FEATURE SERIES: PRACTICAL PROCESS CONTROL

30: Training Engineers

***Myke King** outlines how chemical engineers should be trained in practical process control and explains why these techniques can improve yield, reduce costs and boost plant performance*

QUICK READ

- **Practical skills outweigh theory:** A clear grasp of process dynamics and control techniques allows engineers to identify improvement opportunities and boost operating margins
- **Training delivers fast ROI:** Investing in process control training is often recouped within weeks through increased capacity, improved yield and reduced operating costs
- **Know your tools:** Effective use of PID tuning, level control, feedforward, inferential properties, and monitoring can significantly enhance process performance and reliability

WHILE an engineer working with process control needs, of course, to understand the subject, a clear grasp of the process and its economic objectives is also essential.

The engineer needs to be able to identify improvement opportunities, quantify the potential profit improvement and convince others of the benefit. Such skills are within the remit of chemical engineering. To extend the role of a chemical engineer to include the application of process control requires relatively little additional knowledge. The problem is that most chemical engineers would not agree with this. Their exposure to the subject will usually have started as part of their university course. The process control module in such courses is usually laden with highly theoretical mathematical techniques that actively discourage most to specialise in the subject. However, pursuing it can be very rewarding. An effective control engineer can have an immediate impact on process performance. Those working in process design may have to wait years before their design is commissioned. The role of those working in process support is usually restricted to making recommendations that are implemented by others. The role of a control engineer is more akin the that of the process operator.

Sadly, no longer with us, Francis "Greg" Shinskey (1931–2021) was a prolific publisher of practical process control texts. He summarised the role perfectly. "A proficient control engineer can squeeze more production out of limited plant equipment and contribute more to reducing operating costs than almost any other individual in the plant." But experience confirms another (as yet unattributed) quotation – "A poorly trained engineer can really mess things up." This "messing up" can be simply overlooking an opportunity to apply basic techniques that make a substantial improvement to the operating margin. Or it might be making process design decisions that result in the plant being inherently difficult to control.

MANAGEMENT COMMITMENT

Given that most chemical engineering graduates have not been taught the practical application of process control, industrial training is particularly important. But training, in general, is too often seen as an optional expense. When budgets are tight it is an easy target for cost reduction. Managers are often acutely aware of costs but less clear on the more difficult-to-quantify benefits. One would think that cost of employing an engineer, that is untrained and hence less effective, would be enough of an incentive to commit to training. In the UK, a typical starting salary for a chemical engineer is around £30,000 (US$40,000). Adding salary-related costs and an allowance for the additional supervisory load brings the total to roughly £1,250 per week. The cost of attending a training course is likely to be recouped within a month.

The return can be even more attractive if we consider the value, rather than the cost, of the engineer. Typically, improved control will deliver a profit improvement of around 1% of feedstock cost. Implementing control improvements one week sooner would therefore be worth around 0.02%. To justify the training, the annual feedstock cost needs to exceed £25m. To

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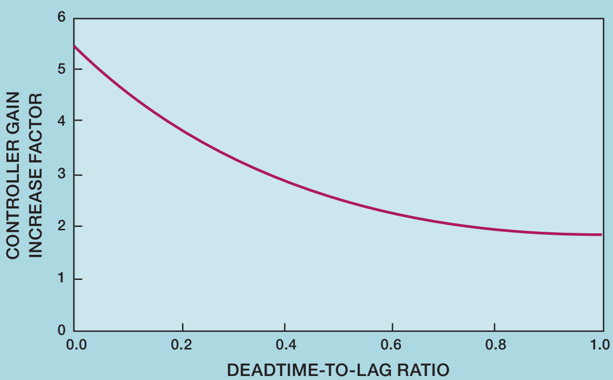
put this into context, the cost of crude oil to a modestly sized refinery is around 100 times larger than this.

PROCESS DYNAMICS

So, what basic skills does a control engineer need? First and foremost is an understanding of process dynamics. This is the first stumbling block in the academic world. Here, dynamics are described using Laplace transforms – theory that the student is unlikely to have seen before and even less likely to want to see again. Rarely do academics teach how to quantify process dynamics. It is difficult to overstate the importance of being skilled in this. The design of even the most complex control strategies is usually quite straightforward once the dynamics are known. And there is no excuse for not obtaining them. Most processes now have data historians and there are numerous curve-fitting tools that enable routine setpoint changes to be analysed. Or, if no suitable disturbances have occurred, will analyse a planned step-test. There's enough detail in *TCE 981* for the self-motivated engineer to learn the techniques. Or half an hour with an experienced engineer would cover the essentials.

Figure 1: Advantage of I-PD versus PI algorithm



PID CONTROL ALGORITHM

The PID control algorithm was developed around 90 years ago and will remain fundamental long into the future. Despite its longevity and more recent enhancements, it is rarely exploited properly. Again, academia is part of the problem – often again using Laplace to describe the controller. Not only off-putting, it is incorrect. While Laplace can be applied to analog control, modern digital controllers are more accurately (and more easily) described using much simpler mathematics. And, if included in the course, the controller tuning methods taught are outdated or just simply wrong.

So few are aware of, or take advantage of, the proportional-on-PV (I-PD) version of the control algorithm as described in *TCE 984*. Even fewer appreciate the resulting advantage of including derivative action (*see TCE 985/986*). Figure 1 shows the benefit of switching from the commonly installed PI algorithm to I-PD. It permits the controller gain to be at least doubled – meaning that disturbances are halved in both size and duration. But, since the deadtime-to-lag ratio is usually small, the increase in gain can be even larger.

Too often, engineers rely on tuning by trial-and-error – both time-consuming and unlikely to lead to the best solution. While just about every published tuning method has at least one serious flaw (*see TCE 983*) there are a handful of effective software packages, one of which can be downloaded, free of charge, from http://www.whitehouse-consulting.com/tune.htm. This can also be used as a learning aid, showing the impact of proper tuning and the effect of changing to an alternative control algorithm.

LEVEL CONTROL

A common mistake is to design all level controllers to give a fast return to setpoint. While required in many cases, there are situations where we want to utilise the surge capacity in a vessel to minimise downstream flow disturbances. A well-trained engineer will know whether tight or *averaging* control is required, will properly select one of the nonlinear algorithms available and know how to tune it. Figure 2 shows a typical

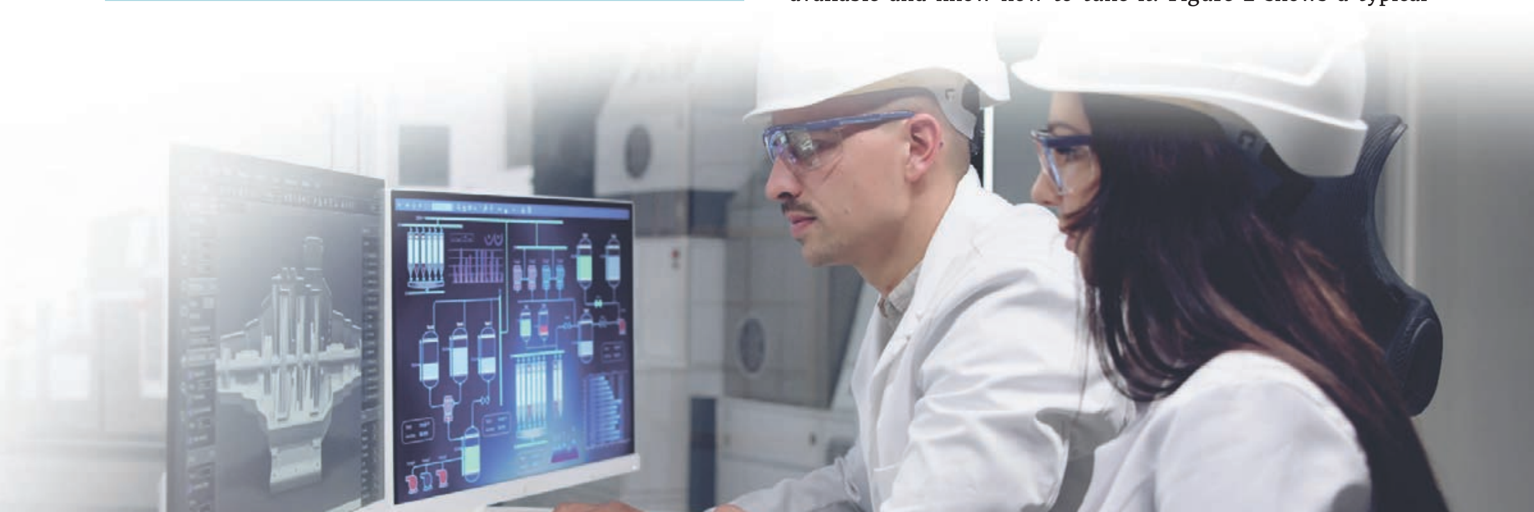
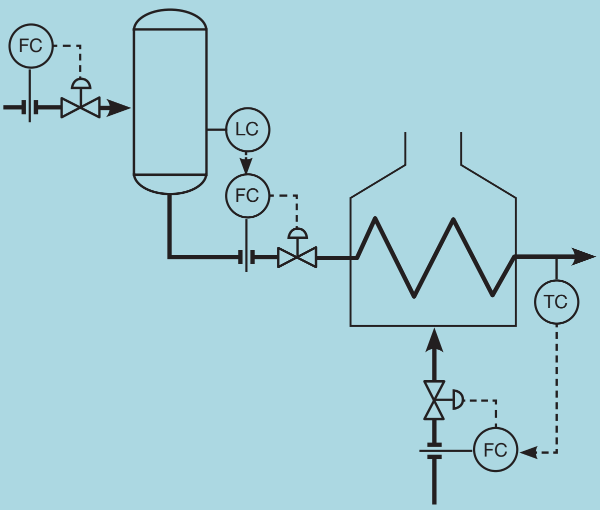


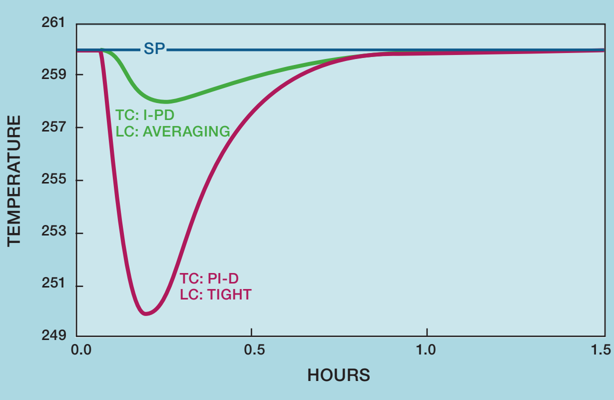
Figure 2: Fired heater control



configuration of a surge drum delivering feed to a downstream process – in this example, a fired heater. In response to a change in feed rate, Figure 3 shows the combined benefit of selecting the I-PD algorithm for the temperature controller and averaging tuning for the level controller (*see TCEs 987 and 989*). Even the most sceptical plant manager would appreciate the five-fold reduction in the size of the temperature disturbance.

Those engineers working on distillation columns or steam plants face additional level control challenges. The first decision on a distillation column in one of *pairing* – which flow should be manipulated to control which level (*see TCE 992*). The configuration directly impacts the effectiveness of composition control and the transmission of disturbances to the downstream process. In a vaporising service, such as steam drums, where the liquid contains bubbles of vapour, the water level can show unusual behaviour and require enhancement of the basic level controller (*see TCE 993*).

Figure 3: Impact of controller algorithm and tuning



CONDITIONING

Conditioning is the application of a simple mathematical expression to either the measurement used by a controller or its output. Control engineers like linearity – specifically the relationship between the controlled variable and the manipulated variable. The slope of this relationship is the *process gain* which, if constant, greatly simplifies controller design. Unfortunately, processes are inherently non-linear. The well-trained engineer will be able to determine whether linearisation is required and be able to implement it. Techniques include the use of *equal percentage* valves or some equivalent characterisation implemented within the control system (*see TCE 995*). If not properly ranged, level measurement on a horizontal drum or sphere may require conditioning (*see TCE 990/991*). And there are many generic examples where a custom polynomial is required (*see TCE 1,016*). Potentially confusing the process operator, some conditioning is better performed by adaptively changing the controller gain. The competent engineer will know when and how to install this.

The other prime application is filtering out noise from a process measurement. The trained engineer will recognise those situations that require it and, more importantly, those where it has been installed unnecessarily. While one technique is common to all DCS, there are custom alternatives that will, in many circumstances, outperform it (*see TCE 994*).

FEEDFORWARD CONTROL

Feedforward control can have a dramatic impact on how quickly a process disturbance can be resolved. By including disturbance variables such a scheme can keep key variables exactly on target. The engineer should be familiar with bias feedforward and ratio feedforward, knowing which to use and how to tune the associated dynamic compensation (*see TCEs 997/998 and 999*).

If the process turndown ratio exceeds 1.5 then the performance of almost all the controllers will degrade as production rate changes. Some processes, such as steam boilers, can have a turndown ratio approaching 4. Under such circumstances controllers can become unstable. Ratio feedforward avoids the need to retune controllers as throughput changes.

SPLIT-RANGING

Split-ranging is a technique for extending the range over which a controller can operate. Usually applied to control valves it permits the controller to adjust a number of valves sequentially – so if the first reaches its limit another begins to move. Traditionally this was achieved by calibrating the control valves so that the first moves full range as the controller output varies 0–50% and the second 50–100%. The engineer should appreciate when this approach is no longer necessary or preferred – knowing, of course, what should replace it (*see TCE 1,004*).

DEADTIME COMPENSATION

While we might intuitively understand that a process exhibiting a long delay might be more difficult to control, more correctly it is the deadtime-to-lag ratio that determines this. As the deadtime approaches lag, to maintain stability, the controller gain must be substantially reduced. The engineer should be aware of more effective control algorithms, particularly if included in the DCS as standard, knowing when and how to apply them (*see TCE 1,014/1,015*).

INFERENTIAL PROPERTIES

Also known as *soft sensors* or *virtual analysers*, inferential properties are often key to the success of improved control. Their development is truly chemical engineering. The engineer develops a prediction of the required property based on the available measurements of flow, temperature and pressure. The prediction may be based on a first principle engineering model or developed by regression of previously collected process measurements. While the technology has been in use for many years, it is often misapplied. This stems from applying regression analysis without due thought to the underlying process behaviour, not properly validating the prediction and naively updating the prediction based on laboratory results (*see TCEs 1,005 to 1,008*). The resulting inaccuracy can often mean that control would be improved by disabling the inferential!

MONITORING AND DIAGNOSIS

Controller monitoring serves two key purposes; the first of which is to identify and diagnose a problem. The second is to form the basis of performance reporting used either to demonstrate a scheme's effectiveness or to support investment in improving one that it failing. While there are commercial packages available, the engineer should be able to implement the key features in Excel (*see TCE 1,016*).

PROCESS-SPECIFIC SCHEMES

While the techniques above are generic there are, of course, control schemes that are process specific. The engineer clearly needs to be aware of control strategies proven to be beneficial. For example, many sites have fired heaters/boilers. Adjusting the duty by adjusting fuel gas pressure (rather than flow) is a common error. Compensation for changing fuel gas density is often misapplied (*see TCE 1001*). Excluding heater inlet temperature from feedforward control is often a mistake.

Compressor manufacturers often insist that load control and surge protection must be implemented in a PLC (programmable logic controller), rather than in the DCS and use a proprietary technique. The engineer should understand why this is a myth and that the so-called "proprietary" technologies are mainly in the public domain (*see TCEs 1,012 and 1,013*).

Tray temperature control on a distillation column is often an effective method for maintaining product composition, but only if the column pressure is constant. Since it is often economic to adjust the pressure (for example, to reduce operating costs or relax a process constraint) the temperature controller should be pressure-compensated (*see TCE 996*). Inferential properties are generally based on this temperature but their accuracy is greatly increased if multiple temperatures are used (*see TCE 1,008*). Usually impractical to install once the column is built, the engineer should be able to specify these at the process design stage. A common problem with binary distillation is simultaneously maintaining both the overheads and bottoms composition. The engineer should be able to analyse the candidate control schemes to enable selection of the most appropriate (*see TCEs 1,009 to 1,011*).

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SO, WHAT'S NEXT?

So, reader, if you're working or soon to work in industry, then recognise that process control is not a black art. Understanding and applying just the basics can have a huge impact on process performance. Or, if you're teaching process control, then please move away from the mathematical theory that puts off so many from applying the techniques. ■

NEXT ISSUE

The next article will be the last in this series. As a finale, a lengthier summary will cover a range of examples where decisions made at the process design stage had a negative impact on the benefits achievable with improved control.

Myke King CEng FIChemE is director of Whitehouse Consulting, an independent advisor covering all aspects of process control. The topics featured in this series are covered in greater detail in his book Process Control – A Practical Approach, published by Wiley in 2016
