

Energy Saving Control Valves

A post-modern perspective on control valve actuation

A great deal has been written about energy saving architecture and fluid systems, and the results of "green" endeavors are well known. It is now appropriate to look at additional untapped energy and dollar savings that are available from the final control element, specifically from more efficient control valve actuation. This discussion will show comparisons between two methodologies, and will assist the reader in making better-informed decisions about control valve actuation.

Historic overview

Historically, the pneumatic, spring opposed diaphragm actuator dominated the control valve actuator marketplace. It could produce large operating forces and was inexpensive to manufacture. It could move quickly and was reasonably accurate, except that expensive positive positioners had to be added for more demanding applications. Perhaps best of all, it could be "powered" by inexpensive compressed air.

Electronic process controller technology brought process control to a new level. A process temperature that might previously be controlled to within plus, or minus five degrees of setpoint can now be reliably and repeatably controlled to within a fraction of a degree. The electronic controller became less and less expensive to purchase, and needed little or no maintenance. The marginal accuracy of the pneumatic actuator became less acceptable, and the positive positioner had to evolve to attempt to keep up. The result was an essentially electronic valve positioner with a pneumatic output and a very high price. Simultaneously, the rising costs of materials and manufacturing increased the price of pneumatic actuators, and the cost of operating and maintaining a compressed air distribution system rose dramatically. A single-valve pneumatic application, such as an isolated potable water heater incorporating a small, dedicated air compressor became prohibitively inefficient and costly. Clearly, new solutions were needed.

Actuator modernization

Concurrent advances in electric motor technology made them significantly smaller and more efficient, as well as more reliable; and mass production reduced their cost significantly. An electric motor valve actuator can operate on a small amount of common electrical power, can incorporate state-of-the-art electronic signal and positioning technology, and many can communicate directly with computerized control systems. Indeed, they might be more accurately described as *electronic* actuators.

Electric valve actuators are broadly categorized as either industrial or commercial devices. The industrial devices may be large and heavy, depending upon the amount of output force that is needed and environmental requirements such as watertight and/or explosion proof integrity. An option that continues to be costly in industrial actuators is "fail-safe" protection, where the actuator travels to a pre-determined position when operating power is interrupted. Fail-safe is, of course, determined by the application. A valve carrying a heating medium might fail shut, and one carrying a cooling medium might fail open. One of three fail-safe methods is commonly used with electric actuators, the earliest being the use of a mechanical spring. The spring is pre-loaded with sufficient force to secure the fail-safe position, and the electric motor must furnish enough force to further load it while stroking the valve. Both the spring module and the more powerful motor/gear package add to the size and cost of the actuator.

Another fail-safe method is the use of a battery as a backup energy source to drive the motor when the primary source of electricity is lost. Unlike the mechanical spring whose force decreases as the valve stem moves, electric fail-safe provides full operating force throughout the actuator's range of travel. Both the battery and the spring eventually succumb to fatigue in use, and repeated electrical outages in quick succession can leave a battery without sufficient charge to perform its fail-safe duty.

The state of the art

The third method, coming into widespread use most recently, is that of storing energy in a bank of compact "super" capacitors with very high charge densities, then using the stored energy to power the actuator in fail-safe mode. Capacitances of one Farad are typical, and motor operating voltages are achieved by connecting them in series. In contrast with a battery, the capacitor can be recharged in less than one minute, and can be discharged and recharged an unlimited number of times. It should be noted that this is not an alternate source of energy for continued valve operation, but is perfect for fail-safe applications.

Returning to the water heater application mentioned earlier, the small heated water storage capacity of compact semi-instantaneous heaters dictates that the control valve must move rapidly, with sufficient force to overcome friction and line medium differential pressures. If operating power is interrupted, the control valve must shut quickly and tightly to prevent dangerous overheating. Those are tall orders for an industrial electric actuator, and the device can command a price in excess of \$5000.00 in addition to the cost of the valve body assembly. One control valve manufacturer has developed an electric control valve using an industrial valve body operated by a fast, low torque rotary actuator incorporating a capacitive fail-safe system. Its use is made possible by linking the actuator to the valve body using a device capable of magnifying the actuator output force and achieving a geometric fail-safe lockup state that is maintained without any continued actuating force. For this discussion, the most noteworthy feature is that the control valve consumes just 30 VA (volt amperes) of power while repositioning, and essentially none while idle.

Economic comparisons

To compare the operating cost of a pneumatic water heater control valve with that of an electric/electronic control valve in otherwise identical installations, the simplifying assumption is made that one VA is approximately equal to one watt of AC power. Each valve is in continual use, and is actively repositioning 15% of the time and idle 85% of the time. A pneumatic positioner on a typical water heater control valve consumes approximately 25 standard cubic feet per minute (SCFM) during valve repositioning, and about 10% of that when idle.

The cost of producing compressed air in large commercial and industrial operations has been reported to be approximately \$0.25 (twenty-five cents) per 1000 SCF. On that basis, the yearly cost of powering the pneumatic valve in our example is:

$$\begin{aligned} \text{Yearly cost} &= \$0.25/1000 \text{ SCF} \times (15\% \times 25 \text{ SCF/M} + 85\% \times 2.5 \text{ SCF/M}) \times 525,600 \text{ minutes/year} \\ &= \$0.25/1000 \times (3.75 + 2.125) \times 525,600 = \mathbf{\$771.98} \end{aligned}$$

This might represent the yearly cost of adding a single pneumatic control valve to an existing, or "legacy" compressed air system. It includes costs for electricity and unavoidable leaks as well as operating and maintaining the compressor(s) and distribution network.

The cost of operating a single pneumatic control valve with a small dedicated compressor in an isolated water heater installation can be derived using 1000 SCFH as full capacity for the 2 horsepower compressor and a current (September, 2007) national average electrical utility cost of \$0.0947 (9.47 cents) per kilowatt-hour (kWh). The lowest rate at that time was seen to be \$0.0514 per kWh in West Virginia, and the highest was \$0.208 per kWh in Hawaii. Air storage tanks are not typically used, so the compressor runs continuously, 8,760 hours each year. Its duty cycle is running at full load 15% of the time, and at 94.5% efficiency. It runs at 25% of full load 85% of the time, at 90% efficiency, with an energy conversion factor of 0.746 kW/hp.

The cost per year to run the compressor is:

$$\text{Fully loaded} = \frac{2 \text{ hp} \times 0.746 \text{ kW/hp} \times 8,760 \text{ hr/yr} \times \$0.0947/\text{kWh} \times 0.15 \times 1.0}{.945} = \$196.46$$

$$\text{Unloaded} = \frac{2 \text{ hp} \times 0.746 \text{ kW/hp} \times 8,760 \text{ hr/yr} \times \$0.0947/\text{kWh} \times 0.85 \times 0.25}{0.90} = \$292.24$$

Total annual energy cost to run the compressor is **\$488.70**. This cost appears to be less than adding one valve to an existing air system, but does not include costs for repair and/or replacement of the compressor. It is left to the imagination of the reader to guess what the real total cost might be.

State of the art efficiency

The cost to operate a single AmurAct electric control valve that is continually on line, repositioning at an electrical draw of 30 VA for 15% of the time, and idle 85% of the time is:

$$\text{Total annual AmurAct energy cost} = \$0.0947/1000 \text{ Watt-Hours} \times 15\% \times 30\text{w} \times 8,760 \text{ hrs/yr} = \mathbf{\$3.74}.$$

From this example alone it is apparent that the cost of "powering" a pneumatic control valve can reasonably be much more than 100 times the cost of operating an AmurAct electric control valve. A university, or similar entity, operating 200 isolated water heater installations might save nearly \$100,000 each year. Electric control valves having the speed, power, fail-safe and other desirable features of a pneumatic control valve may be priced marginally higher, but initial cost is a one-time expense. The energy cost saving reappears each time a reduced utility bill is paid; and the cost savings are not limited to new installations. Electric control valves quickly and easily replace self-contained regulators and pneumatic control valves in existing installations.

Looking forward

Areas of equal concern, but beyond the scope of this discussion include carbon dioxide emissions and other greenhouse gases produced during power generation, and noise pollution typically generated by air compressors. We have shown that, in addition to the value of reducing these pollutants, the electric control valve actuator offers significant operating cost savings in the range of 99% or more. From environmental, economic and technological perspectives, designers, builders and users of "green" systems can benefit from learning more about electrical/electronic control valve actuation.

Sources:

MnTP • University of Minnesota – Fact Sheet / Air Compressor Energy-Saving Tips 4-7-82

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