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Transmitter Location Drives Savings In HVAC Pressure Control Applications

The potential for energy conservation and resultant cash savings continues to fuel the growing popularity of Variable Frequency Drives (VFDs) in HVAC installations.

Energy savings in fan and pump installations employing VFDs and utilizing closed loop control with pressure feedback can be significant. These potential savings are the justification for drive purchase and installation. Advancements in VFD technology continually induce businesses to "spend in order to save."

Realizing that potential, however, has often proven to be elusive, due to the inherent dependency for success on proper placement of the pressure feedback transmitter in the air or water distribution system. In fact, many in the industry can recall projects where the design and installation of new VFD-based energy conserving systems failed to produce the anticipated economies.

It is the location of the pressure transmitter that will determine the amount of actual energy savings attained.

Pressure Transmitter Location

Cryptic recommendations are made regarding transmitter location "two-thirds of the distance" out in the distribution system or "at significant loads" - but why are these locations suggested? The reasons need broader explanation if these rules-of-thumb are to be effective.

The equation for power required by a fan or pump is:

Power = (Flow x Pressure)/Efficiency.

From this equation, it can be seen that a reduction in either flow or pressure will contribute to a reduction in power. And that reduction in both flow and pressure will provide the most power reduction.

Flow reduction occurs because it is directly modulated by the HVAC system control valves or dampers in response to applied load changes. As flow decreases from "design" flow so does system resistance to that flow. Therefore, less pressure is needed from the fan or pump when it is operating under partial load conditions.

Measure Pressure At The Load

To benefit from lower flow resistance it is essential to place the transmitter so that it measures pressure where the load is located -- in the distribution system extremities. This pressure is critical to control performance. It allows the drive's PID controller to take advantage of the decreased resistance to flow in the distribution network as flow is reduced.

With this pressure transmitter placement, as in Figure 1, the controller setpoint requirement is the actual pressure needed by the load. There is no necessity for a controller setpoint based on "worst case" -- maximum load, maximum pressure conditions.

Some installations have incorrectly located the pressure transmitter directly at the pump or fan discharge, as in Figure 2, usually to reduce installation costs or take advantage of standard equipment packages offered by OEMs. A pressure transmitter at this location will ignore much of the potential for energy savings.

Location Effects Energy Conservation
The significance of transmitter location for energy conservation in pressure control applications is not always obvious to the people involved; system designers, drive application engineers, installation technicians and mechanical engineers. Further explanation may be required to accommodate other viewpoints:

The Concept
Location of the transmitter at the optimum distance in the distribution system allows use of a lower controller setpoint. This setpoint reduction provides improved energy performance. Both flow and pressure impact the power required. Therefore, the control strategy must optimize both the flow and pressure that the pump or fan is required to deliver.

Specifically
The system pressure required at the furthest significant load is constant - regardless of load changes. It is the pressure necessary to maintain “design” flow through a load device and control valve or damper that is open to handle “design” load in the conditioned space.

In order to deliver this pressure and flow, the pump or fan must be capable of overcoming the system resistance to flow. System resistance, for much of the flow range, is likely to be a more significant pressure consideration than that of the load device.

As flow to the load increases, pump or fan discharge pressure must be high enough to overcome increasing system resistance. Maximum system flow, therefore, requires the highest pump or fan discharge pressure to overcome system resistance and still deliver the required flow.

If the pressure transmitter is located near a pump or fan discharge, as in Figure 2, the controller setpoint, must be established at the “worst case” high discharge pressure to assure that there will be enough pressure at the load when the flow is greatest. At all other (lower) flows, there will be more pressure than necessary “out at the loads.”

The controller setpoint is a single value, so if the pressure transmitter is located at the pump or fan discharge it must be set to a high level -- the system “design” pressure. Such a high controller setpoint ignores significant potential energy savings that would be produced by variable flow with variable pressure at the pump or fan discharge.

Alternatively, if the pressure transmitter is located at the furthest significant load in the distribution system, as in Figure 1, the controller setpoint can be established at the much lower pressure required by the load. In this case, as flow is reduced by control valves or dampers, the pump or fan only needs to maintain the lower pressure requirements of the load.

As flow decreases and system resistance becomes less, pump or fan discharge pressure will also decrease - by the same amount as the fall-off in system resistance to flow. In this control scheme, the pump or fan discharge pressure is uncontrolled while the pressure that is important to system operation is under closed loop control.

Transmitter Location In HVAC Pressure Control Applications

The transmitter location at the terminal unit end of the distribution network allows a low level setpoint for "best case" energy conservation. The control curve must pass through the setpoint at zero flow, allowing the closest practical approach to the "squared" function system curve as flow is reduced by the terminal units.

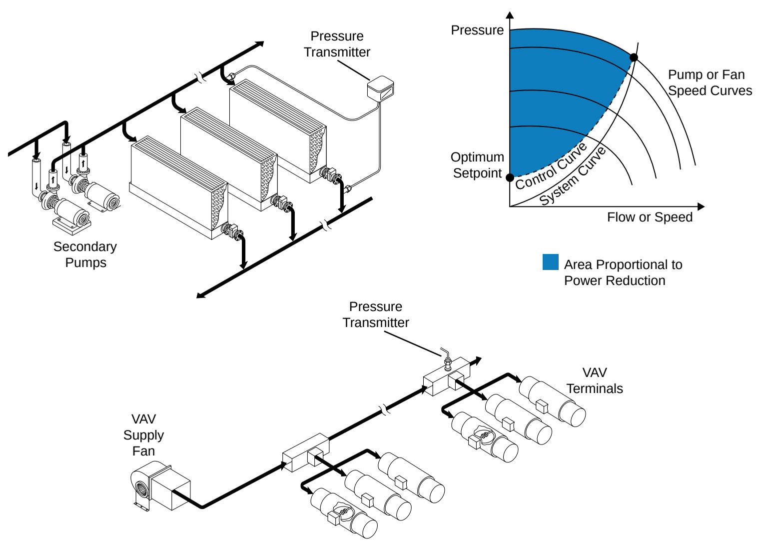

Figure 1.
Correct Pressure Transmitter Location for Chilled Water Secondary Pump Control or VAV Supply Fan Control

The transmitter location at the fan or pump discharge requires that the setpoint be established for the "worst case", which is the "design" pressure for full flow. The control curve, passing through the setpoint at zero flow, has become a horizontal "linear" function which does not permit the discharge pressure to follow the system curve as flow is reduced by the terminal units.

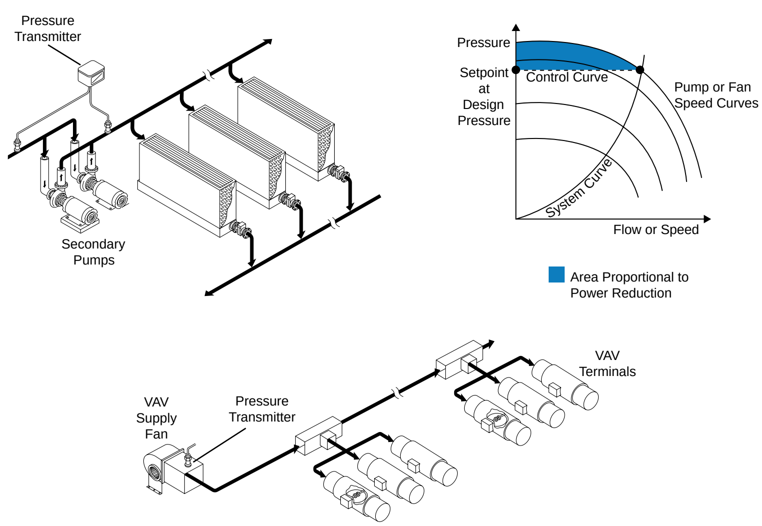

Figure 2.
Incorrect Pressure Transmitter Location for Chilled Water Secondary Pump Control or VAV Supply Fan Control

Improved Conservation

Energy conservation improves with the pressure transmitter at the extremities of the distribution system, as in Figure 1, because this location for the transmitter allows the drive PID controller to utilize a lower setpoint. This means that system pressure at the control valves or dampers will never be more than is required. The potential for energy savings, resulting from variable flow with variable pressure, will be realized because the pump or fan discharge pressure will be able to decrease as flow decreases.

When the transmitter is located at the pump or fan discharge, as in Figure 2, the ability to sense what is happening in the system is lost. To prepare for the worst case (full flow) condition, the control system always must provide "design" pressure at the pump or fan discharge.

With the transmitter "out in the system," at the loads, as in Figure 1, discharge pressure is allowed to vary as needed. This is a "smart" system because the controls automatically adapt to variations in distribution system resistance to flow occurring with changes in flow rates. The lower the controller setpoint relative to the "design" pressure of the pump or fan, the less power required.

Summary

Proper placement of the pressure transmitter in the HVAC system is the single most important factor in realizing projected energy savings. It can mean the difference between a savings of only 5% if the transmitter is situated as shown in Figure 2 or above 30% savings if located in the system as shown in Figure 1.

Definition Of Terms

Closed Loop – Control of output by comparison of a feedback signal to a set point. The feedback signal provided by a transmitter "closes the loop" between a controller, controlled device and controlled variable. Also commonly referred to as "PID control."

Design Point – The maximum load, flow or pressure that the distribution system is designed to handle.

Discharge Pressure – Pressure measured at, or very close to, a pump or fan discharge.

Distribution System – The piping or ductwork that distributes water or air in an HVAC system.

Feedback – The standard signal provided to a drive's PID controller by the transmitter and its wiring.

Load – A device that can demand flow of air or water. In pump applications a coil and control valve. In fan applications a terminal unit damper.

PID – Proportional plus Integral plus Derivative control

Squared Function – A mathematical relationship such as $y=ax^2$ (y equals a times x squared).

Terminal Unit – For the purposes of this document it is the device at the end of the distribution system with flow modulation capability, a variable air volume box or a cooling coil and control value.

Transmitter – A device that generates a standard signal proportional to an analog pressure input. In the applications described above, the transmitter is usually a differential pressure transmitter in pumping applications and a static pressure transmitter in fan applications. For pumping applications, the pressure measured is the difference in pressure across the control valve and coil at the preferred transmitter location.

Setpoint – The pressure that the drive's PID controller maintains at the transmitter location.

VAV – Variable Air Volume.