White Paper

PCV-WP-0321

Are Pump Control Valves Dinosaurs?

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Introduction

At the beginning of the industrial age, water pumps were huge pieces of machinery that were driven by gigantic steam engines incorporating flywheels to dampen the piston engine's pulsations. Due to the mass of its rotating elements, the pump/engine combination had very high rotational inertia. As a result, it took a while for a pump to get up to full speed at startup. Then at pump shutdown, it took a long time for it coast to a stop, gradually decelerating the fluid's pipeline velocity. Since pressure surges are the result of an abrupt change in the fluid velocity, they were virtually unheard of at the time.

Likely in the late 19th century, someone got the bright idea to connect one of those new-fangled electric motors to a pump and everything became smaller and lighter weight with a corresponding reduction in rotating inertia. Electric motor driven pumps came up to speed and coasted to a stop very quickly. It wasn't long before a pipe ruptured because of the pressure surge resulting from this rapid change in fluid velocity.

Pump control valves were introduced to control the rate of change of the fluid's pipeline velocity at pump start and at pump shutdown to minimize pressure surges. The pump control valve is installed on the discharge of the pump and electrically interfaced with the pump motor starter. The valve is closed when the pump is off-line to prevent reverse flow. The pump starts against the closed valve which opens at a controlled speed *after* the pump has come up to pressure to gradually accelerate the fluid velocity to prevent excessive pressure surge. At shutdown, the pump control valve slowly closes against the running pump to gradually decelerate the fluid line velocity. The pump switches off only *after* the pump control valve is closed and the line velocity has been sufficiently reduced to prevent excessive surge. For decades, pump control valves were the only reliable method of preventing excessive pressure surges due to pump operation.

Electronic Motor Control

Over the past 50 years, technology has produced ever more sophisticated methods of controlling motors, primarily to minimize their impact on the electrical system, reduce power consumption and the owner's operating cost. The two most common methods are "reduced voltage soft start/stop (RVSS)" and "variable frequency drive (VFD)." In many cases, the power supplier offers incentives to reduce power consumption which can offset the capital cost of the equipment. When the motor is driving a pump, these electronic methods are also widely promoted as a solution for hydraulic surges resulting from pump start and shutdown. While electronic motor control technologies have certainly impacted the pump control valve market, their limitations must be considered before depending on them to control pressure surges.

Reduced Voltage Soft Starter (RVSS)

- Because a direct across-the-line start draws up to 600% of the running current, RVSS are often mandated by the power supplier to avoid a drop in line voltage affecting other equipment or customers
- RVSS ramp up the motor voltage thereby reducing starting (inrush) amp draw and sudden torque loads on the driven equipment.
- RVSS control the rate of change of motor RPM only during startup and *not* shutdown
- Standard RVSS ramp time from zero to full speed is usually measured in seconds
- RVSS are available with “pump control” (also called “torque control”) feature that can extend the standard RVSS ramping up and down time.
- According to Affinity Laws, fluid flow varies linearly with speed, and pressure with the square of the speed, so the pump will come up to pressure faster than to design flow.
- Motor RPM below the speed required to move fluid forward has no effect on fluid velocity.
- RVSS cannot control the rate of change in fluid velocity upon sudden pump stoppage due to power, pump, motor or RVSS failure.

Variable Frequency Drive (VFD)

- A VFD manipulates the frequency (Hertz) of the voltage applied to the motor to vary its speed. In North America, at 60 Hz the motor is operating at full speed and proportionally slower at lower frequencies
- Like an RVSS, a VFD ramps up the motor speed at start up to minimize inrush current and sudden torque loads. But instead of ramping from zero to full speed, the motor ramps up to the speed necessary to meet the flow and pressure demands of the system.
- As demand varies, the VFD ramps the motor speed up and down so that the driven pump maintains constant pressure under varying demand.
- According to Affinity Laws, power savings are proportional to the cube of the motor RPM. Theoretically, running at 60% full speed reduces power consumption to 22% of full speed (0.6 x 0.6 x 0.6 = .22). The major reason to utilize a VFD is to reduce the cost of pumping.
- A VFD is most effective in *friction dominated* pumping scenarios, especially when the pump operates to the left of its design point much of the time.
- A VFD becomes less effective at reducing power consumption as static lift becomes a larger portion of the total pumping head. In the above example, if the motor has to run at 80% full speed (48 Hz) just to overcome static lift, the power consumption increases to 51% of full speed vs. 22%.
- A VFD can ramp motor RPM down over longer time than SSRV and therefore can be more effective at minimizing surges
- A VFD usually has a 2-3% energy loss as heat. This affects overall efficiency and adds to the operating cost, especially if the heat must be dissipated through cooling.

- Only the portion of the ramping that changes fluid line velocity has any effect on surge. In the above situation, it's the portion between 48 Hz and 60 Hz. So, if the ramp down from full speed is linear, the fluid velocity is changed over only 20% of the total ramp down time.
- A VFD cannot control the change in fluid velocity upon sudden pump stoppage due to power, pump, motor or VFD failure
- Dry pit submersible sewage pumps operating at reduced speed are susceptible to sedimentation buildup and clogging. To avoid this, at least one pump manufacturer recommends a "cleaning sequence" where the pump *quickly* ramps up to and down from full speed once or twice an hour. The slow ramping needed for surge control would not be realized in the "cleaning sequence."

Pump Control Valves

When a SSRV or VFD is deemed impractical, either because it cannot adequately control pressure surges or it is not a cost-effective solution for the operating conditions, pump control valves become a viable solution. In some situations, a pump control valve is utilized in addition to the a VFD.

Virtually any type of valve can be configured to function as a pump control valve, although some are better suited than others. The most common types are globe or angle body valves and ball or cone valves. Regardless of type, electrical logic must properly sequence the valve's operation with that of the pump motor for not only "normal" operation but also "emergency" situations such as power, pump, motor or drive failure.

Globe and angle body valves (such as the GA Industries "Electric Check Valve") are well suited to for pump control service when the pumped fluid is clean water. GA Industries AWWA ball valves and Rotovalve® cone valves, as well as its Checktronic® pump control valves, can be used whether the pumped fluid is clean water, sewage or other debris-laden fluids.

Energy Considerations

Much is said by the VFD folks about the energy cost of throttling a valve to control pumping rate. To reduce the pumping rate (Q), the valve must add head to move the pump's operating point to the left on its curve with a corresponding increase in pumping cost. For that reason, when controlling pumping rate to match demand, a VFD is often better solution than throttling a valve.

However, pump control valves rarely "throttle." They are fully open during pumping and can be selected to contribute very little headloss.

Headloss through the pump control valve is directly proportional to the k-factor of the valve being used and to the square of the fluid velocity according to the formula $HL = k(V^2)/2g$ where HL is in feet of water, V is velocity in ft/sec and g is the gravity constant (32.17 ft/sec/sec).

While it varies a little bit by size and from manufacturer to manufacturer, the k-factor for a particular *type* of valve (gate, butterfly, globe, ball, etc.) is relatively consistent. The typical k-factors for valves commonly used for pump control:

Globe Body Electric Check Valve – 5.6

Angle Body Electric Check Valve – 2.8

CHECKtronic® Wye-Body – 2.5

CHECKtronic® Long Radius Elbow Body – 1.5

Ball or Rotovalve® Cone Valve – 0.05

At V = 10 ft/sec through each of these fully open valves, the headloss would be as follows:

Globe Valve (e.g., Electric Check) – 8.7 ft

Angle Valve (e.g., Electric Check) – 4.4 ft

CHECKtronic® Wye-Body – 3.9 ft

CHECKtronic Long Radius Elbow Body – 2.3 ft

Ball or Rotovalve® Cone Valve – 0.08 ft

Except Ball or Rotovalve® Cone Valves, using a pump control valve that is one (or two) sizes larger than the pump discharge reduces the velocity and consequently the headloss. For example, reducing the velocity from 10 to 7 ft/sec through the globe Electric Check valve would result in a 50% reduction in headloss (8.7 ft. to 4.3 ft.).

Since the k-factor of ball and Rotovalve® Cone Valves is so low, the velocity can be high without producing significant headloss. Therefore, it's rare that this type of pump control valve is larger than the pump discharge size. Even at V = 20 ft/sec, the headloss through a ball or Rotovalve® cone valve would be only 0.3 ft.

Actuation

Globe or angle body water pump control valves are usually "self-contained, pilot-operated" and use line pressure for operation. The valve is opened and closed using solenoid pilots and the opening and closing speed (and in turn the rate of change in fluid line velocity) is controlled by needle valves.

When used on clean water, GA Industries AWWA Ball Valves and Rotovalve® cone valves can be actuated by a hydraulic cylinder using line pressure with both normal and emergency controls like the Electric Check Valve. When the line media is sewage or other debris-laden fluids, the cylinder actuator and pilot controls require a separate pressure source such as clean water, compressed air or pressurized oil.

Whether self-contained or using a separate pressure source, the actuation pilot system is configured to recognize the difference between an intentional pump shutdown with a corresponding slow closure and an unexpected stoppage of pumping (e.g., power failure) requiring it to close the valve at a faster than normal speed to minimize back flow.

Ball valves and Rotovalve® cone valves can be operated by an electric motor actuator, but then closing the valve upon loss of power becomes problematic. Backflow upon power outage can be prevented by installing a separate check valve in series with the pump control valve, but it adds headloss and defeats the purpose of using a virtually zero head loss ball or cone valve. Another option is to incorporate an Uninterruptible Power Supply (UPS) with the ability to store sufficient power to close the valve in the absence of electric power.

If electric motor actuation is preferred, the GA Industries Checktronic® Pump Control Valve uses a standard electric motor actuator to control the valve's opening and closing during pump start and normal shutdown with electronically adjustable stroke time. Plus, the CHECKtronic® Pump Control Valve has an integral check valve that closes, independent of the electric motor actuator, to prevent reverse flow in the event of a pump, drive or power failure. This check feature does not add any head loss and precludes the need for a UPS.

Summary

So, are pump control valves dinosaurs? The short answer is no.

Pump control valves remain a good choice to control excessive surges associated with the operation of a pump, especially a constant speed driven pump. Although primarily chosen for other reasons, if the a RVSS or VFD can also adequately control pressure surges associated with "normal" pump operation, it could preclude the need for a pump control valve.

If an electronic motor speed control solution is deemed an acceptable solution to control pressure surge, a mechanical check valve (such as a swing check) is usually all the only valve that's needed. It will open as fast as the fluid velocity increases and close as slowly as the velocity decreases.

But, upon pump, drive, motor or power failure, rapid flow reversal and/or fluid velocity change can occur resulting in the check valve being slammed shut and/or producing an excessive pressure surge. Therefore, the mechanical check valve should provide non-slam closure (the GA Industries Figure 250 Air-Cushioned Swing Check is a good choice) and a properly sized surge relief valve (such as the GA Industries Figure 6600 for water or Figure 625 for sewage) will protect the system from excessively high-pressure surge.