Control valve actuators: their impact on control and variability

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In a process plant, the general function of a control valve is to restrict the opening of the valve so it affects the flow or pressure of the liquid or gas that is passing through it. In any given application, an installed valve, whether it is a rotary or sliding stem valve, has one fundamental variable - the position of the moving element. That single moving element determines the exposed orifice that allows greater or lesser flow through the valve, which in turn provides the control of the process.

The valve itself may be extremely sophisticated with exotic body and seat material, or it may have complex flow patterns that allow for a high pressure drop or some other function. However, the fundamental requirement to move the valve stem to position the control element remains the same regardless of whether it is a simple or a sophisticated valve.

A control valve actuator is used to move the valve stem (which is attached to the internal control element) to the desired position and hold it in place. In addition to the act of moving and holding positions, there are many other parameters to that movement which determine the best type of actuator that should be used for every specific application. For example, other important considerations might include speed, repeatability, resolution, and stiffness.

Carefully consider the specific demands of your process

The demands of the process will significantly affect the demands of the valve and by association the performance of the actuator.

When selecting the proper actuator for an application, the first and most fundamental consideration is the actuator's ability to overcome the reactive force of the valve. This force is mainly a function of valve size and differential pressure across the valve as well as packing and/or seat friction.

Clearly the force generated by the actuator must be sufficient to overcome the valve forces. In many cases, control valves may have a seating force requirement in excess of the mid-travel force demand. Therefore, valve actuators are required to be sized to the maximum of force demanded by the valve.
Another important consideration is the dynamic performance requirement, or speed of the actuator, so that the valve can adequately meet process demands. There are two elements that should be considered when evaluating actuator speed. The first is the reaction time to initiate movement after a demand signal change, and the other is the speed of operation once motion is initiated.

Electronically controlled electric actuators react almost instantaneously to a demand change when required. However, pneumatic actuators need to physically build up sufficient pressure in the piston or diaphragm to initiate movement. That generates a delay or dead time, which can negatively impact the process.

Once motion is initiated, an electric actuator is restricted by the maximum speed of its motor whereas a pneumatic actuator can move as quickly as the air can drive the piston or diaphragm. For smaller incremental changes in demand, the electric actuator’s reaction time is significantly faster than an equivalent pneumatic actuator with a nominal dead time. Conversely, for large swings in demand signal, pneumatic actuators have the advantage of faster stroking speeds over longer distances.

Other important considerations in actuator selection are resolution, repeatability and precision:

- **Resolution** is defined as the minimum change in demand signal that results in a change in output when moving in the same direction. This is an important measurement as it determines how finely the control valve can be positioned to affect the process.

- **Repeatability** is the closeness of agreement of a number of consecutive measurements of the output for the same value of inputs, when approaching from the same direction.

- **Precision**: the combination of resolution and repeatability impacts the precision in which the control valve can be positioned. The greater the precision, the greater the control that can be exerted over the process. The benefit of precise control on process variability is well documented. Specifically, the impact on the quality of product produced and also the capacity of the plant is profoundly affected by the reduction of process variability when using a more precisely controlled valve. See Figure 1.
Fig. 1: Graphs showing the impact of reducing "process variability" on the set point of a process. On the left hand graph the process variability (red) is high, this forces the set point far below the limit to ensure quality. The right hand graph shows that the lower process variability allows the set point to move upward. This increases quality and also process capacity is increased.

Actuators that are able to deliver high repeatability and high resolution are therefore more valuable to the process than actuators that do not have this capability to position the valve with precision.

**New electric actuators can significantly improve traditional performance**

While some pneumatic valve positioners catalog resolutions on the order of 0.1%, that can be misleading. Once these positioners are coupled to pneumatic valve actuators, feedback linkage connections and other external factors diminish the resolution. Certain new electric actuators, however, combine the position feedback as an integral part of the actuator and are thus able to achieve genuine performance figures in the region of 0.1% repeatability and resolution.

The nature and application of control valves often conspire to diminish the dynamic performance of the valve. Valve packing friction in globe valves or seat friction in ball valves can cause problems when trying to dynamically position a valve to a new set point in a minimum time.

Air is a compressible medium, and because of this, air has difficulty in providing precise control, especially when valves are "sticky." The static friction in the valve requires excess air to be introduced to the actuator in order to break the valve from the seat or the packing friction. Once the valve has broken free, the dynamic friction being less causes the excess air to overshoot the desired set point causing an oscillation.
The oscillation has an effect on the process variability. Similarly pneumatic actuators when mounted on globe valves tend to exhibit resilience under the action of a pressure spike or surge in the pipeline media.

On the other hand, electric actuators with their mechanical drive train are inherently stiffer and are able to hold the set point more easily. This means that under surge or cavitation conditions, the valve will hold its position and maintain the process set point.

**Technological advances**

Currently, the industry standard for control valve actuators is the spring diaphragm unit with a digital positioner. Because of its simplicity, the spring diaphragm actuator is found in virtually every type of application and is simple, robust, and easily provides a fail open/close capability. Digital positioners have become sophisticated enough to overcome, to a certain degree, the problems of a stick slip and overshoot, but can be very demanding in terms of calibration, set up, and maintenance.

Until recently, the control of electric actuators was inferior to spring-diaphragm control valve actuators. Either the electric drive was too slow to provide the response required, or the motor and drive train inertia of high-speed actuators precluded precise positioning.

New control technology has overcome these problems by sensing not just the output position of the actuator but also the motor position and speed.

The block diagram of the control circuit (see Figure 2) shows that the output of the actuator is fed back and compared to the demand position signal. The resulting error signal is fed into the motor speed profile. The actual speed of the motor is then compared to the demand speed and that error signal, in turn, is fed into the motor controller.

The accuracy of the sensors coupled with the control logic results in the elimination of overshoot normally experienced on “sticky valves”. By eliminating overshoot, process variability is significantly reduced and many significant benefits result.
New electric control valve actuators put to rest a common perception that electric actuators are susceptible to mechanical wear when used for constant modulation. With careful gear design and material selection the drive train of the new generation of control valves actuators can achieve many millions of cycles, even under the full-rated load of the actuator. In fact, some tests have shown that over 200 million cycles can be achieved even at elevated loads.

The other obstacle when comparing functionality of conventional spring diaphragm actuators with electric actuators is the ability to fail to an open/close position. Recent developments in electric actuators have utilized stored electrical energy in the form of super capacitors. The electrical energy stored in the capacitor can provide a high power density enabling the electric motor and drive train to position the actuator not only in an open or close position but any selected intermediate position. This versatility can deliver additional benefits to some processes where complete shut down of the process could be disadvantageous.
Summary

The technological developments in the new generation of electric actuators mean that the functionality and performance of the conventional control valve actuator can be surpassed. Electric actuators can deliver improved process control due to the precision of their performance. Reaction to changes in set point and maintenance of the set point, despite upsets in the process, can reduce process variability.

Most importantly, the new generation electric actuators are easily installed and integrated into Bus systems such as Hart, Foundation Fieldbus, and Profibus. Another significant benefit is that electric control valve actuators eliminate the sometimes troublesome instrument air supply requirement.

The new electric control valve actuators have an integral thrust or torque sensor (depending on whether the actuator is a linear or quarter turn output). The measurement of thrust and torque is invaluable when combined with simultaneous reading of position. These readings are retained in the control valve actuator’s built-in data logger and can be downloaded for detailed analysis.

Because thrust measurement or torque measurement is a direct reading - not one that is derived from the pressure over a piston or diaphragm area - the measurement is immediate and accurate. That means the changes in the condition of the valve can be monitored to predict when maintenance on packing or seats is required.

Finally, the human machine interfaces (HMI) that are available for use with these new electric control valve actuators provide easy access to important performance and analytical data. Simple and user-friendly HMI tools such as PDAs and laptop computers can communicate wirelessly via Blue Tooth to the actuator. All of the settings, configurations, calibration, data logging, and analysis tools are available to facilitate easy installation of the control valve actuator and to provide the information appropriate to the modern plant’s asset management systems.

Fig. 3: Rotork CVA electric control valve actuator installation in a power station.