PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Power Plant Improvement Initiative (PPII)

10/2008

Big Bend Power Station Neural Network-Intelligent Sootblower (NN-ISB) Optimization (completed)

Project Description

The overall goal of this project was to develop a Neural Network-Intelligent Sootblowing (NN-ISB) system on the 445 MW Tampa Electric Big Bend Unit #2 to initiate sootblowing in response to real-time events or conditions within the boiler rather than relying on general rule-based protocols. Other goals were to increase unit efficiency, reduce NO_x, and improve stack opacity.

In a coal-fired boiler, the buildup of ash and soot on the boiler tubes can lead to a reduction in boiler efficiency. Thus, one of the most important boiler auxiliary operations is the cleaning of heat-absorbing surfaces. Ash and soot deposits are removed by a process known as sootblowing, which uses mechanical devices for on-line cleaning of fireside boiler ash and slag deposits on a periodic basis. Sootblowers direct a cleaning medium (steam or water) through nozzles against the soot/ash accumulated on the heat transfer surfaces to remove the deposits and maintain heat transfer efficiency.

Conclusions/Benefits

Project testing was completed at the end of December 2004, and the final report was issued in September 2005. The project showed that the NN-ISB can benefit efficiency. There was a clear improvement at low loads, with the benefit decreasing as the load increased. During closed loop (automatic) operation of the NN-ISB, the reported efficiency gains were in the range of 0.1 to 0.4 percentage points compared to baseline. Results with open-loop (manual) operation were not quite as good. A factor in this efficiency benefit was a decrease in the steam used for sootblowing. With more operating experience, gains at the high end of the load range should also be achievable.

A goal of this project was to reduce NO_x emissions, and it is reasonable to believe that optimizing sootblowing would be beneficial for NO_x reduction because the temperature profile in the furnace will be improved. However, the data presented in the final report do not clearly show this. There is a great deal of scatter in the data, with NO_x ranging from about 0.45 lb/million Btu at a load of 150 MW to about 0.7 lb/million Btu at a load of 450 MW. Although automatic operation is clearly better than manual operation, still the data generally fall in about the same range as the baseline data for NO_x emissions.

These results are, perhaps, not unexpected, since the program as originally planned included the use of water cannons, which, because of problems they experienced, were not available during the NN-ISB tests. Ideally, the water cannons would have provided cleaning and de-slagging of the furnace while concurrently optimizing heat rate. Due to the unavailability of the water cannons, the unit suffered excessive water-wall slagging, leading to higher temperatures in the combustion zone and, hence, higher levels of thermal NO_x formation. In addition, much of the instrumentation installed for the project did not perform up to expectations. In a system with fully functioning instrumentation and equipment, the results would be better.

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PARTNER

Tampa Electric Company

ADDITIONAL TEAM MEMBER

Pegasus Technology, Inc.

LOCATION

Tampa Electric's Big Bend Power Station

Apollo Beach,
Hillsborough County, FL

COST

Total Project Value
$3,364,812

DOE/Non-DOE Share
$905,013 / $2,459,799

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Improving stack opacity by providing a more uniform flue gas leaving the boiler was another project objective. Like most coal-fired power plants, Big Bend uses an ElecroStatic Precipitator (ESP) to control particulate emissions in the flue gas. ESP operation is sensitive to rapid changes in inlet particulate mass concentration and total mass loading. Excessive soot removal from heat transfer tubes in the boiler can overload the ESP and lead to inadequate capture of particulate matter (PM), resulting in increased PM emissions. Results from the NN-ISB optimization clearly show an improvement of 1 percent to 1.5 percent in opacity for closed-loop (automatic) compared to open-loop (manual) operation over the entire range of sootblower steam flows.

Prior to this project, sensors and controls related to sootblowing were usually treated as isolated systems that were not fully integrated with any type of comprehensive goal in mind. This project evaluated a NN-ISB system that has the built-in ability to understand, evaluate, and optimize the process as an entire system with multiple, real-time objectives. Integration of the sensors went well, and communication was established to the neural network system with all sensors and elements of the project.

The project proved that such systems could be linked together despite the use of proprietary networks. Further, it proved that the sensors could provide data that could be correlated and could achieve a set of objectives. However, the lack of some anticipated inputs to the model limited the capabilities of the NN system to model the system as accurately as hoped, and this resulted in the project's not fully achieving all its goals. However, the NN-ISB system appears to have worked well and undoubtedly improved boiler operation.

In addition to the main benefits, the following secondary benefits were observed:

- Total sootblower steam usage was lower with the optimization system engaged.
- Full integration of new sensor technology and optimization was completed.
- Boiler drum and pressure operation was qualitatively improved, the operators stated.
- Steam tube temperatures benefited and showed less deviation at high loads.

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. If the coal burned in Unit No. 2 cost $40/ton, an efficiency improvement of 1 percent would decrease coal consumption by 10,000 tons/year for a savings of $400,000/year.

The second 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. The NO_x emitted from Big Bend Unit No. 2 is estimated to be 7,000 tons/year (0.6 lb/106 Btu). A 5 percent reduction in NO_x emissions would eliminate 350 tons/year of NO_x, which, assuming that the NO_x cap and trade program is available at the plant and that the value of a NO_x allowance is $2,000/ton, would amount to an annual revenue stream of $700,000.

Assuming that the cost of installing a NN-ISB system is in the range of $2,000,000 and considering only benefits from efficiency gains and NO_x reduction, the project would pay for itself in about two years. Any additional benefits from improved performance or reduced maintenance would decrease this payout period.

The major conclusion from this project is that NN-ISB is a sound idea with significant potential. This project did successfully demonstrate NN closed-loop operation without causing unit upsets or violating any constraints and with operator acceptance.

Tampa Electric's Big Bend Power Station