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Managing slagging at Monroe Power Plant using on-line coal analysis and fuel blending

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Abstract

Monroe Power Plant of DTE Energy is a 3100 MW (net) station in southeastern Michigan. This station consists of four Babcock & Wilcox wall-fired boilers firing blends of southern Powder River Basin (PRB) subbituminous coal along with Central Appalachian bituminous coals. The station manages the coal properties in the various fuel blends using an on-line analyzer. This analyzer measures the complete proximate analysis, the heating value, and the ash chemistry of the coal being loaded into the silos. The on-line analyzer program has been used to control the slagging properties of the coal being burned, with the result being a dramatic reduction in costly slagging incidents at the plant. The on-line analyzer is used to guide modifications to the blend, it is also used to provide guidance to operators concerning the fuel being fed to pulverizers and burners. This paper describes this effort in the context of an overall combustion program and it details the results of that program.

Keywords: Fuel blending; PRB coal; On-line analyzer; X-ray fluorescence; Slagging and fouling; Ash characteristics

1. Introduction

Monroe Power Plant, consisting of 4 units each capable of generating 775–795 MW_e (net), was originally designed to burn Pittsburgh Seam bituminous coals. Built in the early 1970's, it originally employed B&W cell burners. Further, it was equipped with small electrostatic precipitators with typical SCA values of 191 and 286 depending upon unit.

Over the course of time, numerous changes have been made to the Monroe Power Plant. It was a unit used to pioneer the use of high percentage blends of Powder River Basin (PRB) coals with bituminous coals. As such a large coal blending facility was constructed such that specific blends could be employed. These blends are based upon plow feeders and belt scales underneath the coal pile; with reclaim operations capable of "dialing up" the precise blend required. Fig. 1, an overview of the Monroe Power Plant, shows the coal handling facility in the background. The coal handling facility supports using 3 piles—each of a different type of coal. The facility is capable of blending various percentages of low sulfar central Appalachian (LSCA), mid sulfar central Appalachian (MSCA) and PRB coals. The emphasis for PRB coals is southern PRB coals: Black Thunder, Antelope, North Antelope, and similar fossil energy sources.

2. On-line analyzer program

With initial support from EPRI, Monroe Power Plant installed an on-line analyzer to evaluate coals being sent from the coal yard to the power plant. This program evolved over several years. Currently the plant employs an X-ray fluorescence analyzer (XRF) supplied by QC, Inc. The analyzer is at the heart of a complete program involving the following systems:

- A coal sampler retrieving coal from the C-4 belt and crushing it to a size appropriate for the analyzer
- An on-line analyzer capable of evaluating the coal for numerous constituents as discussed below
- A software package–the digital fuel tracking system (DFTS) supplied by ECG consultants–that provides coal information to the supervising operator, the shift supervisor, and various engineers

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Fig. 1. Monroe Power Plant.

The analyzer, coupled with a moisture meter, has significant capability and provides the plant with the following information:

- As-received heat content (Btu/lb)
- Moisture (%)
- Ash (%)
- Volatile matter (%)
- Fixed carbon (%)
- Sulfur (%)
- Silica (%)
- Alumina (%)
- Titania (%)
- Iron oxide (%)
- Calcium oxide (%)
- Magnesium oxide (%)
- Potassium oxide (%)
- Sodium oxide (%)
- Phosphorus pentoxide (%)

Numerous other minerals are also evaluated by the XRF including barium and manganese.

The plant, and the DFTS software, converts some of those data into additional measures for the plant operations and engineering personnel. These measures include:

- Volatility (volatile matter/fixed carbon ratio)
- Opacity indications (silica plus alumina percentage)
- Base/acid ratio
- Calcium/iron ratio
- Sulfur loading (lb $SO_2/10^6$ Btu)
- Ash loading (lb ash/10^6 Btu)
- Slagging alkalinity (%)

More recently, techniques have been developed to calculate the ultimate analysis from the analyzer signals and data. These coupled with data from the PI system, provide the plant with the capability for calculating heat and material balances about the boiler along with residence times in each section of the boiler (furnace, secondary superheat section, primary superheat section, reheater, economizer). Further these data provide the basis for calculating furnace and boiler cleanliness factors plus temperatures in all zones of the boiler and, consequently, gas velocities through each section and gas velocities influent to the electrostatic precipitators.

The analyzer and digital fuel tracking system are at the heart of the complete computer models of each boiler. They complement extensive instrumentation of the boilers including furnace exit gas temperature (FEGT) measurements and profiles, CO profiles across Monroe Units 1 and 2, and temperature and O_2 measurements at all sections of the boiler and subsequent downstream equipment. These data are critical since Units 1, 3, and 4 have been equipped with selective catalytic reduction (SCR) systems; and all units will be equipped with acid gas scrubbers.

The heart of the system is the analyzer and the DFTS software bringing information to the operators. The DFTS system of ECG is shown schematically in Fig. 2. This system, based upon both experimental data and calculations, provides the basis for documenting when the coal will leave the silos and arrive at the mills and burners.

The operators obtain their information from a screen shown in Fig. 3. Note that the screen conveys both fuel information and guidance. It defines the fuel being fired at the current time plus fuel that will enter the boilers in 1, 2, and 4 h. It also defines the information concerning the fuel on the belt going to the coal silos.

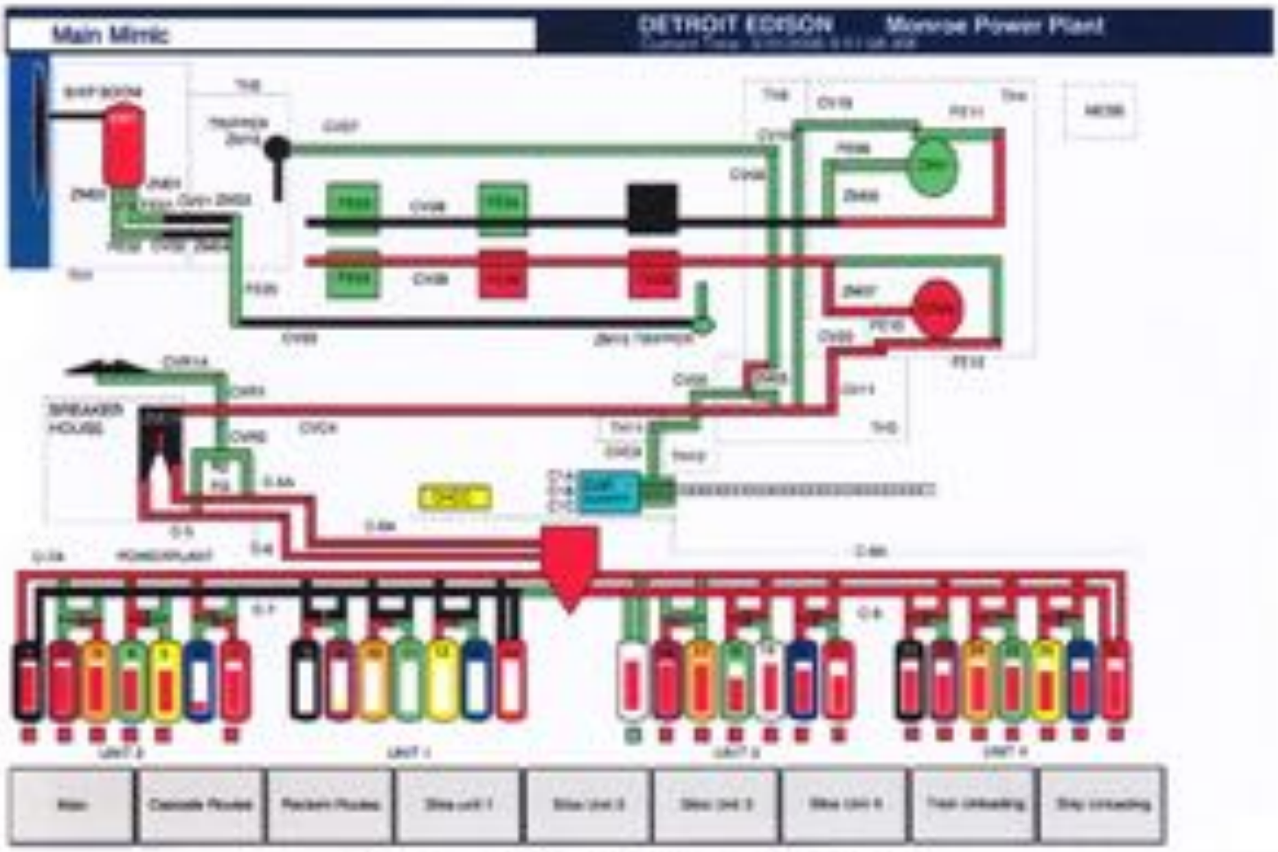

Fig. 2. Schematic of the digital fuel tracking system developed by ECG.

Note that the screen has been designed to give the operator enough information to function, but not so much information that he/she is overwhelmed. Note, also, that trends are shown for critical variables including FEGT. The green values indicate that the fuel is of sufficient quality for full load operation without difficulty. Yellow values provide caution. Red values indicate that the quality of coal–for a given measure–has deteriorated to the point where action may be required.

The operator uses this information to guide his/her control over the operations. The shift supervisor, working with engineering, uses the data concerning the coal on the C-4 belt to adjust the blend accordingly. Small blend adjustments can relieve pressure.

The analyzer program is an essential exercise. Monroe Power Plant has committed to ensuring >90% availability of the analyzer system including sampler, crusher, analyzer, and software. Further, the instrument is calibrated monthly to ensure that instrument drift is minimized.

3. Complementary programs

Given the ability of the analyzer to provide definitive information on fuel quality and its implications, Monroe Power Plant developed complementary combustion programs including installation of swirl-stabilized burners of ACT to replace the impeller-based low-NO_x burners at the plant (see Fig. 4). Updated probes to profile FEGT also have been installed. The burner modifications provided a means for completing combustion lower in the furnace, and provided a means for reducing FEGT by about 100°F.

4. Managing slagging and fouling

Monroe Power Plant uses not only the typical measures (e.g., base/acid ratio) to evaluate slagging and fouling, but it also uses chemical fractionation data developed in a database by Sandia National Laboratories. Further, Monroe Power Plant has commissioned work with The Energy Institute of The Pennsylvania State University to perform chemical fractionation experiments on its parent coals and on its coal blends. This work is performed recognizing that the traditional measures of coal quality are necessary but not sufficient to define the properties of low rank coals.

These data then provide a basis for evaluating slagging properties of coal blends using the following regression equation derived from the Sandia database, based upon the behavior of calcium:

$$AFT_{Ca} = 4397.5 - 2217.1(WLF) - 2262.1(IEF) - 2035.8(ASF)\ r^2 = 0.836. \quad (1)$$

Fig. 3. Typical screen from the on-line analyzer. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Definitions

$AFT_{I,o}$ Ash fusion temperature, initial deformation, oxidizing
WLF Water leachable fraction
IEF Ion exchangeable fraction
ASF Acid soluble fraction

Fig. 5 shows the relationship between measured and predicted ash fusion temperature (initial, oxidizing) from this equation.

This equation permits relating the chemical fractionation data to prior base/acid and slagging alkalinity data from the coal analyzer. Monroe Power Plant is now in a more extensive program to evaluate chemical fractionation and its relationship to the more traditional measures. The lynch-pin for this, however, is the measure of slagging alkalinity used by Monroe Power Plant based upon the analyzer.

Continuous experimentation has shown that the blends do not behave like the weighted average of the two parent coals. When burning high percentage blends (e.g., ~65% PRB) understanding the influences of blending on the parameters measured by the on-line analyzer and transmitted to the operators is essential.

Once the analyses and calculations are made by the analyzer system and by engineers interpreting the data, these calculations and values are used to determine the maximum allowable FEGT. Extensive training is performed continuously at Monroe Power Plant to ensure increasing sophistication on the part of operators in "driving by temperature". It also has permitted Monroe Power Plant to increase the percentage of PRB in the blend safely and with minimum unacceptable consequences.

5. Extensions of the program at Monroe

Given the success of the program in managing slagging and fouling, the program is being extended to provide guidance for operators managing opacity through controlling SO_3 injection to influence ash resistivity. Again models being used are driven by data from the on-line analyzer.

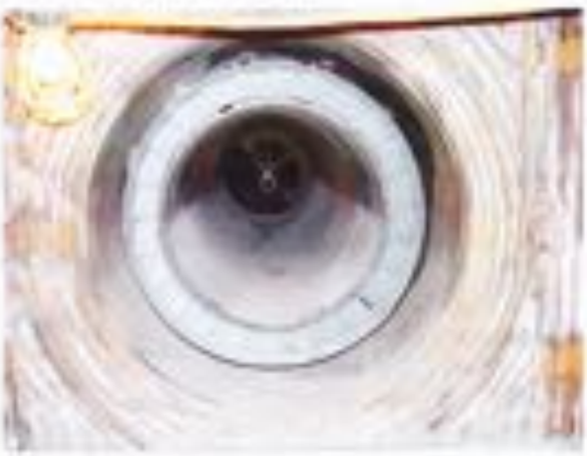

Fig. 4. The ACT swirl-stabilized burner modifications at Monroe Power Plant.

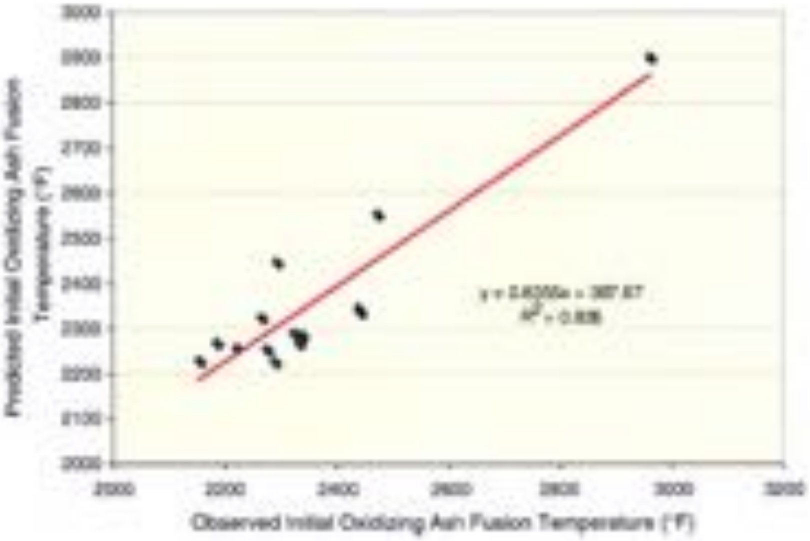

Fig. 5. Relationship between observed and predicted initial oxidizing ash fusion temperature based upon the behavior of calcium.

Monroe Power Plant is also in the process of evaluating a program to install analyzers at the receipt of coal—at the rail car unloader and at the boat unloader (some of Monroe's coal comes by Great Lakes Freighters while most comes by rail). These will permit understanding the parameters of the coal as it is being unloaded and will give the plant advanced warning when coals with high potential for slagging and fouling are shipped to the plant.

Additionally, analyzer programs have been developed for two additional large generating stations of DTE Energy: St. Clair Power Plant and Belle River Power Plant. These generating stations burn sodium-based Northern PRB coals. St. Clair blends this coal with modest amounts of eastern bituminous coals. Belle River burns 100% Northern PRB coals.

The analyzer programs being developed for these stations are less involved with managing (and modifying) the blends being burned. Rather they are involved with understanding the coals being burned and providing guidance to operators regarding these coals. Such guidance can reduce the problems associated with slagging and fouling including forced outages, de-slag events, and derates.

6. Conclusions

Monroe Power Plant has made extensive use of an on-line coal analysis to reduce slagging and fouling incidents, and to control that phenomenon while increasing the percentage of southern PRB coal in its fuel blend. It is now extending the program at Monroe to provide real-time measurement of boiler efficiency, and to provide guidance for operators in controlling opacity. At the same time DTE Energy is expanding its use of on-line analyzers by incorporating them into operations at St. Clair and Belle River Power Plants.