Implementation of Intelligent Sootblowing

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Abstract:

The paper presents a strategy to implement a comprehensive automatic control of soot blowing in power plant boilers. Considerable industry research has been done on the need to control and optimize the soot blowing in coal fired boilers. Deposits in boilers contribute to boiler inefficiency, capacity reductions, and overheated tubes, which lead to tube failures. Large clinker formations can fall and break the bottom tubes. An integrated system will clean the furnace based on feedback from heat flux sensors. The convection pass can be monitored with thermodynamic models and direct reading strain gages. With an integrated system the cleaning system would operate only when and where necessary. The paper will describe the existing installations where individual components are in operation, and describe an integrated system that could combine all these parts to make an integrated intelligent sootblowing system.

Introduction:

The paper presents a strategy to implement a comprehensive automatic control of soot blowing in power plant boilers. Considerable industry research has been done on the need to control and optimize the soot blowing in coal fired boilers. Deposits in boilers contribute to boiler inefficiency, capacity reductions, and overheated tubes, which lead to tube failures. Large clinker formations can fall and break the bottom tubes. The Electric Power Research Institute (EPRI) has funded a number of projects to improve operation of soot blowers and automate the soot blowing process. Boiler outages, many related to ash and slag, are the major cause of lost generation in the US fleet of coal fired power plants. The cost of these outages is in the billions of dollars per year in additional expense for replacement power and the cost of repairs.

Slag Formation:

All coals contain ash, the inorganic matter associated with coal. Ash content and composition vary with the location of the coal deposit. High ash content is associated with Lignite coals, Western coals, and some coal from outside the US. The melting point of the ash and the chemical composition determine where the ash may form slag in the boiler. Temperatures in the furnace can exceed 2700 F, a level at which the ash in most coal is molten. If high gas temperatures extend into the convection pass of the boiler then ash deposits on the convection pendants tend to form as slag. Slag is ash that has melted and as it travels to lower temperature regions of the boiler it has solidified into a rock like mass. Slag deposits are very difficult to remove with traditional soot blowing devices.

Boiler Cleaning:

All boilers designed to burn coal are equipped with soot blowers to clean ash deposits from the heat transfer surfaces. Most have wall blowers installed in the furnace sections. Retractable blowers are used in the convection pass to blow steam or air on the steam generating surfaces. The economizer section is also equipped with soot blowers. The initial design of the soot blowers for a boiler is dependent on the type of coal that is specified for the boiler. Many of the current US boilers have switched to different coal. This results in different ash in the coal and therefore a change in the soot blowing equipment necessary to clean the deposits off the boiler surface. Examples of this change in fuel are the large number of plants that have switched from bituminous coal to PRB fuel. Another example occurs when plants add scrubbers and they switch to high sulfur coal. The drive to lower the cost of generation also provides incentive to switch to lower cost coal. 80% or more of the cost of operation of a typical coal fired plant is the cost of the coal that is burned. So any reduction in the cost of fuel is directly reflected in the cost of generation.

Fuel switching is due to the following reasons:

- Reducing in SO2 production: a switch to Powder River Basin coal or low sulfur eastern coal can accomplish this. The low sulfur content in the coal results in low generation of SO2.
- Design Coal no longer available: Many plants were designed 40 years ago based on an eastern bituminous coal with high btu content and low ash. This coal is not as readily available as it was 40 years ago and often no longer can be burned and meet environmental regulations.
- Cost Reduction: Coal cost is determined by the mining expense and transportation cost. Underground mines, the location of most bituminous coal, are more expensive than above ground mining in general. The mine mouth cost of PRB coal is an example of the low cost of large above ground mining. If the
coal has to be transported long distances to the plant, then transportation costs can add considerably to the price. To reduce cost, utilities search the market for coal with low delivered price.

Traditional Soot Blowing Control System

The original design of soot blowing systems for most existing plants consists of blowing cycles based on time or the intuition of the boiler operator. Often soot blowing was done on a once a day or once a shift basis, regardless of actual plant parameters. This typically results in over cleaning. Excessive use of steam or air is an economic penalty for this type of operation. The weakness associated with such a non-automatic system results in the a set of objectives for an automatic cleaning system.

Intelligent Soot Blowing System Objectives

- Improve boiler efficiency
- Reduce steam/air consumption
- Reduce tube erosion
- Reduce clinker formation
- Increase the range of burnable coals
- Reduce emissions
- Provide optimization based on variable goals

Intelligent Soot Blowing System

The boiler is divided into three main areas in terms of ash deposits and slag formation. The three areas are the furnace, the steam generation section of the convection pass, and the economizer-air heater section. The furnace is the area where combustion takes place and radiant heat is the primary heat transfer mode. The furnace consists of the burners, and a large open area enclosed with water cooled walls. The furnace area extends to the nose arch and up to the convection pass where the steam generation tubing is located. An integrated system will clean the furnace based on feedback from heat flux sensors and FEGT measurement devices. These sensors are located in the water-cooled walls. They utilize a pair of thermocouples imbedded in the water wall tubes that sense heat flux. As the wall develops a layer of slag or ash deposit, the heat flux decreases. This is due to the insulating effect of the slag deposit. Slag deposits can vary in their insulating effect. For example a thin layer of PRB ash on furnace walls can have a large effect on heat transfer due to the reflective nature of the ash. Since most of the heat transfer in the furnace is due to radiation, the energy is reflected and not absorbed by the water wall. This can result in high FEGT temperatures and problems in the convection pass with slag accumulation.

The convection pass can be monitored with thermodynamic models, draft loss, and direct reading strain gages. Thermodynamic models utilize steam temperatures, pressure, and flow rates to measure the effectiveness of a section of the steam generating components in the convection pass. If gas temperatures are known from FEGT measurements and the temperature of gas in the economizer section, then this is also used to derive the amount of energy absorbed in each section. The Center for Electric Power at Tennessee Technology University has developed algorithms that utilize the Continuous Emission Monitoring data to derive coal flow rates. Knowing coal flow rates and the energy content of the coal can provide a starting point for thermodynamic models. The total energy input into the boiler is known. With measurement of excess air, then stoichiometric calculation results in a known gas flow rate. With a known gas flow rate, the fuel rate, and the amount of steam produced an accurate thermodynamic model can be produced. Since all the data, with the exception of coal energy content, is measured in real time, the model can operate on a real time basis. This forms the basis for measurements of cleanliness factors in the steam generation banks of the boiler and input into intelligent soot blowing.

In addition to thermodynamic modeling of the convection pass, direct measurement of the ash build up on pendant sections of the boiler is available. International Paper developed a system that uses strain gages to measure the weight of ash accumulating on steam generating sections. This system is available to the utility industry from Clyde Bergemann. The system measures ash build up by detecting weight changes in the support rods of the pendants in the boiler. Strain gages are attached to the rods that exit the pent house and are attached to the building steel structure. As ash builds up, the weight gain is measured by the strain
gage system. The operation of soot blowers can also be monitored by the system. As blowers are operated, the amount of ash removed is measured by the weight change. Thus individual blower operation and effectiveness can be monitored. This measurement forms the basis for effectiveness measurements for individual soot blowers. And leads to the ability to optimize the frequency of blower operation.

With an integrated system the cleaning system would operate only when and where necessary

Components of an Intelligent Soot Blowing System

- Instrumentation to determine boiler condition
- Algorithms to interpret instrumentation
- Controls to act upon the feedback from the controls
- Equipment that is adequate for ash and slag removal

Instrumentation

Monitoring the condition of furnace walls is done with heat flux sensors, cordial thermocouples, and furnace exit gas temperature devices. Heat flux sensors utilize paired thermocouples installed in the water wall tubes. These devices measure the heat flux through the wall of the tube. They react to an ash deposit on the surface with lower heat flux. There is on going research to find inexpensive heat flux sensors. One approach is to locate a sensor in the membrane between tubes. This would be less expensive than the in tube type sensor. It would also be simple to install with a hole drilled in the membrane, and simple to replace. Typical in-tube installations have about 24 sensors per furnace, 6 per wall. With membrane sensors many more could be installed, thus giving more resolution to the heat flux status of the boiler. One drawback to membrane sensors is the lack of information on the temperature of the boiler tube surface. This data from in-tube sensors can be monitored for the thermal impact of cleaning devices. Cordial thermocouples are devices that have been used for years by boiler manufacturers to measure the initial performance of boilers upon initial operation. With proper installation, possibly using shop built dutchmen sections, these devices can last for long periods. They can also be installed in existing tubes, however, their longevity is dependent upon the skill of the installer. Cordial thermocouples give tube temperature data, but do not give direct measurements of heat flux. Heat flux can be inferred from the reading as the temperature drops as ash deposits build up on the surface. The preferred method of measurement of furnace heat flux is the heat flux sensor because of its direct measurement of heat flux and the ability to measure the thermal impact of the cleaning event on the water wall tube.

FEGT measurements consist of two primary technologies. Infrared instruments that measure the temperature of the ash particles in the gas stream are reliable and can be installed for a reasonable price. These devices are mounted on the furnace wall at about the nose arch location, thus giving the temperature of the flue gas as it leaves the furnace and enters the convection pass. This critical temperature is an indication of the cleanliness of the furnace and the potential for slagging in the convection pass. Higher temperatures result in more molten ash in the convection pass, which will be deposited in the form of slag. Acoustic instruments are an alternative to the infrared technology. Acoustic systems use a sound generator and one or more sound detectors. The speed of sound varies with temperature, so knowing the precise distance between the source and detector, the speed of sound can be measured, and the temperature of the path can be calculated. With numerous detectors a grid of temperatures can be measured.

Two techniques are used in the convection pass for measurement of ash and slag deposits. The most widely used technique is a thermodynamic model which analyzes the temperatures produced by the steam generating sections. Temperatures, steam flow rates, attemperation spray flow, and gas side temperatures are combined in a thermodynamic model to measure the steam production rates of the superheater and reheater sections of the boiler. A theoretical level of performance is calculated and used as a baseline for a clean section of the boiler. Then the actual performance level is measured based on the temperatures and flow rates. The difference between the theoretical and actual is assumed to be due to build up of deposits on the surface of the steam generating section. This can be expressed in terms of cleanliness or as a fouling factor.

The second technique used to determine fouling in the convection pass is the use of strain gages to directly measure ash build up on pendants. The steam generating sections of most boilers are suspended from the building steel above the boiler with hanger rods. Stain gages on these rods can directly measure the increase in weight due to ash deposit build up. This technique can give more resolution to the ash
measurement as it can detect lateral difference in ash deposits. Most ash deposits are not uniform. The deposits follow the temperatures of the boiler, and temperature profiles are not uniform. High temperatures often occur in the center of the boiler, but can occur in corners or on the sides. Temperature profiles are influenced by air fuel ratios, over fire air distribution, pulverizer performance, gas flow profiles, and other parameters. These profiles are not constant and can change with changes in boiler operation, equipment maintenance, and fuel. Thus it is valuable to measure the deposits on a lateral dimension. The strain gage system is also sensitive enough to detect individual soot blower operation and determine the effectiveness of the blower in removing deposits. Such instrumentation has been demonstrated in EPRI sponsored projects at the Tennessee Valley Authority.

To properly interpret the instrumentation installed to monitor deposit build up in the furnace, algorithms are developed to optimize soot blowing. Optimization can be done to achieve various goals. Optimum efficiency or heat rate is often a goal, also, maximum steam generation may be a goal if optimization of unit output is desired. Optimum heat rate is achieved by optimizing boiler efficiency. Minimization of attemperation spray flows, especially in the reheat steam, is desired to optimize efficiency. Minimization of gas temperature leaving the air heater is desired to minimize boiler losses. To achieve optimum performance the intelligent soot blowing system looks at the thermodynamic process and the parts of the boiler that make up that process. FEGT, steam production, attemperator spray flow, and air heater gas exit temperature, and unit load are evaluated in the process. It may not always be advisable to clean sections of the boiler to the maximum level. For example an extremely clean furnace section may result in a reduction in gas temperature going to the convection pass which will not produce steam at design temperature. So it may be advisable to let the furnace slag up to some level to maintain a desired FEGT and the resultant steam temperature.

The algorithms that balance the performance of sections of the boiler drive the control of the boiler cleaning equipment. Modern control systems utilize Programmable Logic Controllers (PLCs) to direct the equipment operation. Operator interface is provided by using PC and Windows based applications. Open system architecture supports all standard communications protocols (e.g. Ethernet, Modbus, DH+, Profibus,…). OPC server is also utilized for the communication. All these features allow an easy integration with other systems (DCS, PI historian,…).

The block diagram shown below illustrates how various elements of Intelligent Soot Blowing (ISB) system are combined to operate the cleaning equipment. The Sensor/Gauge Interface provides ISB algorithms that determine the cleanliness states of various boiler components. This interface derives priority tables that determine which soot blowers are most effective and which should be operated to achieve desired steam conditions. For the furnace the interface determines water cleaning speed and pressure. The Interface receives information from the heat flux sensors in the furnace, the strain gages in the superheater and reheater sections, and from the thermodynamic model. In addition the interface serves as a monitor of other plant conditions, such as steam temperature, unit load, spray flows, draft pressure and other pertinent cycle parameters. The output of the ISB algorithm logic is the operation of the cleaning equipment. This may be water cannons, retractable soot blowers, air heater cleaners, and other cleaning devices.

Installations:

There are a number of installations with portions of an ISB system installed. There are over 70 boilers with water cannon cleaning systems in the U.S. The strain gage system has been demonstrated in a number of installations. There are also a number of thermodynamic models operating. A combined system is being installed this year at a large northeastern power plant. This installation will provide a demonstration of the combined effect of all the elements involved in fully automatic soot blowing.

Conclusion:

Intelligent Soot Blowing can be achieved with currently available technology. The instrumentation and control systems are available to build a system that automatically optimizes boiler cleanliness. Special instrumentation such as heat flux sensors and pendant weighing using strain gages provide the input to the
algorithms that optimize the use of cleaning devices. Integrated systems are currently being installed that will demonstrate the success of this type of system.

Typical system architecture for Intelligent Soot Blowing

References:


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