POWER Engineering

Mirant Deals with Upsets and Transients in Coal-fired Boilers

By Drew Robb, Contributing Writer

Operating a boiler is a careful balancing act, matching the fuel, airflow and draft pressure throughout a wide range of load conditions. As plants are being called on to operate differently than in years past, the range of load conditions has increased even more.

If response times are too slow, the system can trip, losing production and increasing emissions. The thermal stress lowers equipment life and leads to unplanned maintenance.

Safe boiler operation requires optimizing the controls of both the water/steam system and the combustion system. On the combustion side of a boiler, this means mixing the air and fuel in the proper ratio to control the firing rate: maintaining the ideal level of air flow in and out of the combustion chamber, and keeping the air pressure at the desired level. Too great an air flow results in operational inefficiencies and in increased NO_X emissions; insufficient air flow results in incomplete combustion, which amounts to the creation of additional CO, a loss of energy for the plant as well as an explosive hazard.

Within the combustion chamber, the air pressure should be just slightly lower than the surrounding atmospheric pressure. If the internal pressure is higher than atmospheric pressure, then the combustion byproducts will escape through any openings, such as inspection ports or doors, violating emission regulations and creating a safety hazard. If the pressure is too low, cool outside air will enter the chamber through those same openings, lowering boiler efficiency. In extreme cases, the boiler can implode. Plant control systems, of course, have mechanisms to shut down the system before it reaches the implosion level, but unplanned shutdowns are an expensive proposition.

Several approaches have been developed over the years to keep the pressure at the desired level. The simplest is the natural draft method, where the exhaust gases rising through the stack create a pressure gradient that pulls the air through the boiler. While this method does work it doesn't offer the control necessary to maximize efficiency and minimize emissions. Forced draft (FD) boilers use a fan to force air into the furnace. The furnace operates at a positive pressure and must be completely sealed to avoid leaks. The air flow into the furnace is controlled by a damper and/or fan speed control. Induced draft (ID) systems place the fan and damper on the exhaust side, creating a negative pressure and pulling the outside air into the combustion chamber.

Neither of these approaches is ideal for a large boiler with a long exhaust flue. So, to ensure adequate draft and pressure, balanced draft systems are used. These are a combination of forced draft and induced draft, and have fans and dampers on both the inlet and the outlet. Control systems on balanced draft furnaces adjust the damper positions (and/or fan speed) so the furnace operates at slightly negative pressure.

Dealing with Transients

In a perfect world, a boiler would operate under certain constant conditions, making pressure control a simple matter. But in fact, ID fans need to be continually adjusted to keep pressure at the optimal level to maintain efficiency and avoid plant trips. Actuators on the dampers will react to signals from the control system and adjust the exhaust flow as needed to maintain furnace pressure. The problem lies where there is a sudden large demand change, for instance, if a steam turbine has a load rejection and much less steam is required instantly. In such a case the fuel and air are reduced rapidly and the ID fan must adjust rapidly to maintain the vacuum in the furnace. Most plants are using a modified version of feedforward control at the distributed control system (DCS) to accomplish the speed requirements necessary to achieve the desired operational results in this application. However, tuning the speed of response of this system alone in the DCS is not adequate. It is equally important to have a final control element that can optimize accuracy, repeatability and responsiveness (no dead time).

Mirant Corp. of Atlanta operates eight power plants in the eastern U.S. and another three in the San Francisco Bay area. Over the last few years, the company has been replacing the ID fan actuators at its four coal-fired plants in Maryland and Virginia (the Morgantown, Dickerson, Chalk Point and Potomac River generating plants) with Rexa electraulic actuators from Koso America.

"In our applications we look for drive units that have high force as well as high speed capability for the ID fans," said Frank Bennett, Mirant Corp.'s engineering manager for instrumentation and control, who oversees all four plants. "That way we can properly control normal airflow and furnace draft as well as minimize the effects of transients resulting from trips in the units."

Mirant had been using a variety of actuators, some of which were original equipment and others installed as part of a retrofit. But none of the drives met the company's speed requirements. The electric motor-operated drives had stroke times in the vicinity of 24 to 40 seconds for full stroke, and pneumatics were anywhere from 15 to 30 seconds for full stroke.

"For ID fan inlet damper controls, based on some of the dynamics that we've seen on our units, we want something that will operate at 10 seconds or faster for 0 to 100 percent stroke," Bennett said.

Since the existing ID fan actuators were not close to meeting Mirant's criteria, the company started looking for alternatives during a project to install low NO_X burners at its Morgantown plant. Electric motor drives were far too slow, which left pneumatics and hydraulics.

Pneumatic actuators are faster and less expensive than hydraulics, but also less accurate. Since air is compressible, there is a lag between when the actuator receives the signal to increase pressure and when the damper starts to move and they will then overshoot the new set point. "Smart" pneumatic positioners address the overshoot by slowing down the actuator as it approaches the new set point, but this also increases the lag in response time. This longer lag in response time is defined as dead time in the process. This is one of a control engineer's nightmares and needs to be minimized to the fullest extent in applications such as furnace pressure control.

Hydraulic actuators do not have the same lag in response (the dead time after receiving a control signal is less than 70 milliseconds), nor do they have a tendency to overshoot, giving them an accuracy as high as 0.05 percent of span. The downside is that they are far more expensive than pneumatic systems, require a network of high pressure tubing and fittings and also require frequent maintenance of the oil and filtration system. The Rexa electraulic (electro-hydraulic) actuators, however, would meet Mirant's speed and accuracy requirements. Besides Mirant's 11 boilers, these new actuators have been used on more than 400 other ID fan applications on boiler sizes from 200 MW to 1,300 MW.

These actuators incorporate hydraulic, electronic and mechanical technologies. They consist of two main components: the Electraulic power module and a control enclosure. The self-contained units operate by moving hydraulic fluid from one side of a double-acting cylinder to the other, and do not require an external hydraulic pump or tubing.

The control sub-assembly enclosure contains the central processing unit (CPU), power supply and motor drivers. Depending on operating conditions, the two-line status display and five-button keypad can be mounted inside the box or on its front panel. The CPU typically contains a microprocessor, an analog-to-digital converter, a position transmitter, limit switches and warning and alarm systems.

Inside the power module are the motor, gear pump, flow match valve, thermal expansion reservoir, heater and thermostat. Buyers can pick from four different size motors depending on the pumping volume and maximum stroking speed desired. The two smaller units come with stepper motors, while servo motors are used in the larger units for faster stroking speeds. The hydraulic cylinders come in either linear or a rack-and-pinion rotary design. A position sensor is mounted within or adjacent to the cylinders and provides position feedback to the control electronics.

In operation, the CPU converts an incoming control signal to a target position and compares this with the current position as reported by the feedback assembly on the actuator. When the difference exceeds the deadband range preset by the operator, the CPU sends a control signal to the motor driver. Depending on the type of motor installed, the driver then sends either DC step pulses or pulse width modulated (PWM) DC voltage for a servo motor. The positive displacement pump then delivers oil to move the application load up to 2,000 psi to one side or the other of a hydraulic cylinder, opening or closing the damper. Once the desired position is reached, the pump shuts down and check valves close, locking the hydraulic fluid in the cylinder and maintaining the actuator position without having to keep the motor running. The low volume closed loop hydraulic circuit requires no oil or filter maintenance as the positive pressure circuit is inherently clean.

Mirant installed the first Rexa controller on its Morgantown plant. Based on the success at that location it became the company's standard. The Morgantown boilers and Chalk Point Unit One were set up for six seconds for full stroke. At Potomac River the actuators are set for eight seconds. The Dickerson Generating Plant didn't require the same speed, so those units operate in the neighborhood of 15 seconds. Bennett said that having the ability to hold the furnace pressure constant has allowed them to avoid having to upgrade plant components.

"It's a safety issue," he said. "We have some older plants that don't have the same structural integrity to which the newer units are built. With these ID fan controllers, we can make sure we don't exceed the yield or withstand capability of some of the furnaces and gas path components." pe