CONTROLS UPGRADE CASE STUDY FOR A COAL-FIRED BOILER

ABSTRACT

This paper discusses the measures taken to upgrade controls for a coal-fired boiler which was experiencing problems with primary air flow, furnace instability, and inability to meet load ramping and dispatching requirements. A controls upgrade project for an electric utility was conducted and served to illustrate the potential problems and their solutions which are discussed in this paper.

Measures were implemented to improve control of the primary air which enhanced air fan controllability and substantially reduced auxiliary power use. Instability problems in furnace draft and flame quality were corrected by modifying the burner spreader configuration and the position of the gas recirculation system, and upgrading the air register hardware system to simplify interlocking and implementation could then be reasonably performed. The net result of the upgrade program was a more stable flame and a system that could automatically follow load but with much better pulverizer turndown. Dispatching was simplified and permitted a 10 percent per minute load ramping capability. Analysis of the fuel burning hardware prior to the controls upgrade and modification was an essential part of the total program.

INTRODUCTION

The basic functions of a combustion control system other than to manipulate the fuel and combustion air devices to permit the boiler to change load are to provide:

1. Efficiency - Which is made up of two components, burning all the fuel and not utilizing an excessive amount of air.

2. Safety - The prevention of furnace, burner, and pulverizer system explosions, prevention of unnecessary unit trips, and the maintenance of a suitable environment for those who must work near the steam generator.

3. Environmental Compliance - In terms of both NO_X compliance and other emission limits, as well as unit operating limitations which are imposed by precipitators, baghouse and scrubbers.

4. Operator Interface - The provision of adequate information to the control room operator, the roving attendant, and plant staff for making decisions in plant operation, and a reporting system for company management which includes a history and fiscal accounting of the unit's operations.

The above requirements are further defined by the actual boiler configuration. Many will maintain that pulverized coal firing techniques, controls and characteristics are the same in any furnace, but in reality the burner designs and general method of firing are drastically different among the various boiler manufacturers. As a result, a change in fuel burning philosophy requires substantial changes in the various boiler manufacturer's systems. Even within one boiler manufacture's range of pulverizer equipment, substantial changes may be required due to individual variation between units. However, the general philosophy of "if it isn't broke, don't fix it" is a good starting point for applying a generalized control scheme to a given pulverizing system.

Each boiler manufacturer has recommended a standard control scheme for his own pulverizing equipment. Each manufacturer-recommended scheme has worked previously in many applications, and is generally based upon proven principles and methods. Unfortunately, these systems frequently require review and modification in order to provide the optimum control scheme to match the detailed requirements for a specific installation. The boiler manufacturers are justified in recommending conservative designs, but unless they are required to furnish the control system and provide the coordination between the control system, equipment and actual operation, they should not be expected to recognize the various factors which cause a system to fail to operate optimally.

EXAMPLE FROM A CONTROLS UPGRADE PROJECT

For example, these problems and solutions are illustrated in a controls upgrade project for one electric utility's coal-fired unit. The unit, 230-MW turbine served by a pulverized coal-fired boiler with a front and rear fired dry bottom-turbo furnace design, is on a small utility system, and is normally dispatched to have relatively large load swings on a daily basis. Nighttime loads in the 30 to 40 percent range are common, and the unit usually gets up into the 90 to 95 percent load range at some time on most normal days.

A change in fuel heating value created problems with primary air control, furnace stability, and the ability of the unit to follow load. The fuel quality range was intentionally specified to be quite wide to provide as little limitation on the utility's purchasing procedures as possible. Once the units were in operation and the coal under contract, the most economical fuel was found to be at the high end of the range of coal specified: a relatively low volatile eastern bituminous coal with a high heating value and high ash content, but with very good slagging and fouling characteristics.

Primary Air Flow

Since the heating value of the fuel was very high, fuel mass flow rate dropped (so that Btu flow rate could remain constant). This required that the primary air flow (which transports fuel to the furnace) be quite low, creating a situation in which the primary air control was operating in the extreme low end of the overall control range. Although this would sometimes be no problem, in this case it tended to make the response erratic and inconsistent.

Several solutions were tried to improve control of primary air. First, pinning some of the primary air fan inlet dampers closed provided a small improvement in control response by reducing fan capacity. Secondly, using a perforated plate at the fan inlet to shed excess fan capacity provided a somewhat more satisfactory control. The final solution however, involved trimming fan impellers, which enhanced the controllability of the fan, and at the same time conserved a substantial amount of auxiliary energy.

Furnace Instability

While these improvements to primary air control were important, the primary problem with the unit due to the fuel quality continued to be furnace instability. Flame patterns in the lower furnace were quite erratic, furnace draft variations were far higher than normally considered acceptable and flame scanners did not provide a reliable, trouble-free indication of flame, even during a steady load condition. In order to compensate for this erratic firing condition, the combustion control system was slowed down (detuned) so much that load following became almost a manual operation.

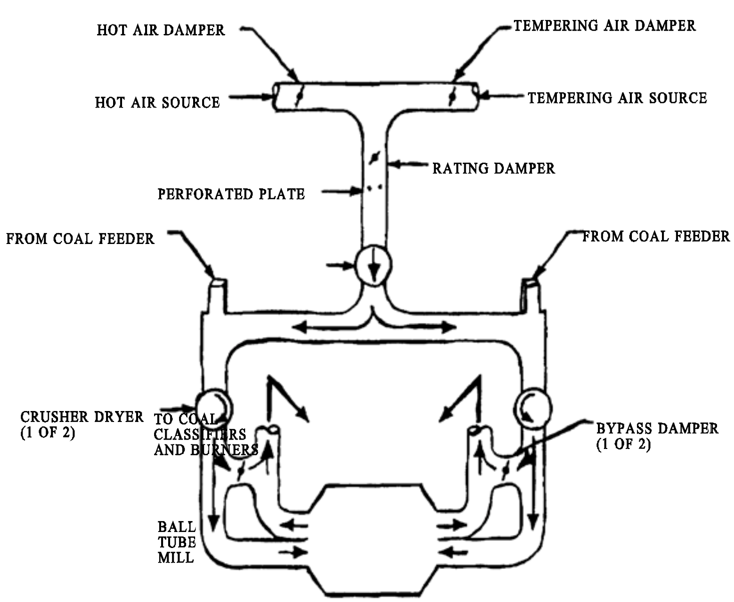
Investigation of the furnace, burners, and firing conditions resulted in modifications to the burner system to correct flame patterns. The burner diffusers which were formerly directed toward the center of the burner not only created an unstable furnace by making a long, black flame, but also probably contributed heavily to the unburned carbon in the bottom ash which had been a consistent problem from the beginning. Modifying the burner spreader to an upswept design provided for better ignition without apparently increasing the NO_X production in the furnace.

The basic furnace stability was improved at full load but was still impaired with a pulverizer out of service. Although the furnace design was symmetrical with a single row of burners on both the front and back, there appeared to be substantial differences in flame recognition and individual burner stability between the two burner fronts. This observation led to speculation that introduction of the gas recirculation system on the rear side of the furnace could be a primary cause. Modifications to move the gas recirculation flow to a relatively symmetrical, center-of-furnace location resulted in the first real progress in furnace stability. In addition, subsequent testing showed that out-of-service burners were leaking so much secondary air that the burners in service were running air-deficient, creating localized reducing atmospheres. General upgrading of the burner air register hardware system corrected this problem and furnace stability again showed immediate and substantial improvement, moving to the normally acceptable range.

Control System Analysis and Simplification

Once furnace stability was achieved, analysis of the control system could be reasonably performed. The control system had been so detuned and modified to compensate for the severe flame instability, that realistic efforts to provide a responsive system were almost impossible. Fortunately, the modern, solid state electronic combustion control equipment which was furnished with the unit and substantial capabilities in terms of flexibility to permit modifications without the purchasing of additional hardware. This flexibility, however, is a two-edged sword. The modern equipment provides a great deal of capability from relatively inexpensive, standard components, but many of the highly acclaimed control system features do not necessarily contributed to solving the problem. Features such as adaptive gain, smart controllers, antireset windup and multiple function biasing are great, but they can occasionally interfere with the basic functioning of the system, particularly if it is operated near the end of the range limits of the control involved.

As a example of the complexity reduction which was accomplished, the “original” pulverizer flow control diagram (see Figure 1) shows a split function from the pulverizer demand signal (see Figure 2). The pulverizer bypass dampers are required to permit the air-to-fuel ratio to be increased at lower loads, so that pulverizer turndown capability can be maintained without coal line velocity dropping below the minimum allowable. This increased primary air-to-fuel ratio also helps flame stability by permitting the flame to move closer to the burner.



By simply calibrating the control drive to the needs of the driven device (see Figure 3), all of the functions required for pulverizer control can be operated in parallel, thus avoiding the need for several different control signals telling this provides amore straightforward control and in this case a more flexible operation. It also makes the system far easier to recalibrate and adjust. Both the air flow control and the gas recirculation fan control systems were similarly simplified (see Figure 4).

Results from the Upgrade Program

The net result of the total upgrade program resulted in not only a more stable furnace and a system that could automatically follow load, but gave much better pulverizer turndown. Previously, when going from minimum load to approximately 80 percent load, the transition between single pulverizer operation and two pulverizer operation had essentially no overlap. The operators were actually avoiding one certain load range because it was above the capability of single pulverizer operation, but below the turnbowd for two-pulverizer operation. The relatively large, ball tube pulverizers (40 percent capacity of the unit, per pulverizer) were relatively slow to bring o line, due to their large stored coal inventory. Therefore operation needed substantial overlap in the allowable range of operation between single pulverizer and two pulverizer operation. After the modifications, there was a 10 to 20 percent overlap in capability giving the operators, under normal load changes, plenty of time to bring a pulverizer into service on increasing load, or taking one out of service on decreasing load. This simplified the load dispatching and has permitted essential compliance to a 10 percent per minute load ramping capability.

SUMMARY

Modification and upgrading of control systems, in the specific case involved, would have been impossible without a thorough review, analysis of the fuel burning hardware, preceding the controls upgrading and modification, was an essential part of the total program.