Mercury Specie and Multi-Pollutant Control

Demonstration Operations Complete

CCPI-2

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

Participant

NeuCo, Inc. (acquired original participant, Pegasus Technologies)

Additional Team Members

NRG Texas, LLC—collaborator and host

Location

Jewett, Limestone County, TX (NRG Limestone Plant)

Technology

Advanced sensors and neural network-based optimization and control system for enhanced mercury and multi-pollutant control

Project Capacity/Production

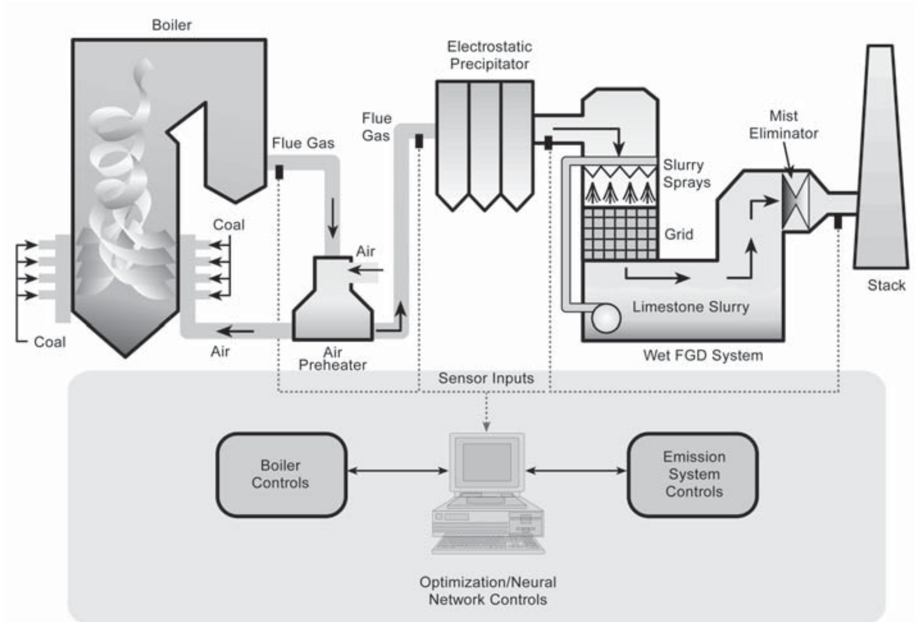
890 MW (gross); 14,500 tons of coal/day input

Coal

Texas lignite and Powder River Basin (PRB) subbituminous

Project Funding

Total	$15,560,811	100%
DOE	6,079,479	39
Participant	9,481,332	61



Objectives

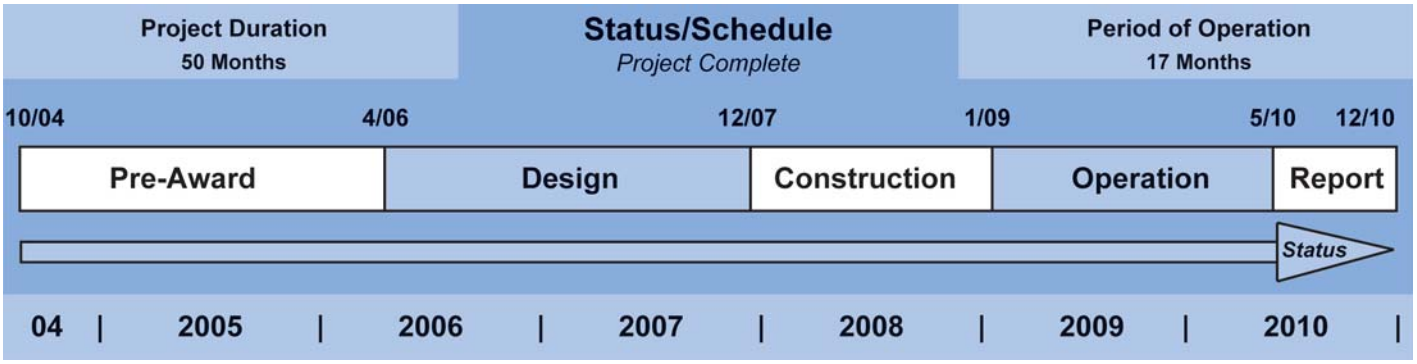
To demonstrate that state-of-the-art sensors and neural network-based optimization and controls can measure mercury species (elemental and oxidized mercury); control mercury emissions with existing flue gas desulfurization (FGD) and electrostatic precipitator (ESP) systems; and reduce pollutant emissions in general without major capital expenditure.

Technology/Project Description

The project demonstrated non-intrusive, advanced sensors and neural network-based optimization and control technologies for enhanced mercury and multi-pollutant control on an 890-MW tangentially fired boiler at the NRG Limestone Plant in Jewett, Texas. The plant is equipped with both a cold-side ESP rated at 99.8 percent particulate removal efficiency, and a wet limestone FGD system rated at 90–95 percent sulfur dioxide (SO_2) removal efficiency. The wet FGD system is capable of high mercury capture efficiency if the mercury is in an oxidized state rather than elemental state. The plant burns a blend of Texas lignite and PRB subbituminous coal, which are known to emit relatively high levels of elemental mercury under routine combustion conditions. NeuCo applied sensors to evaluate the mercury species at key locations, developed optimization software that sought the best plant conditions to promote mercury oxidation and minimize emissions in general, and used neural networks to effect the optimization conditions.

Benefits

The technology affords plant operators the means to: assess how plant operating parameters affect mercury species determination; translate the data into plant-wide optimization software that provides the lowest possible pollutant emissions; and effect optimization through neural networks. The technology allows operators to maximize emissions control with existing pollutant control systems. This



capability maximizes emission reduction with minimal capital expenditure. The technology has broad application to the existing fleet of coal-fired boilers and minimal impacts on the quality of salable by-products.

Status/Accomplishments

The Categorical Exclusion (CX) for the project was signed in March 2005. The cooperative agreement was signed in April 2006.

The project was conducted in three phases: installation of advanced sensors; installation and integration of optimizers; and validation and demonstration of all control systems and software. The first phase consisted of installing advanced sensors, designing the optimization application, and establishing the plant's baseline operating metrics. The second phase began in December 2007 and consisted of configuring the optimizers for maximum emissions removal, increasing unit performance, and development of a virtual on-line mercury analyzer. Optimizers were installed for combustion, sootblowing, unit performance, and equipment reliability. New optimizers were developed for the fuel, FGD, and ESP systems. The various products were operated in closed-loop with a focus on mercury and multi-pollutant performance. The third phase began in January 2009 and continued to operate the optimizers in an on-line mode with a focus on product tuning and interactions.

Results Summary

The project involved the application of a suite of advanced instrumentation and integrated optimization systems to improve unit operations across a variety of performance objectives, including mercury removal. Specifically, the Mercury Specie Control System was comprised of a boiler optimization system, in-furnace laser sensors that provided real-time information indicating species compositions and temperatures directly within the combustion zone, and continuous emission monitors (CEMS) at key post-combustion locations.

The boiler optimization system used neural networks, model predictive control, and other technologies to extract knowledge about the combustion process and determine the optimal balance of fuel and air mixing in the furnace. The system was used to adjust dampers, burner tilts, pulverizer settings, over-fire air and other controllable parameters to their optimal levels for a given set of conditions, objectives and constraints.

The boiler optimization model intended to utilize in-furnace mercury data; however, the laser sensors were subject to intermittent signal problems due to high ash content and slagging issues. Several sensor upgrades were made by the vendor to address these issues; however, a series of network technology issues prevented integration of the new, more consistent data into the real-time optimization during the demonstration period. While the improved sensors were not able to play a strong role in the boiler optimization or analysis for this project, their

The project demonstrated a new multivariable process controller utilizing direct search optimization designed to facilitate test efficiency through direct learning combined with statistical tools.

Over thirty manipulated variables were used to optimize NO_x while the neural network was monitoring and learning the effects of these variables on mercury.

The final phase of the project began in January 2009 and involved an operational demonstration of plant-wide optimization.

Contacts

Participant

John McDermott, Vice President,
Product Management
(617) 587-3198
mcdermott@neuco.net

NeuCo, Inc.
33 Union St, 4th Floor
Boston, MA 02108-2414

NETL

Anthony Zinn
(304) 285-5424
anthony.zinn@netl.doe.gov

Headquarters

Joseph Giove
(301) 903-4130
joseph.giove@hq.doe.gov

expectation of future utility is very high and their value has been demonstrated at other sites.

Additional difficulties were encountered with the post-combustion mercury CEMS. The Mercury CEMS were installed at the ESP inlet, FGD inlet, and FGD outlet and proved to be challenging to maintain. The instruments used were not sufficiently hardened for the harsh conditions and frequent repairs were required to obtain reliable data. Despite good faith efforts on the part of the vendor, the amount of mercury data taken from around the ESP and FGD was smaller than expected. Furthermore, analysis showed that even when data was coming in it was not always of usable value, presenting inconsistent or infeasible results that could not be reconciled with other indications. Calibration drift and hardware failure were the most frequent culprits. Relatively late in the project and on the plant's initiative, an additional mercury monitor was added in the stack that ultimately provided the majority of useful data. Utilizing the data from the stack monitor, mercury was added as a direct optimization objective in the form of a "down" objective for the neural optimizer.

Mercury data collection using the stack-based CEMS was discontinued on December 31, 2009. The decision to stop was based largely on a change in the regulatory context for mercury emissions. It was also decided to decommission the other mercury CEMS instruments due to the high cost of maintenance.

Analysis of mercury removal across post-combustion equipment found that the total amount of mercury removed across the ESP is essentially zero (to within measurement error). However, significant mercury oxidation occurs across the ESP. The ratio of elemental mercury to total mercury decreased from 35 to 25 percent. It was also shown that the FGD removes most of the oxidized mercury; thus, oxidation of mercury across the ESP is important to the total mercury removal rate of the FGD. It was also shown that there is a slight increase in elemental mercury across the FGD (commonly referred to as re-emission). The results also support the importance of upstream changes to combustion on the total mercury reduction from the inlet of the ESP to stack, suggesting that primarily combustion processes can have a large effect on removal rates.

Despite the instrumentation issues and other challenges, the project delivered significant benefits for plant performance and reduced emissions. NO_x production was reduced by 16 percent while carbon monoxide (CO) was reduced by 24 percent. Losses efficiency showed an improvement of 0.5 percent with a heat rate improvement of between 0.52 and 1.2 percent. Over the course of the project, the fuel blend was transitioned from a 70/30 lignite/PRB blend to a ratio closer to 50/50. This transition was significantly aided with the optimization systems through improved control over combustion and heat transfer processes. With respect to mercury emissions, total stack mercury emissions were reduced by 22 percent, primarily as a result of changes in the fuel blend with additional reductions attributable to optimization.

Project Summary

The project applied a suite of advanced instrumentation and integrated optimization systems at NRG's tangentially-fired Limestone Power Plant.

Of the systems evaluated, several were abandoned due to equipment difficulties or overriding operational priorities. These systems included: the Advanced ESP Optimization System, the Advanced FGD Optimization System, and a High Fidelity Control Room Simulator.

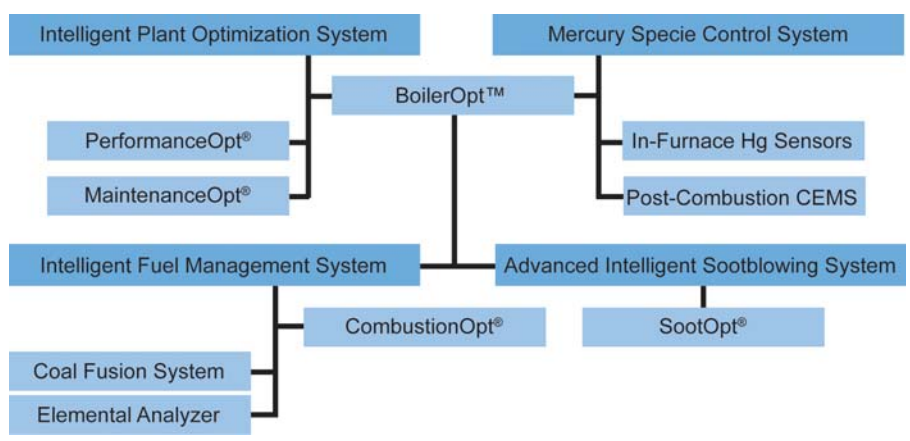
The Advanced ESP Optimization System was abandoned following equipment and vendor support issues with the carbon-in-ash (CIA) virtual online analyzer, identification that negligible mercury was removed in the ESP, and determination that the ESP already had an adequate power optimization system to control opacity from the stack. The value of developing an Advanced FGD Optimization System was undermined by the low cost of SO_2 credits and the operator's priority to minimize costs by reducing FGD operation. The Control Room Simulator was abandoned after it was determined that there was limited value from the simulated setting that enhanced the operators' understanding of how the optimizers functioned.

The deployed systems included fuel management, mercury specie control, soot blowing, and plant optimization. The components and interactions of the various systems are shown in Exhibit 3-5.

The Intelligent Fuel Management System was composed of the Combustion Optimization System (CombustionOpt®), Ready Engineering's Coal Fusion System, and Sabia's elemental analyzer. The Coal Fusion System controls the coal transport hardware that blends lignite coal with PRB coal. Changes to the blend impact the amount of Hg and NO_x in the flue gas due to the inherent characteristics of the two coal types. The coal analyzer required routine calibration and was used to determine and adjust the Btu content of the blend allowing operator to adjust the blend to account for variations in coal quality.

Exhibit 3-5

Overview of Advanced Instrumentation and Integrated Optimization Systems



The Mercury Specie Control System included the boiler area optimization system (BoilerOpt™), in-furnace laser sensors that provided real-time information indicating species compositions and temperatures directly within the combustion zone, and CEMS at the ESP inlets, an FGD inlet and outlet, and the stack.

The Advanced Intelligent Soot Blowing (ISB) System was composed of the SootOpt® intelligent soot blowing software. This module was previously demonstrated; however, certain advances were made. SootOpt® models the effect of soot blowing activity on heat transfer throughout the furnace and backpass and dynamically determines the optimal boiler cleaning actions to improve availability, heat rate and emissions performance.

The Intelligent Plant Optimization system ensures that all of the other optimization systems are working together effectively and consists of BoilerOpt™, which ties together the optimization of the combustion and heat transfer processes, as well as PerformanceOpt® and MaintenanceOpt®, which measure unit performance and provide early detection of operating and equipment problems. Specifically, BoilerOpt™ consists of the integration of the combustion and soot blowing optimization systems (CombustionOpt® and SootOpt®). PerformanceOpt® is a real-time proactive performance management system. It continuously monitors thermal performance, alerts users to unit efficiency and capacity degradation and provides the contextual data to efficiently diagnose unit-wide performance issues. MaintenanceOpt® employs adaptive neural network models that monitor plant data in real-time, constantly searching for anomalies that point to equipment health problems.

The project encountered a number of challenges including:

- Maintenance of consistent mercury level readings from the mercury CEMS;
- Changing regulatory and market conditions resulting in varying operator priorities;
- Installation and maintenance of wide array of instrumentation from multiple vendors;
- Remote management of network systems and evolving security requirements; and
- Achieving high rates of optimization technology utilization.

Despite these challenges, the project delivered significant benefits on plant performance. Some of the key findings included:

- With reliable mercury CEMS, the use of inductive methods can most likely support mercury optimization product development;
- Significant benefits are provided by an integrated platform upon which to bring the wide variety of data management and analytics approaches including advanced optimization technology;
- Advanced instrumentation must be reliable, robust and cost effective to have significant utility in a real production setting; and
- Regulation and market uncertainty are major obstacles to progress in developing the benefits of optimization opportunities.

While mercury emissions were not regulated during the project demonstration period, future regulations are expected and the most likely instrumentation scenario is one where stack-based mercury CEMS will be used to report against those regulations. The project analysis suggests that this kind of instrumentation supports some opportunity for reducing mercury emissions through the optimization of standard upstream processes, similar to NO_x, CO and opacity. It is likely that optimization can play a role in helping to achieve the fastest possible path to effective utilization of those systems, while minimizing other impacts.