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Advanced actuation for precise pump station control

In this article, Mr. Dave Buchwald, President of Pipestone Equipment highlights the importance of preventing pressure surges. Mr. Steffen Koehler, an International Sales Manager for SIPOS Aktorik provides input regarding the company's innovative approach to controlling water hammer using variable speed actuation. A pioneering concept currently in development in partnership between Pipestone and SIPOS to aid plant optimisation is also revealed.

By Dave Buchwald, Pipestone Equipment, & Steffen Koehler, SIPOS Aktorik

Colorado based Pipestone Equipment has installed SIPOS 5 actuators since 2006 to support valve control functions that are an integral part of its customers' projects. With electronic processor control, the actuator is very different from conventional electric actuators. Electrical power is transferred via an internal frequency converter similar to that used for a pump Variable Frequency Drive – this provides many benefits including the ability to vary actuator operating speeds. The stroke-time function of the actuator helps minimise pressure surges and Pipestone Equipment has supplied pump stations throughout the United States with the advanced actuation solution to ensure the smooth running of their facilities.
Whether in water purification, waste water treatment, water reclamation or general water distribution, procedures are subject to increasing automation. Modern pumps are combined with valves to ensure reliable and controlled flow rates. Minimising the risk of pressure surges within such systems is essential, and this can be achieved by using variable speed actuators. A number of other challenging requirements are often faced by suppliers of actuation technology to the water industry – these include:

- Withstanding extreme climatic conditions.
- Providing a corrosion resistant solution to assure functionality.
- IP68 enclosure protection to protect the facility in the event of flooding.
- Offering higher actuator torques to support the increasing size of water industry valves.

Avoiding water hammer is of particular interest, as this is a very real potential danger for plants and pipeline systems. With their variable speed functionality directly integrated into the firmware, the actuation solution spearheaded by SIPOS has been identified by Pipestone as the optimum solution for minimising, or avoiding, water hammer using intelligent control of pump or pressure compensation valves.

Travel-positioning time function of SIPOS 5

Free selection of output speed is the basis of SIPOS technology. This is achieved using an integrated frequency converter for control. Intelligent software within the actuator not only controls the motor but also provides a special travel-positioning time function.
Actuators are historically selected to open or close within a specified time, which defines the output speed. Typical water industry pump control ball valves have very high flow capacities (Cv) and, when combined within a waterline, have non-linear flow capacity curves whereby relatively small opening percentages (i.e. 10%) result in capacities of greater than 50% and full flow rates can be achieved at openings in the one third range. As such, constant speed actuation only provides flow rate control over roughly the first third of the operating time. Additionally, the control provided is non-linear and is determined by the valve characteristics not the actuator. Figure 1 shows the flow capacity curve for a ball valve and waterline used in the pump station example detailed in this report. Ball valves have a rugged, simple design and a high volume throughput which minimises headloss during pumping operation and saves energy cost. When the high capacity ball valve is combined with a waterline and pump station, the flow capacity of the waterline quickly becomes a limiting factor. Effective valve control is therefore essential for maximising the benefits of ball control valves, while minimising transients within the system.
Ideal pump station start-up and shut-down sequences would accelerate and decelerate water within the pipeline at a constant rate or linearly. Due to the complex inter-relationship between pump curve, ball valve Cv curve and pipeline configuration, achieving linear flow rate changes has been difficult to achieve over the years. However, if the rotational speed of the valve shaft during the opening and closing sequences could be varied, linearisation

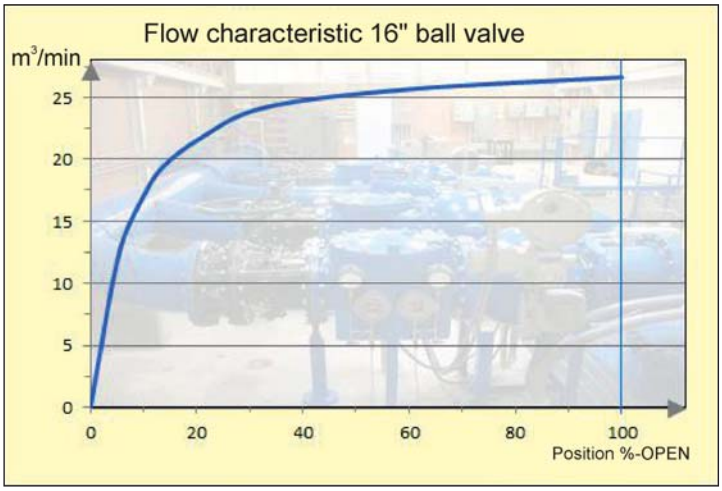

Figure 1: Throughput curve of a typical ball valve and waterline. For 6% open, the throughput rate is already 50%.

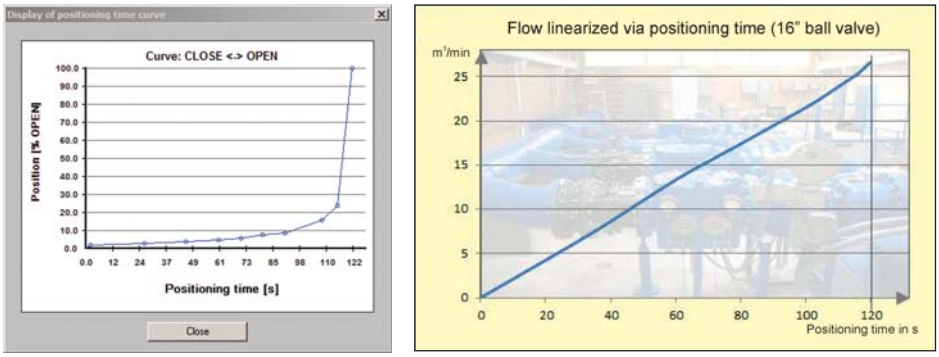

Figure 2a: Example of a travel-positioning time function for the SIPOS 5 actuator. The parameterised curve compensates for the curve of a ball valve and pipeline. Rapid operation within the OPEN range, from approx. half the closing time is indicated with considerably reduced output speed. Figure 2b shows the resulting linearised curve of the ball valve and pipeline from the figure 1.

becomes possible. With this ability, computations could be made to determine valve shaft rotational speed at various points during operation and a valve could be programmed to essentially be a linear control valve for that specific installation site. This theory applies to any type of valve or gate, any water source and any type of fluid control system.

Bridging the gap between theory and reality is the SIPOS 5 actuator. By defining up to ten value pairs (position; positioning time); the required parameters may be set directly within the actuator according to the system characteristics. Once programmed, the actuator will operate the valve as required to achieve optimised and linearised flow rate changes. For first-time input based on manufacturer curves, use of COM-SIPOS actuator parameterisation software is highly recommended. Separate operation curves for opening or closing the valve can be specified. COM-SIPOS presents the entered values on a chart enabling quick verification of figures, see Figs. 2a and 2b. For the operator, the result is a practical linear relation of run time and throughput, see figure 2b.

Preventing pressure surges

Pressure surges are often caused by valves opening quickly with excessive pressure variation in front of and after the valve. Pressure peaks, due to simultaneous closing of several valves within closed systems, are also known. The flowing medium suddenly halts and kinetic energy is turned into pressure.

Another reason may be the quick start of a powerful pump. The overpressures and low pressures, also called water hammer, can be reduced by combining a pump with additional start-up control and a ball valve with variable speed actuator. Pressure relief valves and/or bladder surge vessels can also be used to aid pressure surge reduction and system attenuation.

Pump failure, e.g. in case of power failure has major impact. See also the comments on uninterruptible power supply (UPS) below. Pipeline breaks may also generate pressure surges and cause further damage to the entire system.

Every day, companies like Pipestone Equipment have to face the problem of pressure surges and water hammer. Central competences include detailed examination of the behaviour of systems which comprise pumps, shut-off valves and pipelines with water. The starting point for all considerations is often measurements and simulations, such as the pressure curve shown in red on figure 3.

The amplitude at measuring point 2 after the pump ball valve shows significant pressure surges. As an alternative, or in addition to reduced mechanical and hydraulic measures, pressure waves can also be remedied by means of intelligent control of the pump valve. The blue curve clearly shows softer pressure variations when using the SIPOS 5 travel-positioning time function.

Pump station example

The pump station, figure 4, is connected to an existing part of the water supply of a large city in South-West USA. Due to soaring demand, the capacities had to be significantly extended. The units, consisting of ball valves and modulating actuators, were required to suppress hydraulic surges during pump start and shut-down. Additional system attenuation was provided via a bladder surge vessel.

The SIPOS 5 actuator's travel positioning time function provides linear control for water throughput during normal operation. Figure 2b shows the almost linear increase of throughput (m³/min) with the positioning time (0..120 s). This is achieved by compensating the valve and pipeline characteristics of figure 1 with the actuator's travel-positioning time curve - as shown on figure 2b.

Power failure - the most critical incident

Sudden power failure is the most extreme situation for an entire system made of pipelines, pumps and valves. For low pump inertia, the pump suddenly stops and acts like a rapidly closing check valve. Due to the high level of inertia, the head of liquid tears off at the pump output - the resulting cavity is filled by steam and outgassed air. Once the water flows back and clashes, high pressures are generated (cavitation).

Thus, pressure drop also translates into surges within the plant. If pressure rapidly

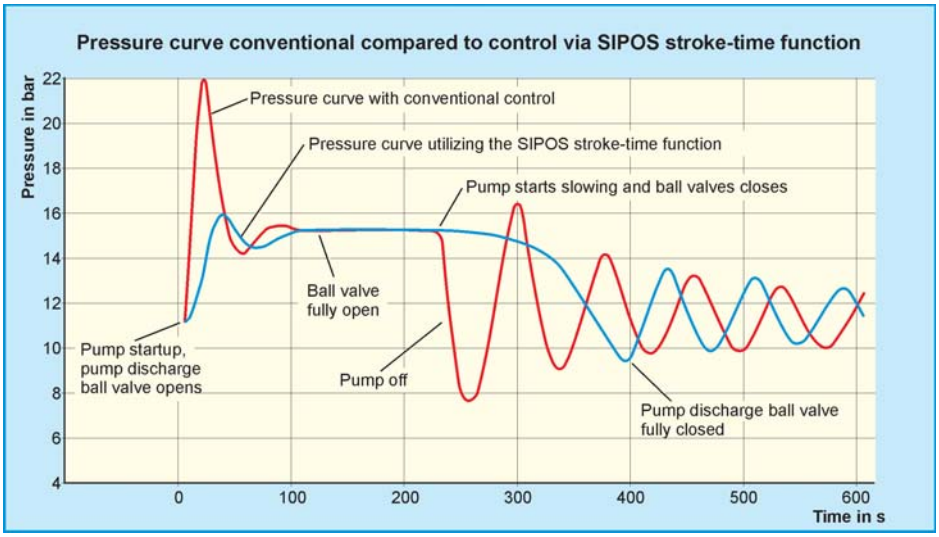

Figure 3: Pressure curve measured at the pump or after the pump valve (ball valve) for starting up or shutting down at a pump station project. The blue curve clearly shows the reduction of pressure surges when using the SIPOS 5 travel positioning time function.

Figure 4: Pump station project - SIPOS 5 actuators controlling 16" ball valves are shown. Due to linear throughput control, the actuators ensure smooth pump operation.

drops to zero, as in our example, these pressure surges are reasonably strong and therefore present the most significant danger for the system.
Pressure vessels with gas cushions and a volume between a few and several hundred cubic meters are generally used to compensate for destructive cavitation forces.
If ball, plug and butterfly valves can still be closed rapidly in accordance with a defined curve, forces acting upon pipeline linings may be controllable when using small-scale action, even in the event of a power surge.
At many similar plants, these actuators have been buffered by uninterruptible power supply providing the required energy for emergency operation in the event of power failure.

Optimised plant concept

When it comes to the actuator, and associated functions, SIPOS focuses on developing specific industrial solutions to address the needs of real applications.
The SIPOS travel-positioning time function has been fine-tuned in co-operation with Pipestone Equipment to optimise system performance. For customers, the solution provides the security that they can adapt their applications at any time, and at limited cost.
Inspired by the success with pump stations installations, Pipestone Equipment is developing a new, optimised plant concept in close cooperation with SIPOS Aktorik.
To date, the promising results have been exclusively based on the optimised control of the pump ball valve. The extended concept comprises a combination of speed-controlled pump with control ball valve along with a butterfly valve as well as two SIPOS 5 modulating actuators.
The actuators combine two functions: integrated process controller and travel positioning time curve, the functions are selected according to prevailing process requirements. The whole process is monitored by programmable logic controls.

Conclusion

The highly damaging impact of water hammer has long been a concern for those working in valve control. At best, high pressure build up culminates in shock waves and at worst pipelines can break. Vacuum can also be created that causes pipes to collapse or implode. The topic of pressure surge reduction is, therefore, a key consideration for pump station projects and an issue that requires considerable engineering work at such schemes. The impact of water hammer is such that the attention given to addressing it will increase in the coming years. The use of powerful sizing tools, with functions adjusted to the desired application and increased user control, meet the continuous challenges of this trend.

About Pipestone Equipment

Pipestone Equipment is a supplier of components for pump stations for both municipalities and industrial users. The company performs hydraulic analyses as well as the engineering element of the plant incorporating the directly linked control valves, other shut-off valves and air valves or surge tanks. Services include product selection, system design and equipment specification - support is offered from enquiry through to installation and project start-up.

Figure 5: The topic of pressure surge reduction is a key consideration for pump station projects for Pipestone Equipment.

Figure 6: SIPOS Aktorik focuses on developing specific industrial actuation solutions to address the needs of real applications.

About the authors

Prior to becoming President of Pipestone Equipment, Mr. David Buchwald was Director of Engineering at the Henry Pratt company. He moved on to become General Manager of Hydro Gate and President of Earth Energy Solutions before heading up Pipestone Equipment. He has an MSME in Fluid Dynamics and a BSME in Mechanical Engineering. Additional memberships include the American Water Works Association (AWWA) and the Colorado Renewable Energy Society (CRES).

Mr. Steffen Koehler holds a diploma in Chemical Engineering from the University of Erlangen, Germany. After five years working in research institutes specialising in environmental engineering, he became Sales Manager for AQUADATA, a company dedicated to control and instrumentation strategies for water and wastewater treatment plants. Steffen has worked as an International Sales Manager for SIPOS Aktorik for 14 years and has extensive experience of global business and electric actuation projects / applications.