcessLink® platform; and to reduce the Baldwin Energy Complex nitrogen oxide (NO_x) emissions by 5 percent, increase efficiency by 1.5 percent, and improve reliability and availability, thereby increasing net annual electrical power production by 1.5 percent.

Technology/Project Description

The project demonstrated an integrated on-line optimization control system, incorporating inputs from two 585-MW cyclone-fired boilers with SCR and a 595-MW tangentially fired boiler with low-NO_x burners (LNBs). Optimization modules were developed and operated in a non-manual, neural control (closed loop) mode for control of combustion, sootblowing, and SCR operations. In addition, modules were developed for overall unit thermal performance and plant-wide maintenance optimization. These five optimization modules were integrated through NeuCo's ProcessLink® architectural platform that includes neural networks, genetic algorithms, and "fuzzy logic" techniques. ProcessLink® capabilities enable the various optimization techniques at the Baldwin Energy Complex to be linked to each other, leveraging the existing control network. Each module was designed, installed, and individually tested to verify effectiveness before being integrated with the other modules.

Benefits

NeuCo's ProcessLink® architecture offers plant operators a highly flexible control platform. Optimization modules can be designed and applied to individual subsystems in a plant, leveraging existing sensors, actuators and networked computational resources, and then linked to other individual subsystems to afford overall integration of controls responsive to plant operator and corporate criteria. As plant complexity increases through retrofit and repowering applications, the introduction of new technologies, and plant modifications, this integrated process optimization approach can be an important tool for plant operators.



Status/Accomplishments

The project was awarded on February 18, 2004. The National Environmental Policy Act (NEPA) requirements were met with a Categorical Exclusion (CX) at the time of award.

During the course of the project, NeuCo deployed five optimization models that were integrated through the ProcessLink® architectural platform. Different combinations of the optimization models were installed on each of the three units depending on the boiler type and configuration as shown below:

Unit 1 (Cyclone-fired)

- CombustionOpt®
- MaintenanceOpt®
- PerformanceOpt®
- SCR-Opt®

Unit 2 (Cyclone-fired)

- CombustionOpt®
- MaintenanceOpt®
- PerformanceOpt®
- SCR-Opt®
- SootOpt®

Unit 3 (Tangentially-fired)

- CombustionOpt®
- MaintenanceOpt®
- SootOpt®

The CombustionOpt® model continuously evaluates and adjusts numerous boiler settings to improve the mixing of the fuel and air in the furnace seeking to optimize the combustion process and reduce NO_x formation. The SCR-Opt® model closely coordinates with CombustionOpt® to minimize NO_x formation, thereby reducing the amount of ammonia needed for SCR operations, and also determines the precise amount of ammonia needed for the desired NO_x rate. The PerformanceOpt® predictive model identifies problems that are causing performance deficiencies, and determines the impacts of each problem. The SootOpt® model regulates cleaning actions on heat transfer surfaces to minimize unnecessary cleaning operations. The MaintenanceOpt® model monitors a broad spectrum of data looking for anomalies that might indicate the presence of reliability, capacity, or efficiency problems.

The models were integrated with existing equipment and digital controls, followed by an evaluation, refining, and documentation period. The operation phase of the project was completed in November 2007. The Final Technical Report was approved in September 2008.

Results Summary

The Baldwin Energy Complex consists of two cyclone-fired boilers configured with SCR systems (Units 1 and 2) and a tangentially-fired boiler (Unit 3). The three units were equipped with state-of-the-art instrumentation and Digital Control System (DCS) prior to the start of the project. All three units were initially designed to fire high-sulfur Illinois coal. In 2000, the units were switched to Powder River Basin (PRB) coal for sulfur emissions compliance. This switch complicated the relationships among various parameters and operator activities including: sootblowing; SCR operations; combustion optimization; and minimizing unit heat rate.

The project far exceeded the targets for NO_x reduction with average reductions of between 12 and 14 percent.

The project realized lower operating costs, improved reliability, and greater commercial availability while reducing greenhouse gases, mercury, and particulate emissions.

The integrated optimizers commercialized as part of this project are expected to yield well under a one-year payback for average-sized coal units across all unit types and fuel categories comprising the U.S. power industry.

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Five optimization products were developed, addressing combustion, sootblowing, SCR operations, overall unit thermal performance, and plant-wide availability optimization. The initial goals were to establish each system and demonstrate their integration in unified plant optimization. The models and settings were improved and refined based on input from plant personnel, overall objectives, and actual experiences.

Initially, optimization activity was focused on achieving improved control of the 28 cyclone burners on Units 1 and 2 and the numerous fuel-air and auxiliary air dampers on Unit 3. The major challenge for the cyclone units was moving toward reduced stoichiometry (lower NO_x production) without losing good cyclone slag flow. Cyclone function is largely based around the physics and chemistry of slag formation and flow. The PRB coal has higher ash content than high sulfur Illinois coal and a much narrower range of temperatures over which slag (molten ash) flows well. PRB coal also has a lower overall energy density, requiring more flow through the combustor to provide the same heat release. For these reasons, boilers are typically derated after switching to PRB coal.

To avoid derating, stoichiometry, temperature, and mass flow have to be controlled within narrow ranges. The consequence of failing to meet these combustion control challenges is clogging a cyclone with hardening slag, a condition that often requires an outage. The project was able to meet these challenges and avoid derating of the boilers.

Improvement of sootblowing operations also provided multiple benefits towards project goals. The project achieved a 33 percent reduction of boiler cleaning actions (via water cannons and soot blowers). Frequent sootblowing operations increase steam usage and can increase the frequency of tube failures. Less steam usage for sootblowing improves heat rate. Tube failures can result from erosion and thermal shocking that occurs when high pressure, relatively cool steam impinges clean tubes. Tube failures are a significant cause of forced outages.

The project demonstrated that multiple optimization products could be integrated into a single software architecture and coordinated to achieve plant-wide objectives. The overall results of the project are discussed below.

- NO_x Reduction: The 5 percent target for NO_x reduction was exceeded with NO_x reduction between 12 and 14 percent.
- Heat Rate Improvement: The optimization systems delivered an average heat rate improvement of approximately 0.7 percent. This was less than the 1.5 percent target and fell short primarily due to greater emphasis on NO_x reduction. With a different prioritization of objectives, it is believed the project would have achieved the target heat rate improvement. The plant's desire to maintain a safe margin of error with respect to a 30 day average NO_x rate cap led them to prioritize NO_x reduction over heat rate improvements.
- Increased Annual Available MWh: Although difficult to measure precisely, the target of increasing available MWh's by 1.5 percent was met by providing prioritized alerts and knowledge-based diagnostics for a wide array of plant equipment and process anomalies; helping the plant to move from Illinois coal to PRB coal without derating of the boilers; and improved management of cyclone flame quality and reduced slag build up.
- Commensurate Reductions in Greenhouse Gases, Mercury, and Particulates: Reductions in all three of these indices can be associated directly with the optimization leverage observed in the heat rate and NO_x reductions.
- Commensurate Benefits from Lower Costs, Improved Reliability, and Greater Commercial Availability: These benefits are mostly due to the previously described achievements. Also playing a role were the sustained operation of the cyclones while using less expensive fuel; improved catalytic reduction of NO_x; and the reduced time required to discover, prioritize and diagnose equipment issues.

The optimizers commercialized as part of this project are expected to yield well under a one-year payback for average-sized units across all unit types and fuel categories comprising the US fossil power industry. This represents a highly cost-effective way of addressing some of the industry's most pressing challenges and leverages the benefits of investments in SCR equipment, low-NO_x systems, and modern control and instrumentation systems.

Project Summary

The project established the broadest application to date of advanced optimization software. The project demonstrated five optimization models that were integrated through NeuCo's ProcessLink® technology. This technology uses neural networks, expert systems, and fuzzy logic to best achieve specific performance objectives and operator priorities. The models have the ability to "learn" the various interactions and tradeoffs between multiple plant control settings and optimize operator objectives based on real-time and historical data from actual plant operation.

The project was performed in two phases. During the first phase, a suite of integrated online optimization systems were installed and integrated with plant operations. The second phase of the project focused on improving the products and quantifying the benefits of the integrated system. A series of updated models were issued during both phases of the project based on actual experience and input from plant personnel.

During the course of the project, the following five products were developed:

- CombustionOpt®: CombustionOpt® continuously evaluates and adjusts numerous boiler settings to improve the mixing of the fuel and air in the furnace seeking to optimize the combustion process and reduce NO_x formation. For example, the bias and trim settings are manipulated by CombustionOpt® to fine tune the relative proportion of primary air delivered to the burners and secondary air delivered to the flame just above each burner. Changes to the relative proportion of primary to secondary air has a significant effect on the properties of the flame, particularly its temperature and oxygen distribution, both of which impact the formation of NO_x. Other manipulated boiler settings include the proportion of the total coal flow between the upper and lower elevations of the furnace; biases that control the overall air/fuel ratio for the boiler; and the amount of over-fire air delivered to the final stages of the furnace combustion process. On a typical unit, CombustionOpt® manipulates between 25 and 50 of these types of biases, making small step changes, once every few minutes.
- SCR-Opt®: Selective Catalytic Reduction (SCR) uses a catalyst with ammonia as a reagent to reduce NO_x emissions from combustion exhaust gases leaving the boiler. SCR-Opt® allows the operator to set the desired NO_x rate and the optimizer determines the precise amount of ammonia needed. SCR-Opt® is closely integrated with CombustionOpt® and optimization is coordinated so that CombustionOpt® is focused on minimizing the amount of ammonia needed for SCR operations. For example, changes made to the mixing of the fuel and air in the furnace to reduce NO_x formation also increased SCR efficiency.
- SootOpt®: SootOpt® regulates cleaning actions on heat transfer surfaces throughout the furnace to improve control of steam and exit gas temperatures and minimize unnecessary cleaning operations. The overall solution results in improved consistency and quality of soot-cleaning decisions, improved insight into soot-cleaning activity and its effects on unit performance, and improved bottom line performance of emissions, heat rate, and reliability indicators.
- PerformanceOpt®: PerformanceOpt® is a predictive performance management system that identifies problems that are causing performance deficiencies, and determines the impacts of each problem. Following problem identification and prioritization, PerformanceOpt® facilitates the analysis needed to determine the root cause and identify remedial action by providing the operators with detailed information on measured as well as estimated process conditions and equipment performance.
- MaintenanceOpt®: MaintenanceOpt® continuously monitors process and equipment health data looking for anomalies that might indicate the presence of reliability, capacity, or efficiency problems. MaintenanceOpt® can detect both slowly developing problems and problems that could have a critical near-term reliability impact. When anomalies are detected, the system's heuristics knowledgebase supports the identification of the most likely causes of the anomalies.

The user interface for the optimization models are specific to the particular optimization model; however, each provides the operator with further optimization advice, a summary of recent actions the model had taken and why, and graphs of actual optimization performance for key benchmarks over time. In addition, the models provide a variety of analysis screens that provide greater details and insight to the operators.

Each optimizer can address a variety of operating situations and rapidly accommodate changing conditions and objectives. The optimizers can be easily modified or expanded to incorporate new controls and objectives, or to address additional optimization goals.

The suite installation was completed at the end of 2006 and was followed by a one year evaluation and documentation period. Quantitative project benefits included: reduced nitrogen oxide (NO_x) emissions by 12–14 percent; improved average heat rate (fuel efficiency) by 0.7 percent; increased available megawatt hours by an estimated 1.5 percent; reduced ammonia consumption by 15–20 percent; and commensurate reductions in greenhouse gases, mercury and particulates. These benefits translated to lower costs, improved reliability, and greater commercial availability with significantly reduced environmental impacts.