Opening up on control valves

There are three key steps to ensuring that control valves don't cause process plant instability. Mark Perry explains the problems and their solutions

Plant engineers and engineering managers often find themselves responsible for improving plant efficiency and/or availability, as well as cutting raw material and utilities usage, improving product quality etc. To bring about these improvements, investments are often made in the glamorous end of process automation – for example, the latest all-digital control system, the best advanced process control software and higher accuracy process transmitters.

All well and good, but if the one component in the process 'loop' that moves – the control valve – is not up to the job, then no amount of that kind of investment is going to achieve the goal. That is where so many plants fall down: the root cause of plant efficiency problems is often excessive process variability caused by poorly selected or poorly maintained control valves – which, in turn, makes processes difficult to control. It can cause plant trips and premature wear of equipment, including of control valves. It can also result in loops having to be detuned or valves placed under manual control.

On the face of it, there's little choice: without such interventions, scrap or rework increases, along with unplanned shutdowns and unbudgeted plant maintenance. However, the consequences of these supposed corrective actions are typically worse plant efficiency and/or excessive utilities usage and cost.

So we need to look more carefully at our prime movers – the control valves themselves – to establish proper, optimal process control right from the start.

Remember, it is the function of a control valve to react to a signal change to maintain the required process condition, whether that be level, flow, pressure, temperature or any other continuously variable parameter. If the valve does not react correctly, variability can be introduced. But even if it does react correctly, there may still be reasons why the process does not correct itself as expected, leading again to that unwanted variability.

Ball valves are often selected when flowing fibrous media

Valve characteristics

To understand how these problems can occur, it is necessary to look first at some control theory and what that means for valve selection. In an ideal world, a control valve would have an installed gain of one across its entire operating range, such that, when its input signal changed by 10%, its output would also be 10%. Then if the process, too, had a linear characteristic, everything would be easy. However, very few processes are linear and the same applies to valves (considering the full range), so the trick should be to select a valve that cancels out the process non-linearity.

Control engineers typically select from equal percentage, linear or quick-opening valve characteristics – and there are derivations of these, such as modified equal percentage and approximately linear. An equal percentage characteristic is when the valve's flow capacity increases exponentially with its trim travel – leading to increments of travel producing equal percentage changes in flow (considering the power relationship between flow, pressure drop and fluid velocity).

As for linear trims, unsurprisingly they exhibit a linear relationship between valve travel and flow capacity, while quick-open trims deliver a large change in flow for a small change in valve opening. Generally, quick open trims are not used so much for control, but in on/off or relief valve applications. By far the most common used are the equal percentage types.

That said, in practice it is difficult to precisely match any valve to a process such that its gain is one across the range. Indeed, control valves are generally deemed to have a useable range only where the gain is between 0.5 and two – outside which it is difficult to provide accurate control. Rotary valves (such as butterfly, ball, rotary globe and segmented ball) can be difficult to characterise, because of their fixed form. Globe valves, on the other hand, can be easily characterised to a process, simply by designing bespoke trims. Depending on the valve type, these can be achieved by modifying the plug contour or changing the size and shape of holes in the valve cage.

Nevertheless, there are many reasons for specifying the range of valve styles. Ball valves, for example, are useful in flowing fibrous media duties, involving, for example, paperstock. The ball delivers a shearing action against the seal, which helps to sever fibres and prevent clogging. Meanwhile, segmented ball valves are frequently used in erosive or coking duties, because they feature streamlined flow passages and rugged trims. Then again, rotary globe valves and butterfly valves offer larger flow rates than equivalent-size globe valves. Also, when used at line size, they exhibit a lower pressure drop.

Another reason often cited for selecting butterfly valves is cost, particularly by suppliers of packaged plant. These valves are compact, so consume less metal in manufacture and weigh less – also making them cheaper to install and reducing the requirement for pipe bracing or supports.

Positioner power

It is also the case that, if your chosen valve style does not exhibit the desired characteristic it can be characterised in the positioner by modifying the input to output in relationship. However, this is far from ideal.

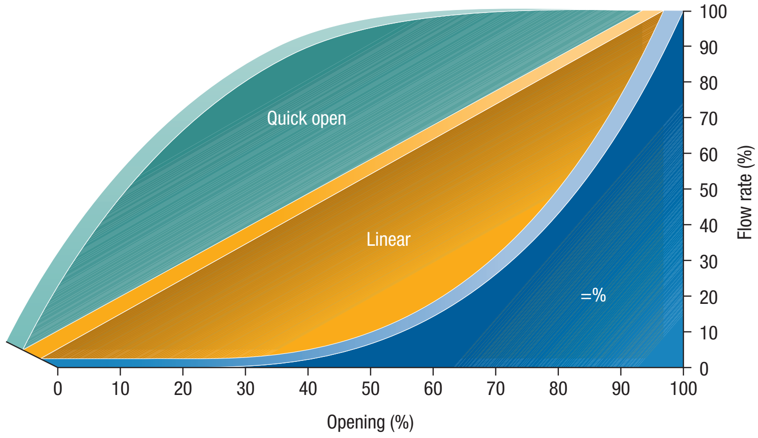
Butterfly valves have a linear characteristic, so in most applications offer a controllable range between 25 and 50% of travel. Below that, the gain is too high and attempting control results in setpoint under- and over-shoot. The valve gets a signal telling it to open, which it does, but the resultant change in output is larger than intended, so the valve is signalled to close, and so on, resulting in loop oscillation that may be reflected and magnified in connected loops. Equally, operating at the other end of travel, gain is very low, so valve performance would be too sluggish – particularly where the loop has been tuned to restrict overshoot at low opening.

Often the effect of loop oscillations is not evident and operators learn to live with them. However, if not, engineering may be asked to re-tune the loop. One solution may involve slowing the loop down, so it does not react to every change in signal. Often this appears to solve the problem, but it does have a negative effect on overall plant efficiency. Another option may be to move the setpoint further from optimum, so that more of the cycle remains within controllable limits. Both options may be acceptable, but neither addresses the cause – the valve itself.

And it's not just the valve style that can introduce variability. Valve and actuator design can also be a factor. Some valves exhibit excessive deadband, caused by loose linkages, large actuator volumes or pressures that need to be exhausted before the valve can change direction.

Even poor positioner design can be a factor: some versions quote a static air consumption figure of zero, but that is often because they use spool valves with built-in deadband to prevent the spool from constantly shuttling back and forth. Together, however, these limit the ability of valves to react promptly or accurately to input signal changes.

Control valve characteristics



Above: representing the three standard valve characteristics: quick open, linear and equal percentage

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Photographic evidence

Agfa Graphics, which produces photographic film at its Leeds plant, used to encounter loop problems on its cooling system. To meet production specification, process temperature has to be within ½ degree of the setpoint (44.5ºC), but the cooling water storage tank was outside and exposed to the elements.

In the summer, the source water was generally above 15ºC and the loop controlled well. However, in the winter, when the water temperature fell below 10ºC, the valve would move below its control range (around 8% open) and start to limit cycle – with high gain at low travel causing excessive flow rate changes, in turn forcing the controller to signal the valve to reverse direction, and so forth.

With that valve unable to provide for automatic control, it had to be placed in manual and adjusted any time there was a change in film width or production speed. Getting this adjustment right was taking too long and resulting in large amounts of scrap product.

Because Agfa was already using butterfly valves, any change of valve design would have led to expensive piping modifications. In addition, plant managers wanted to use the existing actuators and positioners. The valves were replaced with Fisher Control-Disk butterfly valves, which have the advantages of conventional butterfly valves, but with an equal percentage characteristic, giving them a much wider control range.

Subsequently, when the control loop was switched to automatic, the improvement was immediate. Whereas the old valve travel had been varying between 6–12%, with the control disc in place, the valve now controls steadily at 11% open.

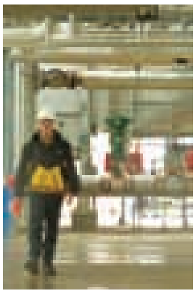
Having established the right control valve, actuator and positioner combination for a project (also taking into account pressure drop requirements, fluid characteristics and the rest), the next phase is about maintaining performance. For this, plant engineers need to find a means of measuring control valve behaviour inline, and of detecting when it deviates outside acceptable limits.

Many manufacturers offer digital positioners with predictive capabilities – among them Emerson's Fisher Fieldvue digital valve controller, which can run periodic diagnostic tests while the plant remains fully operational. Typically, diagnostic checks enable friction and deadband to be monitored and trended, while alarms alert engineers and operators to measurements moving outside set limits – indicating a requirement for maintenance.

However, control valves are mechanical devices, so their condition will deteriorate over time to the point where, eventually, they will need repair and reconditioning – the process termed retrieval. Identifying the nature of a problem and its causes is also the job of today's digital valve controllers. Now, though, we're talking about diagnostic tests, with the valve off-line or during plant shutdown.

Full diagnostic tests are able to pinpoint the reason for any deterioration, ensuring that only those components that need full service attention are stripped down or removed. Then, following repair and rebuild, plant engineers should carry out further tests to ensure that performance of the control valve has been retrieved to previous levels.

Follow these steps and you're on the path to minimising variability and plant efficiency problems, whatever the fancy controls.



Turbine variability

A gas-fired power station in the UK used to experience oscillations at the turbine, due to instability in the main gas stream supply pressure. This resulted in an uneven loading, which increased turbine wear and necessitated additional maintenance. Under varying plant load, the oscillations were amplified, which also led to occasional plant trips.

Emerson consultants identified that the control valve itself was responsible for 70–80% of the problem. Replacing the old valve controller with a Fisher digital valve controller reduced variability by 50%, immediately resulting in marked plant performance improvement.

In addition, implementing refined controller tuning parameters, recommended by Emerson, further reduced process variability and optimised loop operation. Total savings from these minor modifications were in the region of £80,000 per annum as a result of reducing plant trips, improving plant life and reducing requirements for maintenance on the turbine.