Recommendation #: Use adjustable frequency drive to replace throttling system (ARC 2.4143)

Est. Electric Energy Savings	=	*164,700kwh/yr*
Est. Electric Energy Cost Savings	=	$10,200/yr
Est. Demand Cost Savings	=	*$3,100/yr*
Est. Total Cost Savings	=	*$13,300/yr*
Est. Implementation Cost	=	*$5,000*
Simple Payback Period	=	*18 months*

Recommended Action:

Install a variable frequency drive to the 40HP induced draft fan to control the flow. Leave the existing adjacent valve damper fully open.

Background:

In an enclosed system, the flow rate is inversely proportional to the head pressure on the fan. Currently, the flow rate is controlled by a valve damper. The electric motor powering the fan runs at full load and at a constant speed. A valve controls the flow rate of air though the duct by restricting airflow. This restriction in air flow increases the head pressure of the fan. Currently, the head pressure on the fan is being increased by partially closing the valve damper.

The disadvantage of this control system is that the flow rate is reduced by increasing the difficulty of the motor to move air. This increased difficulty results in a marginal decrease of the power consumed as the flow rate is decreased.

$$\text{From the Affinity Laws: } \frac{Desired\ Flow\ Rate}{Open\ Flow\ Rate} = \sqrt{\left(\frac{Head\ Pressure}{Open\ Head\ Pressure}\right)}$$

An alternative method for controlling the flow rate is directly controlling the speed of the fan. By controlling the flow rate of air via the speed of the fan, the power consumed by the motor is proportional to the flow rate. Because the fan is belt driven, the fans speed is controlled by the motor speed.

$$\text{From the Affinity Laws: } \frac{Desired\ Flow\ Rate}{Open\ Flow\ Rate} = \left(\frac{Modulated\ Fan\ Speed}{Normal\ Fan\ Speed}\right)$$

Anticipated Savings:

The power reduced is equal to the power used for valve controlled modulation minus the power used for motor speed modulation. From the measured amperage(34A) and voltage(510V) with the calculated power factor(0.75) , the motor currently consumes 22.53kW.

$$kW = \frac{(volts)(amps)(\sqrt{3}_{three\ phase\ power})(power\ factor)}{(1000\frac{W}{kw})} = \frac{(510)(34)(\sqrt{3})(.75)}{\left(1000\frac{W}{kW}\right)} = \textbf{22.53kW(30.207hp)}$$

The 40HP(29.85KW) Motor has a damper adjacent to it to control the flow. During the audit, the flow rate was observed to be at 55% of the open valve flow rate via the boiler room control panel. The motor power needed to move the air at 55% of the open flow rate is calculated from the affinity laws. In the affinity laws, the amount of air moved is proportional to the rotational speed of the fan. Additionally, the amount of power consumed is the cubic root of the flow rate or fan speed.

From the affinity laws:

$$\frac{Power\ Consumed\ Motor\ Modudated\ Flow\ Rate}{Power\ Consumed\ Valve\ Modulated\ Flow\ Rate} = \left(\frac{Modulated\ Fan\ Speed}{Open\ Flow\ Fan\ Speed}\right)^3 = \left(\frac{0.55}{1.0}\right)^3 = 0.166$$

The Power consumed using a variable frequency drive is 16.6% of the power consumed using valve modulation. Therefore the new power consumption is estimated to be 0.107kW.

$$Power\ consumed\ with\ variable\ speed\ drive = (22.53kW) \times (0.166) = 3.74kW$$

The power saved is the difference between the two methods of modulation, which is 18.8kW.

(Power needed for valve modulation)-(Power needed for motor modulation) = 22.53kW-3.74kW =18.8kW

The estimated annual energy savings, ESi, and annual energy cost and demand savings, ECSi & DSi, for the variable speed motor modulation are as follows.

$$ESi = (18.8kw) \times \left(8760\frac{hrs}{year}\right) = 164{,}700kWh\ annually$$

Consumption cost per kW =$0.06185 (when over 15,000 kW/month)

Monthly demand cost per kW=$13.35 (taxes included)

*ECSi=ESi*cost per consumed kW=(164,700)*(.06185)=$10,200/yr*

*DSi=Power Saved * Monthly demand cost* 12 months = (18.8)*(13.35)*(12) = $3,010/yr*

The estimated annual energy demand savings, DSi, and annual energy demand cost savings, DCSi, for the variable speed motor modulation are as follows.

TCSi = (ECSi + DSi) = ($10,200 + $3,010) = $13,300/yr

Note: The power factor of .75 comes from a motor performance program developed by U.S DOE Energy Efficiency and Renewable Energy.

Implementation

The implementation cost, ICi, is the combination of the labor and equipment cost. Many variable speed drives are on the market for three phase AC power. It is estimated that the project will cost in the neighborhood of $5000.

The simple payback period, SPi, associated with installation of variable speed motor control is the estimated implementation cost divided by the estimated total cost savings

$$Sp_i = \$5000 / \$3,300 = \mathbf{1.5yrs = 18\ months}$$

Additional Notes:

The dampening valve adjacent to the 40hp fan is currently controlled automatically by the combustion control panel associated with the boiler. The equipment selection and installation of a variable speed drive will have the additional complication of being compatible with the existing control panel.