POWER Engineering

Tightening Turbine Control

Nevada Energy slashes unplanned downtime with high-tech actuators.

By Drew Robb, freelance contributor

Combined cycle plants give greater output for the same amount of energy and emissions. But this comes at a cost—increased complexity of design and operations. Optimizing a combined cycle plant requires tuning the gas turbine not just for its own efficiency but also to maximize the stability and efficiency of the heat recovery steam generator (HRSG).

The best place to start is right at the beginning: controlling the inlet guide vanes (IGVs) for the combustion turbine in order to regulate the exhaust temperature leading into the HRSG boiler. Precision control of the IGVs is critical for quickly bringing units on-line without risking thermal damage, particularly when the units are being cycled daily.

At Nevada Energy's Clark Power Plant near Las Vegas, for example, the pneumatic IGV actuators that came with the CTs not only failed to provide the required level of control, but even led to unplanned outages.

"It was a real Rube Goldberg setup," said Frank Romans, an instrumentation and control engineer for Nevada Energy. "It was complex, difficult to calibrate, did not have high repeatability and was prone to failure all the time."

Replacing them with Rexa electro-hydraulic (Electraulic) actuators from Koso America Inc. led to improved efficiency as well as lowered maintenance costs.

"The principal objective was to increase reliability and get rid of the old components that had turned into a headache," said Romans. "As a result, the forced outages or derates decreased significantly."

Controlling Inputs

To get the right output, you need the right input. For combined cycle systems, there are several inputs that really matter. For the combustion turbine, these are fuel and air. The chief HRSG inputs, on the other hand, are feedwater and the exhaust gas from the combustion turbine. The IGV controls the inputs for both. First, it regulates the airflow into the combustion turbine. The amount of airflow then determines the temperature of the exhaust gas entering the HRSG and, as a result, the boiler temperature.

The setpoint for the IGV is typically derived from the CT exhaust temperature, the compressor discharge pressure and the speed of the turbine. The IGV modulates during acceleration of the turbine, the loading and unloading of the generator and the deceleration of the turbine. In so doing, it maintains the proper flows and pressures in the compressor, minimizes the pressure drop across the fuel nozzles and maintains a more consistent exhaust temperature even at low loads.

What's important to remember is that exhaust temperature directly relates to turbine efficiency. When running a simple cycle plant or a combined cycle unit in simple mode, exhaust heat just represents wasted fuel. In a combined cycle plant, however, operators want to maximize the exhaust temperature and maintain it as consistently as possible even at lower operating loads. The exhaust temperature determines the boiler temperature in the HRSG and unstable boiler temperature leads to thermal fatigue. In addition, unstable steam temperature means lower than optimal temperature setpoints, highly active spray valves and unnecessary throttling of feedwater valves.

Limitations of Pneumatic Actuators

Due to these factors, accurate control of the IGVs is critical to optimizing output of both combustion and steam turbines. For that, operators have traditionally had two options: pneumatic actuators and hydraulic actuators. Both of these, however, have their drawbacks.

Pneumatic actuators are fast-acting and less expensive than hydraulic ones. Their principal downside is that air is compressible. As a result, there is a lag while the air pressure increases to the point necessary to overcome the static friction (stiction) of the actuator. Then, once they start moving, they tend to overshoot the new set point. To improve accuracy, one can use a "smart" pneumatic positioner that slows down the actuator as it nears the new setpoint. This does reduce the level of overshoot, but it also results in longer dead times, especially when dealing with small changes. Even minor instabilities in temperature and pressure increase the thermal fatigue.

Since hydraulic fluids are incompressible, hydraulic actuators do not have the same lag in response nor the tendency to overshoot. The dead time after receiving a control signal drops to less than 70 milliseconds and they can be tuned to be repeatable within 0.1 percent of span. This would make them the clear choice for turbine control systems except that they are far more expensive than pneumatic systems and require frequent maintenance of the central hydraulic power unit as well as the network of high pressure tubing and fittings.

Combined Design

To give plant operators the accuracy of hydraulic actuators without the maintenance headaches of conventional hydraulic systems, Koso America has developed the self-contained Electraulic actuators that incorporate hydraulic, electronic and mechanical technologies. These actuators consist of two main components—the "actuator" that comprises an Electraulic power module and cylinder and the control enclosure. They do not

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require an external hydraulic pumping unit, reservoir tank or tubing. They operate by moving hydraulic fluid from one side of a double-acting cylinder to another.

The power module contains a motor, gear pump, flow match valve, thermal expansion oil reservoir, heater and thermostat. Upon receipt of a control signal, the pump delivers oil (Castrol SYNTEC SAE 5W-50 motor oil) at a nominal 2,000 psi to one side or the other of a hydraulic cylinder, causing motion in the desired direction. Buyers can pick from various sizes of motors depending on the pumping volume and maximum stroking speed desired. The two smaller units come with stepper motors, which have a slower frequency response than the servo motors used in the larger units. 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.

Within the control sub-assembly enclosure are the central processing unit (CPU), power supply and motor drivers. On the outside of the box (or inside when conditions require) is a two-line display giving actuator status and a five-button keypad used for set-up and calibration of the actuator. The CPU typically contains a microprocessor, an analog-to-digital converter, a position transmitter, limit switches and warning and alarm systems. The power supply takes the incoming AC power and converts it to +5, +15, -15 and VDC power for the control components. The motor driver receives commands from the CPU and sends control signals to the motor DC step pulses for a stepper motor or pulse width modulated (PWM) DC voltage for a servo motor.

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. If the difference is outside the range preprogrammed by the user, the CPU will send a signal to start the motor. The motor then drives the reversible hydraulic pump to pressurize one side of the cylinder or the other, moving the piston in the desired direction. 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.

Linear actuators are typically used to modulate combustion turbine IGVs. Properly sized high pressure (2,000 psi) hydraulic cylinders are selected to operate the IGVs on turbines ranging in size from 5 MW to 360 MW.

Replacing an existing pneumatic or electromechanical actuator with an Electraulic model can give operators greater repeatability in controlling their IGVs and the exhaust temperature. At part load, the IGVs are active. The response and duty cycle of the Electraulic model improve reliability and reduce down time. As a result, operators have retrofitted their IGV actuators with Rexas on Siemens V84.2/3 and V94.2s; Westinghouse 701D, 501B and 501Ds; and GE Frame 3, Frame 5 and Frame 7 turbines. They now come as the standard equipment on KHI units and Siemens includes them as part of its OTC Optimization upgrade package.

At Nevada Energy's Clark Station, which has two blocks, each with two Westinghouse 501B GTs and a Westinghouse HRSG in a 2x1 configuration, the original pneumatic actuators were replaced. The Rexa Model L20,000-6-C-P linear actuators selected provide 20,000 lbs. thrust with a 6-inch stroke.

Installation was done by plant staff during a scheduled outage with Rexa providing engineering assistance. Romans said the changeover was simple, taking two to three days including electrical, calibration and testing. The units performed reliably and gave them better control over the IGVs, so when the utility went to a different water injection system, a Rexa unit was put in instead of using a pneumatic positioner on the flow control valve. In addition to providing better control, Romans said the maintenance load is less.

"With any product there is periodic maintenance such as replacing the O-rings," said Romans. "But it is much better to only do scheduled maintenance on it instead of the higher frequency, unplanned problems we used to have." pe