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Variable-Frequency Drive Improves Boiler Operation

Reduces energy costs, maintenance, noise and vibration

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At the University of Rochester in northwestern New York, a utility cogeneration plant provides electricity, steam, hot water, and chilled water to several internal customers, including the 154-acre, 158-building River Campus—the university's main center of learning—and the 750-bed Strong Memorial Hospital.

The plant has the capacity for instantaneous production of 23 MW of electricity, 550,000 lb of steam per hour, 250 million Btu of hot water, and 21,000 tons of chilled water. Electricity production is based on thermal and chilled-water load.

The plant's primary driver is Boiler No. 9. Installed in 2006, it feeds 900-psi superheated steam at rates of up to 175,000 lb per hour to a turbine. The turbine is connected to an 11,500-VAC generator that can generate up to 16 MW of electricity. Natural gas is the boiler's primary fuel, but it also is capable of using No. 2 fuel oil. The turbine's condensate loop, which provides thermal energy to the university's district heating loop, is capable of producing 175 million Btu.

Installed in 1967 and converted to gas operation in 1996, coal-fired Boiler No. 6 produces additional steam during peak demand. Along with three other dual-fuel boilers, it provides backup in the event the No. 9 boiler fails or is out of service for maintenance.

Combustion air for the University of Rochester's No. 9 boiler is supplied through a 500-hp forced-draft fan. The university had difficulty achieving maximum boiler output because of incorrect damper control.

Better Control?

Air is supplied to the No. 9 boiler through a 480-VAC, 500-hp forced-draft (FD) fan. The university was having difficulty achieving rated boiler output partly because of an inability to maximize the capabilities of the FD-fan motor. A soft starter was used to start the FD-fan motor. The distributed control system (DCS) that controls the No. 9 boiler also controlled the pneumatic actuators that drove the inlet dampers of the FD fan.

The No. 9 boiler was designed to run at a high firing range. However, the damper control prevented the boiler

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CONTROLLING BOILER DRAFT

High-pressure boilers depend on mechanical draft, rather than natural draft, because of the large amount of air required for proper combustion and because natural draft is subject to ambient-air conditions. The three types of mechanical draft are induced, forced, and balanced.

Induced Draft

Induced draft can be achieved with a heated chimney or stack (stack effect), a steam jet, or an induced-draft (ID) fan. With a heated chimney or stack, combustion air is forced into and through a boiler, in which the air is less dense than the ambient air.

With a steam jet, steam oriented in the direction of flue-gas flow induces flue gas into a stack, increasing flue-gas velocity and overall draft in a boiler. This was common with steam-driven locomotives, which could not have tall chimneys.

An ID fan removes flue gases from a boiler and forces exhaust gas up a stack. Nearly every ID furnace operates with a slightly negative pressure.

Forced Draft

Forced draft (FD) is achieved by forcing air into a furnace with a special fan and ductwork. Often, air is heated prior to entering a boiler to increase overall efficiency. FD boilers usually operate with a positive pressure.

Traditionally, dampers have been used to control the quantity of air admitted to a boiler. Using a variable-frequency drive to control the speed of a FD-fan motor eliminates the need for dampers.

Balanced Draft

Balanced draft is achieved through the use of both induced and forced draft. This is common with larger boilers, in which flue gases have to travel long distances through many boiler passes. An ID fan works in conjunction with a FD fan, allowing boiler pressure to be maintained slightly below atmospheric. Balanced draft is controlled at a slightly negative pressure.

Source: Adapted from Wikipedia, http://en.wikipedia.org/wiki/Boiler.

from performing as designed and operating efficiently during the shoulder months of spring and fall. Additionally, a considerable amount of vibration and noise was created in the vicinity of the FD fan because of poor air-path conditions.

To improve the situation, the university decided to install a variable-frequency drive (VFD) to operate the FD-fan motor.

The VFD was built to meet the application's specific needs and installed during a scheduled power outage. During the process of integrating the VFD with existing controls, the boiler's damper sequence was discovered to be incorrect. The damper to the wind box located on top of the boiler was not opening sufficiently, causing a restriction in airflow and excessive vibration.

When demand increased, the boiler was starved for air because the FD fan could not keep up. Often, the fan ran at maximum capacity. The wind-box-damper situation was corrected, allowing the university's most efficient boiler to produce steam at full capacity.

Automation System and VFD Work in Concert

The boiler-combustion control logic operating the VFD and FD-fan motor is metered-flow tie-back, cross-limited with excess-air correction.

Commissioning of the VFD went smoothly, the biggest challenge being matching accel and decel times to the process. With the VFD, the FD-fan motor responds better than ever to speed-command changes. The university was particularly impressed with the VFD's ability to recover quickly after a power-loss fault. The VFD is able to rapidly speed search and catch the coasting motor with minimal delay.

Lower Costs, Less Maintenance, Improved Operations

The university's cogeneration plant has run continuously and without issues since the VFD was installed. Both the VFD and the FD fan have operated reliably and efficiently.

Over a 50-day period prior to the VFD's installation, the plant consumed 383,087 kwh of electricity while producing 141,093,563 lb of steam. Over a 50-day period following the VFD's installation, the plant consumed 217,000 kwh of electricity while producing 139,988,998 lb of steam (Table 1). Thus, electrical consumption decreased by about 43 percent, with steam output remaining relatively constant.

The new FD fan and its upgraded controls allowed the university to change the way it operates the plant by increasing the steam load on the No. 9 boiler and reducing the steam load on the No. 6 boiler. Additionally, the No. 9 boiler now can run very efficiently throughout the year, regardless of ambient temperature or demand. First-year energy savings are expected to be about $84,000. Depending on boiler utilization, annual operational savings could be as much as $200,000.

The project qualified for a New York State Energy Research and Development Authority (NYSERDA) rebate of

$26,000. The rebate is the maximum the NYSERDA can grant, and it amounts to 50 percent of the total project costs. The project will help reduce carbon-dioxide emissions by more than 400 tons. Considering the VFD purchase price, the installation cost, and the NYSERDA rebate, payback should be less than four months.

Other benefits of the VFD installation include precise and efficient control of the No. 9 boiler through the full span of its production rating. The motor's average speed is down to about 45 Hz, which has reduced maintenance, vibration, and ambient noise. And because the motor runs cooler, its lifespan, along with the operating life of the FD fan and associated equipment, should be increased.

Conclusion

With the matching of accel and decel rates to the operational requirements of the boiler and generator the greatest technical challenge, the VFD upgrade was relatively smooth. With the resulting energy savings, lowered operational costs, and ability to operate the No. 9 boiler at rated capacity, it is full steam ahead for the university.

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The University of Rochester installed a variable-frequency drive to operate its forced-draft-fan motor. This resulted in improved boiler performance, lower operating costs, less maintenance, continuous operation throughout the year, and less noise and vibration.

	Before	After
Cogeneration-plant 50-day electricity consumption	383,087 kwh	217,000 kwh
Cogeneration-plant 50-day steam production	141,093,563 lb	139,988,998 lb
Vibration in vicinity of forced-draft (FD) fan	High	Low
Ambient noise in vicinity of FD fan	High	Low
Maintenance requirements of FD-fan system	High	Low

TABLE 1. Plant performance before and after installation of variable-frequency drive.

With a variable-frequency drive controlling forced-draft- (FD-) fan-motor speed at the University of Rochester, FD-fan inlet dampers no longer are needed.

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