ENERGY TECH
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Improving turbine control with more accurate actuators

By Mike Murphy

Driven by both economics and regulations, power plant operators are continually looking for new ways to improve the uptime and reliability of their units. It is a multi-front battle, and now more units are designed for combined-cycle or co-gen applications to recover heat that would be wasted otherwise. Turbine manufacturers also are building combustion and steam turbine rotors out of lighter materials and with tighter tolerances.

Heat Recovery Steam Generator (HRSG) manufacturers are doing their part with advanced designs that help them deal with the stresses of frequent cycling. Vogt has developed methods to retain heat in the boiler in order to minimize thermal stress and reduce startup time. Rather than the two hours plus it would take to go from a cold start to a full load, for example, keeping the water hot cuts the time in half. Alstom, on the other hand, has a once-through design that eliminates the high pressure drum, allowing for a 25 minute cold start, and also a design called the OCC (Optimized for Cycling and Constructability) Horizontal HRSG – which uses single row harps and thin-walled header pipes.

Then there are the steps that are taken on-site to improve the operations of existing equipment. Older turbines are being retrofitted with retractable and brush seals that close off even more of the heat loss. Updating plant control systems can optimize air/fuel ratios and improve heat output. But just upgrading the control software won't do the job if field equipment, and in particular actuators, can't match the speed and accuracy of the software.

Controlling combined-cycle inputs

Combined-cycle plants offer greater power output for the same amount of fuel expenditure and emissions, but require greater control of the inputs to achieve the desired results. 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 HRSG. There are 4 inputs that matter: fuel and air for the combustion turbine; exhaust gas and feedwater for the HRSG. The inlet guide vanes (IGVs) control the inputs for both the CT and the HRSG. First, the IGVs regulate 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 IGVs' setpoint is determined based on the CT exhaust temperature, the compressor discharge pressure and the turbine speed. The IGV modulates during acceleration of the turbine, the loading and unloading of the generator and the deceleration of the gas 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 high exhaust temperature, even at low loads.

With both simple- and combined-cycle plants, the CT exhaust temperature directly relates to turbine efficiency. While running a simple-cycle plant, or a combined-cycle unit in simple mode, exhaust heat simply means wasted fuel and should be minimized. With a combined-cycle plant, the opposite applies. Optimum operation consists of maximizing the exhaust temperature and maintaining that level at all operating loads, since the exhaust temperature determines the HRSG boiler temperature and temperature instability causes thermal fatigue. Unstable steam temperature also means lower than optimal temperature setpoints, highly active spray valves and unnecessary throttling of feedwater valves.

The limitations of air and oil

Controlling both the CT and HRSG efficiency, therefore, starts with precision control of the combustion turbine IGVs in order to regulate the exhaust temperature leading into the HRSG boiler. Such control is critical to quickly bring units on-line without risking thermal damage, particularly when the units are being cycled daily. Traditionally, operators have had two options: pneumatic actuators and hydraulic actuators. Both technologies, however, have their drawbacks – they are difficult to calibrate, do not have high repeatability and can even lead to unplanned outages or plant derates.

The choice between pneumatic and hydraulic actuators has focused on price, speed and accuracy. Pneumatic actuators are the lower cost alternative and are fast acting, but also are less accurate due to the compressibility of air as a control medium. 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 the actuator starts moving, it tends to overshoot the new set point. "Smart" pneumatic positioners offer better accuracy by slowing down the actuator as it nears the new setpoint, reducing the amount of overshoot. But this slowdown increases the response time (dead time).

The greatest enemy of a control engineer is dead time in a process loop. Plant control strategies are determined by calculating the dead time inherent in the process loop and tuning the control system for optimal performance. Pneumatic actuators have always been a main contributor to dead time, and in critical applications, if their response can be improved upon, the plant can yield many operational gains. Consequently, the control system can be more effectively tuned for optimization.

To achieve greater accuracy and repeatability, therefore, many plants have utilized hydraulic actuators in applications that require optimal performance. Since hydraulic fluids are incompressible, hydraulic actuators don't have the dead time or the overshoot of their pneumatic counterparts.

The dead time after receiving a control signal drops to less than 100 milliseconds, and they can be tuned to be accurate within 0.05 percent of span. The downside, however, is that they are far more expensive than pneumatic systems, both in terms of initial purchase price, as well as the total cost of ownership since the pump and the network of high pressure tubing and fittings require frequent maintenance.

A happy medium can be achieved via self contained electrohydraulic actuators. These actuators are able to achieve the accuracy of hydraulic systems but are more affordable and simpler to maintain. They consist of two main components: a power module and a control enclosure. The basic mode of operation uses an integral pump to move hydraulic fluid from one side of a double-acting cylinder to another, thereby eliminating the external hydraulic pump, tubing or fluid reservoir.

Units generally include a motor, pump, valve, and some type of oil reservoir. Upon receipt of a control signal, the pump delivers oil to one side or the other of a hydraulic cylinder causing motion in the desired direction. A position sensor is mounted within or adjacent to the cylinders and provides position feedback to the control electronics. The control electronics contain the power supply and motordrivers, as well as the display and user interface.

Out with the old

Electro-hydraulic actuators solve several problems for turbine operators. A plant in Nevada, which has two blocks each with two Westinghouse 501B GTs and a Westinghouse HRSG in a 2x1 configuration, replaced the original Fisher Model 480 pneumatic actuators with electro-hydraulic actuators after frequent maintenance problems and unplanned shutdowns due to actuator failures. Because of the reliability, these actuators were then installed on the flow control valve for the water injection system.

One of Europe's largest co-gen plants – which primarily uses 146 MW (nominal) Mitsubishi Heavy Industries Westinghouse 701DA gas turbines connected to Nooter Ericksen HRSGs with supplemental firing – installed electro-hydraulic actuators on several units as a means to increase output. The original pneumatic actuators had a locally mounted positioner with no remote indication of actual position. They operated in a range of 37 degrees, which was fully closed, to 0 degrees, which was fully open. The intent was to move them past the 0 mark into the negative region up to about -5 degrees. This would allow more air flow through the machine, cooling the exhaust gas temperature, allowing more fuel in the machine to get back to the firing curve, which would generate more megawatts. As a bonus, they have found the electro-hydraulic system much easier to calibrate– taking only about 30 minutes rather than the 2-4 hours they used to spend going back and forth measuring the vane angles to properly zero out each of the old pneumatic positioners.

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