Big Bend Power Station Neural Network-Sootblower Optimization

Demonstration Operations Complete

Participant

Tampa Electric Company

Additional Team Members

Pegasus Technologies (a division of NeuCo, Inc.) — technology supplier

Location

Apollo Beach, Hillsborough County, FL (Tampa Electric's Big Bend Power Station)

Technology

NeuCo's Neural Network-Intelligent Sootblowing System (NN-ISB) control system with advanced sensors and water cannons

Plant Capacity/ Production

445 MW

Coal

Bituminous

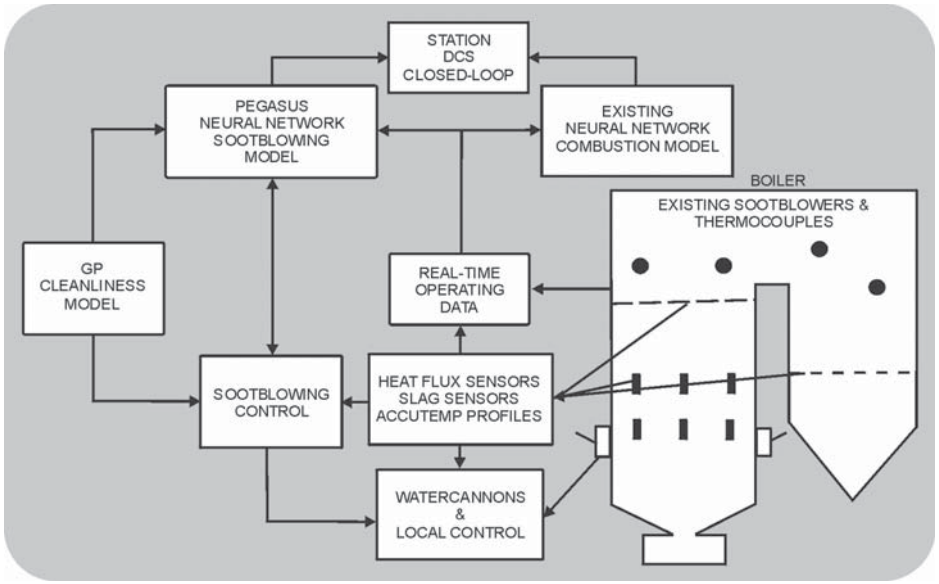
Project Funding

Total	$2,381,614	100%
DOE	905,013	38
Participant	1,476,601	62

PPII

Emissions Control

Mercury	☐	NO_x	■
SO_2	☐	$PM_{2.5}$	■



Objectives

To demonstrate that the Pegasus Technologies Neural Network-Intelligent Sootblowing System (NN-ISB) control system, along with advanced instrumentation and water cannons, can optimize sootblowing on a 445-MW boiler, reduce nitrogen oxide (NO_x) emissions by up to 30 percent, improve heat rate by 2 percent, and reduce particulate matter (PM) emissions by up to 5 percent.

Technology/Project Description

The project demonstrates Pegasus Technologies' NN-ISB control system, along with advanced instrumentation and water cannons, to optimize engagement of sootblowing systems in the control of boiler fouling on a 445-MW wet-bottom, turbo-fired boiler. Heat flux sensors, slag sensors, and temperature profiling instrumentation are applied at key locations to provide real-time data to the NN-ISB, which interprets the data through optimization software developed to send appropriate signals to existing sootblower controls. Signals are sent only to the sootblowers in the specific section(s) of the boiler requiring cleaning. The NN-ISB operates in a closed loop mode; *i.e.*, the on-line system responds to real-time data and adjusts controls without need of manual activation by the plant operator. Adjustments are made to optimization software as results are obtained. Also, water cannons are installed to provide sootblowing of boiler tube-walls in the furnace area. The NN-ISB optimization system is programmed to activate sootblowers only when and where needed. The need is determined by signals indicating that heat transfer from combustion products to the heat-absorbing surfaces in the boiler is being impacted to the point where NO_x emissions and heat loss could rise to unacceptable levels. Activation also is influenced by opacity readings. Spikes in opacity readings indicate that the PM control system is being overloaded, which calls for earlier or sequential activation of sootblowers.

Benefits

NN-ISB technology offers a low-cost approach to enhancing the efficiency and reducing NO_x and PM emissions at coal-fired plants by optimizing control of heat transfer surface fouling. Fouling of heat transfer surfaces in coal-fired boil-

Project Duration 30 Months	Period of Operation 24 Months	Status/Schedule *Estimated date

ers by ash and slag compromises plant efficiency by impeding transfer of heat to the working fluid (water/steam). Heat remains in the flue-gas and exits to the environment without beneficial use. This loss in efficiency translates to higher consumption of fuel for equivalent levels of electric generation; hence, more gaseous emissions are produced. Also, as fouling of the boiler increases and the rate of heat transfer decreases, peak temperatures increase, which increases NO_x emissions. Due to the composition of coal, PM is also a by-product of coal combustion. Modern utility boilers usually are fitted with electrostatic precipitators (ESP) to aid in the collection of PM. Although extremely efficient, these devices are sensitive to rapid changes in inlet mass concentration as well as total mass loading. Without extreme care and due diligence, excessive soot can overload an ESP, resulting in high levels of released PM. Utility boilers use sootblowers to dislodge and clean heat transfer surfaces through application of steam, water, or air using established rules or operator judgment. As noted above, NO_x and PM emissions and boiler performance are directly affected by the sootblowing practices on a unit. NN-ISB technology optimizes sootblowing by controlling ash and slag buildup based on real-time events and conditions in the boiler, through neural-networks that use programmed logic to act on the information before certain performance thresholds are crossed.

Status/Accomplishments

The project was selected for award on September 26, 2001. On July 9, 2002, a cooperative agreement was awarded. The National Environmental Policy Act (NEPA) requirements were met with a Categorical Exclusion (CX) on June 21, 2002.

Design, procurement, and installation of subsystems were completed in December 2002. Project operations were initiated in January 2003 when baseline testing of individual system components commenced. Checkout of each subsystem was conducted to verify the manufacturer's specifications.

In May 2003, parametric testing was initiated for training of the neural network, and preliminary first stage NN-ISB was installed at TECO Big Bend in September 2003.

Preliminary closed-loop (automatic mode) testing was initiated in December 2003, with verification and validation of automatic-mode operation using real-time operating data in April 2004.

STATUS		
Report	*Final Report Issued*	*9/05*
	Draft Report Issued	*2/05*
Operation	*Operation Completed*	*12/04*
	Operation	*1/03*
Construction	*Construction*	*11/02*
Design	*Award*	*7/02*
PreAward	*NEPA Completed (CX)*	*6/02*
	Selection	*9/01*

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In August 2004, acceptance testing of the NN-ISB system in the automatic mode was completed. In late December 2004, testing of the system was completed, ending the "benefits demonstration" phase of the project.

The draft final report was issued in February 2005, and the final report was accepted by DOE in September 2005.

Results Summary

There are innumerable soot blowing control systems with varying levels of sophistication in use throughout the industry. The NN-ISB system is believed to be a superior control system largely because of the innovative software it employs. Indeed, the improvements demonstrated by this project are evident in NO_x emission reduction, efficiency, and opacity control, albeit the overall success of the technology was somewhat compromised by problems with water cannons and some other components originally intended for the project. The benefits achieved go well beyond ordinary manual sequencing protocol, and include higher integration of soot blowing systems. To accurately measure operating results, it was determined that open loop, closed loop, and extended modes of operation should be examined. These modes were performed in 15-minute intervals during the months of September and October 2004. Two types of coal blends were used during the open loop, closed loop, and extended modes, one producing relatively higher NO_x than the other. Specific conclusions from the demonstration follow.

1. A neural network soot-blowing system, *i.e.*, the NN-ISB system, was installed on the test unit along with the instrumentation to permit measurement of NO_x and opacity reduction, as well as improved efficiency. This instrumentation provided the measurements as planned.
2. Unit efficiency contribution was calculated by means of the total Performance Efficiency Index, revealing an improvement of 10 Btu/kWhr at high load to 50 Btu/kWhr at low load, when comparing the open loop to closed loop NN-ISB tests.
3. When the closed loop NN-ISB was compared to the 2002 baseline year, improvements of 20 Btu/kWhr at high load points to as much as 420 Btu/kWhr at low load were observed. The project participant acknowledges, however, that several other operational conditions may have contributed to these values.
4. NO_x reductions recorded by the NN-ISB ranged from no measurable difference to 8.5 percent NO_x reduction, compared to baseline conditions using a variety of coal and unit operating conditions.
5. Opacity measurements during the same period of NO_x data acquisition indicated no measurable difference, while examination of the opacity trends during open loop and closed loop indicated an improvement ranging from 1 percent to 1.5 percent during soot blowing activities.

Tampa Electric Big Bend Station.

Project Summary

The neural network process is dependent upon a component, known as the Executive Pegasus, for coordinating the tasks associated with the NN-ISB and an optimizer. The Executive Pegasus determines the optimum heat distribution relative to the target objectives of the project. The process adjusts the factors needed under the list of target objectives for use by the optimizer. A model is used to project the timing of soot buildup. The system also includes a process for generating and maintaining certain system constraints.

An Application Programing Interface (API) was used for several key components and sensors, and a Human Machine Interface (HMI) for the operators was programmed into the unit's existing Distributed Control System (DCS). In order to activate intelligent soot blowing, a set of standard displays was developed and coded for this component of the project. A set of overview displays also was created to track essential information.

Because there was an existing base of relevant knowledge gained from pre-existing soot-blowing practices, information was codified through a combination of parametric tests, and then was incorporated as part of the NN-ISB constraints. Information relevant to new factors also was gathered during the parametric tests, and similarly incorporated into the system.

While accumulation of data pertinent to the objectives of the project is necessary, the heart of the project remains the neural networks that provide the ability to build non-linear empirical models. This technology has the advantage of the capability to self re-tune the system while on-line. It is this feature that takes into account changing fuel conditions, equipment performance, and environmental conditions.

The project was full scale and established significant results for emissions reduction and unit performance improvements. The unit is rated at a nominal 455 MW, and in this respect was well suited to demonstrate applicability of the technology to other utility boilers. The unit also experienced a variety of typical unit circumstances during the demonstration period, and therefore was representative of units across the United States.

Economics

It is difficult to perform an economic analysis because the cost of installing a NN-ISB system will vary widely from plant to plant, depending on many factors including boiler type and size, fuel being burned, and the instrumentation and control system already in place. The following analysis is based on a new installation in a unit similar to Big Bend No. 2. Although the benefits assumed in this analysis were not fully achieved by this project, it is likely that they are achievable in a new installation that incorporates the lessons learned.

There are two major potential savings from installation of a NN-ISB system. The first is a reduction in coal usage as a result of an efficiency gain. The coal burned in Unit No. 2 is estimated at one million tons per year, at a cost of $40/ton. If an efficiency improvement of 1 percent can be achieved, this would decrease coal consumption by 10,000 tons/yr for a savings of $400,000/yr. Furthermore, this efficiency improvement would result in a reduction of SO_2 and CO_2 emissions in direct proportion to the reduction in fuel consumption.

The other potential savings is in the area of NO_x reduction, which can be quantified by using the value of a NO_x allowance on the trading market. At an assumed heat rate of 10,000 Btu/kWh and a capacity factor of 60 percent, the NO_x emitted from Big Bend Unit No. 2 is estimated to be 7,000 tons/yr (0.6 lb/10^6 Btu). A 5 percent reduction in NO_x emissions would eliminate 350 tons/yr of NO_x. Assuming that the NO_x cap and trade program is available at the plant installing the NN-ISB system, and that the value of one NO_x allowance is $2,000, this would amount to an annual revenue of $700,000.

The cost of this project was about $3,400,000, which included not only testing the NN-ISB system, but also testing water cannons and various novel instruments, as discussed above. The cost of the NN-ISB system alone was about $600,000. Because this was a first-of-a-kind project with special challenges, Pegasus Technologies estimates that costs for a new project to install NN-ISB incorporating lessons learned would be in the range of $300,000 to $500,000, provided that no new equipment or instrumentation were required at the plant. If only benefits from efficiency gains and NO_x reduction are considered, the project would pay off in five to nine months. Any additional benefits from improved performance or reduced maintenance would decrease this payout period, while any additional costs would increase the payout period.