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BY: SCOTT KEMPF, HAROLD BECK AND SONS

SIMPLE IMPROVEMENTS, SIGNIFICANT RESULTS

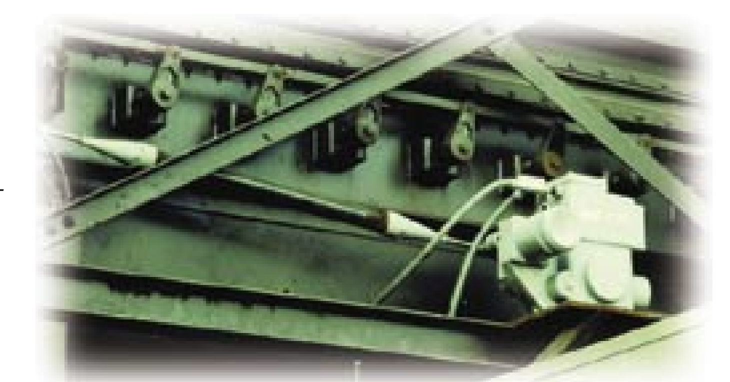
TVA Kingston reduces NO_x emissions and maintenance costs by replacing pneumatic actuators.

Digital control systems and advanced technologies like selective catalytic reduction (SCR) and low-NO_x burners are commonly used in the power industry. Yet poor or inconsistent damper actuation remains a limiting factor in boiler control. Even the most powerful and advanced controls are incapable of correcting the performance limitations caused by ineffective damper resolution and actuator-induced dead time and lag. In fact, power plants can achieve immediate operational improvements and reduce emissions even without SCRs by simply improving damper and tilt positioning.

"By improving combustion control, coal-fired power plants can achieve a significant decrease in NO_x; and, that's without spending a dime on aftermarket burners or SCRs," said Rob Frank, the EPRI center director at the TVA Kingston Steam Plant. Frank gained first-hand NO_x reduction experience with final control element positioning when he led an EPRI demonstration project at Kingston in 1996. Project results showed that with the installation of high-accuracy electric actuators on specific final control elements, coal-fired boilers could improve efficiency and combustion control, and reduce maintenance costs. Today, almost 10 years later, Kingston Steam Plant is still reaping the benefits of the demonstration project. In fact, the benefits were so great on the demonstration unit that TVA installed electric actuators on all the units at the Kingston plant.

TVA's and EPRI's strategy for reducing NO_x and lowering operating costs focused on:

1. *Reducing oxygen at the burner, then introducing combustion air at higher levels to complete combustion and reburn the gases*
2. *Reducing excess oxygen*
3. *Reducing the furnace's peak operating temperature*
4. *Reducing the coal fines particle size to ensure that at least 99.5% of the coal particles pass through a 50-mesh screen.*



Beck drive installed on utility boiler louver damper

The team identified several areas critical to the project's success. Precise trim to the windbox dampers was required to obtain optimum combustion air ratio for better burn. To reduce tube failures, finer control of burner tilts was necessary to accurately control steam temperature in the boiler tubes. In addition, to maintain proper fuel-to-air ratio, the coal mill hot air dampers had to be trimmed.

ASTOUNDING RESULTS

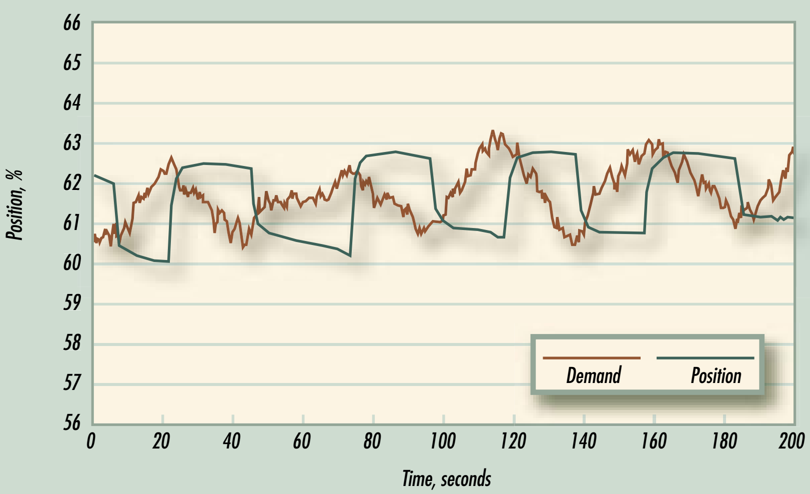
By installing precision electric actuators designed for continuous modulating control along with new sensors and a DCS, EPRI improved boiler efficiency at Unit #9 of the TVA Kingston Steam Plant and reduced NO_x emissions by 25%. Prior to the upgrades at the plant, the NO_x baseline was 0.6 to 0.7 lb/MMBtu. One month after the upgrade, the NO_x level was reduced to 0.45 lb/MMBtu. This efficiency improvement, which the plant is still enjoying today, was achieved without separated over-fire air (SOFA), low-NO_x burners or SCRs. Frank determined that the actuator and field instrument upgrades represented a total annual savings of $350,000, about the same amount TVA spent to purchase and install the precision electric actuators on Unit #9. Frank estimated that two-thirds of the savings, approximately $230,000, was directly attributable to the actuator replacement. TVA paid back their investment in only about one-and-a-half years.

Frank cites the actuators as major contributors to a number of operating improvements, including improved steam temperature, lower turndown, fewer boiler tube failures resulting from less thermal cycling, reduced loss of ignition (LOI), faster start-up and lower exit gas loses.

The decision to install the same type of electric actuators on all of the units at the Kingston plant was not solely based on the efficiency and emission improvements, but also on sustainability of the result. After almost 10 years, the electric actuators continue to provide repeatable, reliable performance without the maintenance needs typical of pneumatic and many other types of actuators.

"The Unit 9 project set the bar for how well a system could operate with accurate, responsive control elements," said Keenon Hethcoat, a senior instrument mechanic at Kingston. "And, in addition, the reliability and accuracy of the electric actuators installed on Unit 9 and the other units here at Kingston have reduced our work load, allowing the instrument shop personnel to focus on preventive maintenance instead of spending all of their time on corrective maintenance."

FIGURE 1
PNEUMATIC ACTUATOR DEMAND AND POSITION VS. TIME



THE PROBLEM WITH PNEUMATIC ACTUATORS

The original damper actuators at the Kingston plant were pneumatic cylinders and were typical of pneumatic-style damper actuators used in coal-fired boiler applications. Pneumatic actuators work on a force-balance principle with pressurized air as the motive power, but the force-balance principle has a major drawback—air is compressible. Given the frictional and inconsistent nature of the damper loads, this drawback leads to many pneumatic actuator positioning problems. Figure 1 illustrates the performance problems often experienced with pneumatic actuator demand and position.

In a frictionless world, the compressibility of air would pose no serious performance issues. In the real world, however, friction governs everything. This is especially true in dampers, which are subject to high loads, changing conditions and dirty environments. Significant friction exists within dampers, and it tends to vary and get worse over time. In fact, friction by nature is variable whenever start and stop motion occurs because static and dynamic frictional forces differ. Static frictional forces resist movement when the damper is at rest, while lesser dynamic frictional forces produce resistance when the damper is in motion. Resistive forces resulting from static friction are always greater than the resistance posed by dynamic friction. Therefore, an actuator must produce more force (compress more air) to overcome static frictional forces and initiate damper movement than it does to keep it moving. This physical phenomenon results in stick/slip response, or stiction, as it is often called, in the damper and actuator.

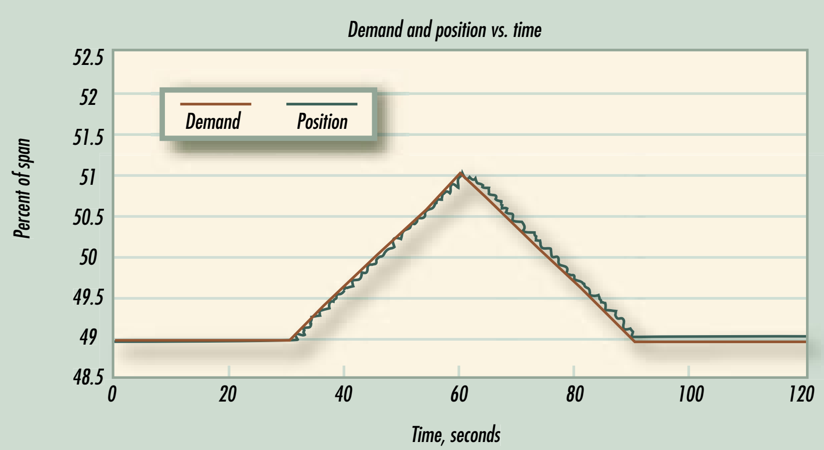
Consider a simplified example. If the actuator must reposition the damper a small amount, the pressure in the actuator cylinder must be precisely changed to effect a new force-balance. The positioner will begin to increase the actuator air pressure to establish a new force and initiate movement. Before movement occurs, though, the static frictional forces must be overcome. Air is continually pushed into the cylinder and compressed until the pressure produces a force great enough to overcome the static frictional forces. Once that critical point is reached, the actuator begins to move. The problem is that once the damper is in motion, frictional resistance decreases while the actuator is still being moved by a pressure greater than that required to move the damper a small amount to the desired position. The actuator overshoots. It then compensates by repositioning in the opposite direction and the same scenario is started all over again. It bounces back and forth around any desired position, never really finding the equilibrium point. The result is poor positioning resolution and poor control.

In addition to performance limitations, pneumatic actuators are susceptible to maintenance problems induced by dust, dirt, temperature extremes, supply air quality and changing process conditions. Over time they suffer performance degradation that in turn degrades control performance and combustion efficiency.

SWITCHING TO PRECISION MODULATING ELECTRIC ACTUATORS

The Kingston project results demonstrate that electric actuators can eliminate the stiction problems caused by pneumatic actuators. In addition, they can virtually

FIGURE 2
BECK ELECTRONIC CONTROL DRIVE
RESPONSE ON A 3" BALL VALVE, 2% RAMP



eliminate the dead time and lag that invariably limit closed-loop process control when pneumatic actuators are used. However, not just any electric actuator will do. Many electric actuators are not designed for the rigors of continuous modulating control, and most of them are not capable of the precision necessary for adequate — much less optimal — process control.

Many electric actuators are best suited to open/close, multi-position or infrequent modulating control. Like pneumatics, these electric actuators have their own performance issues, such as overheating and eventual motor burnout, an inability to track control signal commands effectively, and poor reliability in modulating service.

Because all electric actuators are not the same, there are several attributes that should be considered when evaluating an actuator for modulating control service. The actuator should be designed for continuous modulating duty without any duty-cycle or thermal motor limitations. It should be able to start instantaneously at full-rated torque and to stop instantaneously without coast or overshoot. It is important for the actuator to have a high degree of positioning precision and accuracy, be unaffected by frictional or dynamic load, be suitable for difficult environments, and be consistent over time, over the damper's operating range and under varying — and continually degrading — process conditions.

Figure 2, which depicts the response of a Beck electronic control drive installed on a three-inch ball valve, shows the precision and instantaneous response required of an electric actuator suitable for modulating control. There is essentially no dead time, lag or deviation in response to the ramping demand signal. The actuator response is almost invisible.

The actuator must also be capable of positioning as often as the control loop dictates. Many electric actuator designs have a duty-cycle limitation that dictates how often the actuator positions. This clearly sets limits on the control loop since the actuator will trip out when the duty cycle is exceeded. Duty-cycle limitations are typical of most electric actuator designs using induction motors, making the actuators incompatible with precision or critical control. An electric actuator truly suited for control without risk or guesswork needs to utilize a 100% continuous duty motor.

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Conclusions

The EPRI study at TVA Kingston shows that coal-fired power plants can achieve immediate improvements in boiler efficiency, NO_x reduction and maintenance costs by improving final control element positioning. Therefore, even if plants have already installed or plan to install advanced control instrumentation, SCRs and low-NO_x burners, they should recognize the value of upgrading their final control elements.

In addition, the EPRI study shows that NO_x reductions can be achieved even without advanced technologies like SCRs and low-NO_x burners. More responsive, more accurate and more consistent damper actuation allows every utility to get the most out of any control system, new or old. PE

Author—
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The Electric Actuator's Impact on Power Generation

TVA Kingston wasn't the first coal-fired power plant to reap the benefits of precision electric actuators on boiler dampers and tilts. Prior to this study by EPRI, Beck drives had already achieved tremendous success in the utility industry. In fact, EPRI selected Beck for the demonstration project because of its track record for helping utilities meet the more restrictive requirements of the Clean Air Act.

Prior to EPRI's work, the Salt River Project in Arizona conducted a study to determine the impact of modulating electric actuators on overall boiler control. The Salt River Project's study results were just as compelling as those at Kingston. Beck drives greatly improved the ID fan damper actuation reliability, while improving furnace pressure control and, ultimately, efficiency. Before the Beck drives were installed on the ID fan dampers, the plant experienced poor pressure control resulting from stiction and the typical inconsistent response of pneumatic actuators. The resulting furnace pressure variability caused regular positive pressure excursions in the boiler and forced the operators to set a less than ideal furnace pressure setpoint.

After the pneumatic ID damper actuators were replaced with Beck drives, not only did the plant eliminate the maintenance attention on the pneumatic actuators, it immediately improved furnace pressure control, without any other changes to the boiler, control system or loop tuning parameters. The improvements eliminated the positive pressure excursions and tightened control so much that the furnace pressure setpoint could be more optimally set. Today, approximately 14 years later, the Beck drives are still in place and providing excellent control of the plant's modulating control dampers.

The benefits of improving final control element positioning are recognized throughout the utility industry. Today, Beck drives are installed on more than 1,000 boilers at utilities including AEP, Ameren, Alliant Energy, Con Ed, Connective, Constellation Power, Covanta Energy, Duke Energy, Dynegy, Excel Energy, Kansas City Power & Light, Midwest Energy, Minnesota Power, Mirant Energy, NIPSCO, Sask Power, Southern Company, Progress Energy, Tri-State Energy and Tucson Electric.

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