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SUCCESSFUL LOW NO_x AND BMS UPGRADE PROJECT EXPERIENCE AT PENNSYLVANIA POWER AND LIGHT COMPANY'S MARTINS CREEK SES UNITS 1 & 2

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ABSTRACT

This paper presents the successes and lessons learned during a recent low NOx retrofit and control system upgrade at Pennsylvania Power and Light Company's (PP&L) wall fired, coal burning Martins Creek Steam Electric Station Units 1 & 2. The principals involved in the project were PP&L and DB Riley, Inc. Both Units were retrofit with twelve Controlled Combustion Venturi (CCV®) low NO_x burners with advanced overfire air (OFA) systems. In addition, new burner management systems (BMS) including burner front piping and valves were installed. The installation was performed by PP&L.

The entire fuel system from the top of the exhausters to the furnace was replaced as part of this effort. New coal pipes meeting current National Fire Protection Association (NFPA) guidelines with coal plug valves and knife gate valves were installed. To support the new burners and OFA systems, complete new windboxes were installed to take full advantage of the burners movable shroud. DB Riley designed and programmed the new BMS using Allen-Bradley programmable logic controller (PLC) hardware interconnected to the existing Leeds and Northrup distributed control system (DCS). The system start-up and de-bugging was a combined PP&L/DB Riley effort.

PP&L upgraded the existing rotating table coal feeders to incorporate variable speed drives to improve mill performance throughout the load range. This paper will present the coordinated effort put forth by each company toward the goal of a successful retrofit with the hope of assisting others who may be planning a similar effort. A summary of the operating results will also be presented. The lessons learned from this joint effort will also be presented.

BACKGROUND

This project was part of PP&L's company-wide plans to comply with the NOx reduction requirements of both Title I & Title IV of the 1990 Clean Air Act Amendments. Low NO_X burners with separated overfire air systems were retrofit to five tangentially and four wall coal fired boilers. The low NO_X burner and overfire air systems for the wall fired retrofits were furnished by DB Riley.

These projects, like other environmentally driven projects, had to be designed prior to the release of final regulations to meet aggressive compliance dates. PP&L recognized that proper planning and a team approach would be essential in successfully executing the projects on schedule and within established budgets.

PROJECT ENGINEERING

PP&L conducted boiler emissions testing and a review of available NO_X reduction technologies. Operating data was collected and two proposal specifications were prepared; one for the tangentially fired and one for the wall fired boilers. Proposals were solicited from vendors with proven low NO_X retrofit experience that included burners, OFA, coal piping, ignitors and BMS equipment. PP&L evaluated the proposals and awarded the wall fired burner work to DB Riley in November of 1992. The detailed work fell into eight work packages:

1. **Baseline Testing**–The collection of any operating data necessary to properly design the low NO_X retrofit was the responsibility of DB Riley. This included any special test instrumentation.
2. **Equipment Design**–Burner design, combustion air modifications, and design of all components necessary to adapt them to the existing boilers was the responsibility of DB Riley.
3. **BMS and Controls**–Design of the flame scanners, BMS, new control loops and integration with the existing DCS hardware was the responsibility of DB Riley.
4. **Physical Electrical**–Design associated with the BMS/DCS cables was the contracted by PP&L to an Architect/Engineer (A/E).
5. **Design and Fabrication Monitoring**–Vendor design and fabrication monitoring was joint effort between PP&L, the electrical design A/E and a contracted shop inspector.
6. **Installation**–This was the responsibility of PP&L's Construction Department.
7. **Start-up and Optimization**–Burner start-up was a joint effort between DB Riley and PP&L. Optimization was the responsibility of DB Riley.
8. **Warranty Testing**–Performance acceptance testing was PP&L's responsibility.

During the detailed engineering phase of the project meetings and detailed drawing reviews were held with the required project team members present. These meetings helped to identify and resolve problem areas before equipment was purchased and to insure a smooth transition from the drawing board to the final installation.

EXISTING EQUIPMENT

Martins Creek Units 1 & 2 were originally placed in service in 1954 and 1956 respectively. Each Unit is rated at 140 MW net. The steam generators were manufactured by Foster Wheeler and can each produce 1,340,000 pounds of steam per hour at 955°F and 1325 psig. They are outdoor, single drum, natural circulation, balanced draft, dry bottom, front fired with pulverized western Pennsylvania bituminous coal and have divided furnaces with steam cooled front wall radiant superheaters and water cooled side, division and rear walls. The original burners were located on the front wall in two levels of six burners each. Each unit's burners are supplied with pulverized coal from two D-7-D double ended ball mills. Each mill has two exhausters that each supply pulverized coal to three burners.

Martins Creek Units 1 & 2 are cycling, load following units that are typically on-line only between 6 A.M. and midnight on weekdays. Each unit typically goes through approximately 150 start-ups each year.

NEW BURNER EQUIPMENT

The basic fuel firing arrangement was not changed with the installation of the new low NO_X burners. The original number of burners were replaced with the appropriate number of #6 DB Riley CCV® low NO_X burners in new windboxes. Pressure part modifications were not required for burner installation.

Each new low NO_X burner consisted of a patented Venturi coal nozzle, 30 degree coal spreader, stainless steel burner barrel with expansion joint, silicon carbide throat refractory, air register/shroud assembly, shroud electric linear actuator, register vane manual operator, coal receiving chamber head, air flow measuring device, air atomized number 2 oil fired Class 1 ignitor and two flame scanners.

The burners were supplied with a removable center plug as an option to allow the future firing of natural gas. If it is desired to add future gas firing capability, the center plug can be replaced with a new plug containing a gas plenum and stainless steel gas canes.

A new pulverized coal delivery system was installed from the outlet of the existing exhausters to the burner coal receiving chamber head. This consisted of new three way riffle boxes, air actuated coal plug valves, 14 inch coal piping, and manual knife gate isolation valves located at the burner inlets. It was DB Riley's responsibility to design good pulverized coal distribution to each Unit's twelve burners and the new system tested at less than +/- 5% variation between coal pipes.

NEW BURNER DESIGN FEATURES

The CCV® burner was initially developed in the early 1980's as a low NO_X coal burner for new and retrofit applications. NO_X reduction is achieved with only a single register resulting in a mechanically simple design. Another advantage of the register design is the location of all vane linkages and levers outside the windbox. Only the vane shaft penetrates the burner front plate into the windbox.

The key elements of burner design NO_X reduction are the Venturi nozzle and the low swirl coal spreader located in the center of the burner. The Venturi nozzle concentrates the fuel in the center of the coal nozzle creating a very rich mixture. As this mixture passes over the coal spreader, the spreader blades divide the coal stream into four distinct streams which enter the furnace in a gradual helical pattern producing very gradual mixing of the coal and secondary air. Devolatilization of the coal in the fuel rich mixture occurs at the burner exit in an oxygen lean primary combustion zone resulting in lower fuel NO_X conversion. Peak flame temperature is also reduced, thus suppressing the formation of thermal NO_X.

Another important design feature is the air register/shroud assembly which provides independent control of swirl and secondary air flow. The backward curved, overlapping air register vanes provide manually adjustable swirl control through a direct drive gear reducer. These vanes are manually positioned during initial start-up optimization and are locked into the optimal position for subsequent operation. Burner secondary air flow is controlled by a movable shroud that slides over the vanes. An electrically operated linear actuator is used to position the shroud to maintain the proper windbox pressure. Independent control of the vanes and the shroud offers significant flexibility in controlling combustion, particularly at low load. Secondary air velocity can be maintained at low loads by automatically decreasing the shroud opening. This retains the high degree of swirl necessary for low load flame stability. Burner turndown ratios of 3:1 were demonstrated at Martins Creek Units 1 & 2.

For longer life and improved reliability, the complete register/shroud assembly is located away from the furnace. Also, critical burner parts such as the coal venturi nozzle, coal spreader, and burner barrel are manufactured from heat and wear-resistant materials. All of the vane and shroud shafts penetrating the burner front plate are fabricated from stainless steel to reduce corrosion.

OFA SYSTEM

In addition to low NO_X burners, Riley's advanced OFA system was installed on both units. The system contains one port located roughly above each of the six burner columns and four wing ports. The wing ports are located next to each side wall and on both sides of the division wall. All ten OFA ports are located on the front wall, at the same elevation, approximately twelve feet above the centerline of the upper row of burners. The ports were sized to provide efficient velocity for good furnace penetration and rapid mixing. The elevation selected provides the proper separation from the primary combustion zone for NO_X reduction and sufficient remaining furnace residence time for carbon monoxide reduction.

Each OFA port is rectangular in shape and is divided into 1/3 and 2/3 sections. The air flow through each of the twenty sections is controlled by an individual open or closed damper. With the 1/3 and 2/3 sections, the proper amount of OFA can be controlled throughout the boiler load range. The ports and the dampers are located inside the original upper secondary air ducts above the new burner windboxes. DB Riley's scope of supply included all ductwork, dampers, linkages, front wall tube modifications for the ten port openings and four electric actuators per unit as well as the required control system hardware and logic.

OFA DESIGN FEATURES

DB Riley performed significant research work for EPRI in the mid-1980's to develop the proper design guidelines for OFA systems. This research work utilized both 3-dimensional cold flow modeling and simulations. During these studies, the engineering guidelines for the proper design of OFA systems were developed. From these guidelines, the following key elements were considered to be very critical when designing a retrofit OFA system:

1. Adequate separation must be available between the primary and secondary combustion zones to reduce NO_X.
2. Rapid mixing of the OFA with the primary combustion zone products must exist to promote efficient burnout of the remaining fuel.
3. Adequate residence time in the secondary combustion zone must be available for complete burnout.
4. Independent control of OFA from the burner air must be incorporated into the overall combustion system design.

For long life and improved reliability, the OFA control dampers are located around a bend away from furnace radiant heat. Also, the OFA ports are manufactured from heat resistant stainless steel material. All of the damper shafts penetrating the secondary air duct are fabricated from stainless steel to reduce corrosion.

NEW BMS AND CONTROL EQUIPMENT

To meet current NFPA codes, a supervised manual BMS was included in DB Riley's scope of supply. This included new air operated individual coal pipe shut-off valves, manually-operated coal pipe isolation valves, individual oil ignitor combination purge/shut-off valves, air operated oil header safety shut-off valves, high energy spark ignition for oil gun light-off/purging, numerous safety interlocks and flame scanner equipment. To provide the ability to use different flame scanners and/or different sensitivity settings for coal and oil flames, the burners were specified with two separate scanners, one for oil and one for coal. During start-up and optimization of a prior PP&L boiler, it was discovered that when only one of the two scanners was used, it had difficulty picking up a signal from the random movement of the oil flames. To eliminate this problem, both scanners were wired in parallel to observe the flame simultaneously. This could be done since different scanners and settings for the different fuels were not required.

The BMS uses redundant Allen-Bradley PLC-5 processors which provide automatic transfer without interruption to monitor the burner process. The PLC's were connected to the existing DCS via redundant serial links to provide control room operators with an interface to the BMS through existing familiar equipment.

DB Riley also furnished the DCS hardware and logic for the control additions associated with the new burner/OFA installation. This included control of ignitor oil pressure, secondary air windbox pressure, exhauster auxiliary air damper position, OFA damper position and superheater condenser biasing valve position. Operator display graphic development was a joint effort between PP&L and DB Riley. This included incorporating the above controls into the existing graphics and providing the operators with information on individual burner flame intensity, burner temperatures, NO_X emissions and carbon monoxide emissions.

CONSTRUCTION

All aspects of the project construction were handled by PP&L. The structural/mechanical portion was installed using PP&L's in-house Construction Department labor. Wiring was contracted to local electricians. The simplicity of the burner design and the intensive team design approach greatly minimized burner fit-up problems. The Unit 2 burner and OFA installation was completed during a 35 day outage. The Unit 1 installation required a

61-day outage due to the planned replacement of the furnace front wall burner zone tubing/refractory and additional asbestos abatement.

PERFORMANCE

Optimization of the first unit (Unit 2) was completed during a one month period following the completion of installation. This process was completed while the unit was being dispatched following PP&L's system load fluctuations. This consisted of daily cycling with the unit on-line around 6 A.M. and off-line at midnight.

Initial optimization attempts were restricted due to burner coking and high stack opacity. Coking problems were eliminated when the exhauster auxiliary air damper position optimization was completed. These dampers were optimized to provide sufficient primary air velocity to prevent coal from accumulating in the burner nozzles during low load operation. The high stack opacity was eliminated by changing from the initial 15 degree coal spreader to their 30 degree coal spreader and removing the secondary air diverter. Optimization of the second unit (Unit 1) was completed in less than one week basically using the same burner settings developed during the Unit 2 optimization.

PP&L conducted warranty performance testing on both units during December of 1994. All contract requirements were satisfied. These requirements consisted of boiler capacity, furnace stagging, steam temperature control, opacity, carbon monoxide, burner metal temperature, furnace exit gas temperature, coal distribution, air heater gas exit temperature, fly ash combustibles, NO_X and secondary air pressure drop. The burners and OFA systems have the ability to reduce NO_X by greater than 65% with very little effect on normal boiler operation. The following is a brief summary of key boiler performance data:

	Baseline	LNB	OFA
NO_X, lb/mmBtu	1.0	0.5	0.35
Fly Ash LOI, %	20	21	22
Stack CO, ppm	N/A	50	90
AH Gas Out, °F	280	285	284

LESSONS LEARNED

1. **Flame Scanners**–Including the flame scanners in the burner supplier's scope gave them the responsibility for locating, mounting hardware, scanner type and instrumentation. This resulted in the burner supplier having the responsibility for system performance and eliminated conflicts between equipment selection and mounting location.

2. **Burner Coal Balancing**–Extending the burner supplier's scope of supply to begin at the outlet of the exhausters gave them responsibility for fuel distribution design. This resulted in achieving good fuel balance which is critical to burner NO_X and fly ash combustible performance.

3. **Operator Interface**–Expanding the existing DCS graphics to include the new BMS information and controls provided the control room operators with a system they already had familiarity. The BMS and DCS serial link has proven to be both responsive and reliable.

4. **Auxiliary Air Control**–Installing automatic control of the exhauster auxiliary air dampers has been an effective method of controlling primary air velocity over the entire load range. This maintains adequate velocity to prevent coal fall-out in the piping and burners. It also maintains the proper velocity in the CCV® burner venturi for optimum NO_X reduction. It is important to set-up the automatic operation of these dampers as early as possible in the start-up/optimization process to prevent coking problems.

5. **Variable Speed Coal Feeders**–The variable speed drives installed on the existing rotating table feeders have improved both raw coal flow to the pulverizers and pulverizer fineness. The original drives controlled pulverizer coal level by operating either off, on low speed or on high speed. Operation between off and low speed created interruptions in raw coal flow. This could result in raw coal plugging the downcomers supplying the feeders and in pulverizer level fluctuations. The varying level created pulverized coal fineness and furnace oxygen fluctuations. The variable speed drives have improved pulverizer coal fineness from 60% to 80% through 200 mesh and from 98% to 99% through 50 mesh.