Process control

PID has been the mainstay of process control for more than 60 years, but technology and the ever-expanding role of plant engineers merit a new, closer look, advises Brian Tinham

Pointers

- Three-term PID control is still the workhorse of the process industries
- PID loop tuning today is at least semi-automatic
- Operations engineers are ideally placed for fine PID tuning, because of their detailed plant knowledge
- PID tweaking is key to ensuring that controllers reject disturbances and do not upset downstream units
- Take note: plant actuators and/or valves are more often the cause of plant variability than PID control
- Controllers may be as small as 1/32 DIN units with huge inbuilt functionality
- PID-plus controls are now fairly standard 'function blocks' in software

PID (proportional, integral, derivative) feedback control is still the workhorse of process control on plants ranging from petrochemicals to pharmaceuticals, food and beverage, the utilities – the list goes on and on. That's been the case almost for ever. Crude three-term control instruments were enabling more or less automatic control of variables, such as temperature, pressure, level and flow, long before the Second World War.

Indeed, the concepts probably originate as far back as 1868, with research by the physicist James Clerk Maxwell – at the time, examining mechanical governors and moderators invented 50 years earlier to regulate rotating plant. Certainly, the defining work of John Ziegler and Nathaniel Nichols (who together perfected a practical technique for repeatable feedback loop 'tuning' – see panel) was fully 67 years ago, back in 1942. And that method is still the foundation for today's control loop optimisation – albeit that function is now almost entirely automated in software tools.

Needless to say, a lot has changed since the 1930s and '40s, with their pneumatic devices – first with the flapper-nozzle amplifier, then negative feedback control and subsequently integral (called 'reset' at the time) and derivative (pre-act) actions. Analogue electromechanical P, PI and PID controllers, and subsequently electronic valve-based equivalents, emerged during the '50s and '60s, to be replaced, in turn, with digital instruments in the late 1970s, as the so-called microprocessor revolution took hold.

Then came distributed control systems (DCSs), clustering tens, hundreds and eventually thousands of control loops, but with generalised PID control software 'blocks' able to run on computing power embedded in field instruments (for example, pressure transmitters) and/or auxiliary panels around process plants. And much the same happened with PLCs (programmable controllers) as they broke beyond the bounds of relay logic.

Plant challenge

Since the late 1970s and early '80s, such systems have communicated (increasingly now using wireless technology) with SCADA (supervisory control and data acquisition) screens, displaying plant schematics, alarms etc, for control room operators sitting on the bridge, much like the Star Ship Enterprise. It's been quite a journey – and that's just skimming the surface.

But so what? Well, the challenge for us is that, with the departure from our plants of so many specialist instrument and control engineers, it now falls to us not only to install these controllers, but also to commission and configure the kit, and then maintain and troubleshoot it, as well as the plant it's running. Some of us are even finding ourselves required to specify elements of control schemes and – even though, behind the scenes, the computing enables very sophisticated control, with plenty of automatic assistance – that's a fair stretch beyond most plant engineers' training.

Hence this update which, we hope, will both aid understanding and help you perform your extended role competently – either now or in the future. So what do you need to know? First – and without wishing to teach grandmothers to suck eggs – you'll find a quick explanation of P, I and D, their practical control effects and controller tuning issues, in the panel below. With that under your belt, you need to know about product types available, and their pros and cons. And you need advice on practical setup and related plant issues.

Looking first at controller products, modules right down to 1/32 DIN for mounting in panel cut-outs and on OEM plant (such as plastic injection moulding machines), are now commonplace. Most come equipped with dual displays (measured variable and setpoint), as well as multi-function, universal configuration and control buttons on the front panel, auto-tuning and more.

For example, units aimed at temperature control will have linearisers for the common ranges of thermocouples and RTDs (resistance temperature detectors), as well as cold junction compensation, multiple configurable output drivers and bumpless transfer facilities (taking control smoothly from manual to automatic). They may also feature digital output retransmission for old-fashioned cascade control, alarm and event annunciators, multiple setpoints and programmer facilities for more complex processes, where setpoints need to be cycled or follow prescribed profiles.

Control freak

That said, for the vast majority of plants where operators need overviews, as well as detailed displays of control conditions, the preference today is instead for configurable software control 'blocks', which provide universal PID-plus functionality. Such systems are typically behind everything from packaged boiler controls to bottling lines, right up to full-blown process plants.

So the good news for us is twofold. First, controllers are nigh-on standard and you can't go far wrong: product vendors can help with the detail. Second, whatever the controller, PID tuning is, at the very least, semi-automatic. And there's a third point: plant engineers are ideally placed to take on the responsibility for getting tuning right. Why? Because,

Left: Andrew Riley, advanced control consultant at Emerson: "You still need an engineer between the auto-tuner and setting the live controller"

Three-term PID feedback control: the basics

So what are P, I and D? And what are their roles in feedback loop behaviour and tuning? In a nutshell, these three terms – proportional, integral and derivative – are the route to enabling smooth, stable control of otherwise continuously varying process parameters, such as temperatures, pressures, levels and flows.

On its own, proportional (P) negative feedback of the difference between a process variable value (as measured by an appropriate sensor) and its desired setpoint, when applied to a control valve or variable speed drive (for pressure, flow or level control) or heating/cooling equipment (for temperature control) acting on that loop, should be enough to stabilise that variable. The final control element continuously drives the parameter back to setpoint, at a rate directly proportional to the divergence from it.

That's the theory, and it works in many cases. However, in others, the real world gets in the way. Plants are subject to all sorts of disturbances – such as opening and closing of furnace doors, charging of product, process stages etc – and proportional control alone may then be inadequate. At the two extremes, it can either cause the process parameter to overreact and then overshoot its setpoint (which could damage the plant or product being processed and/or result in hunting) or simply take forever to get there.

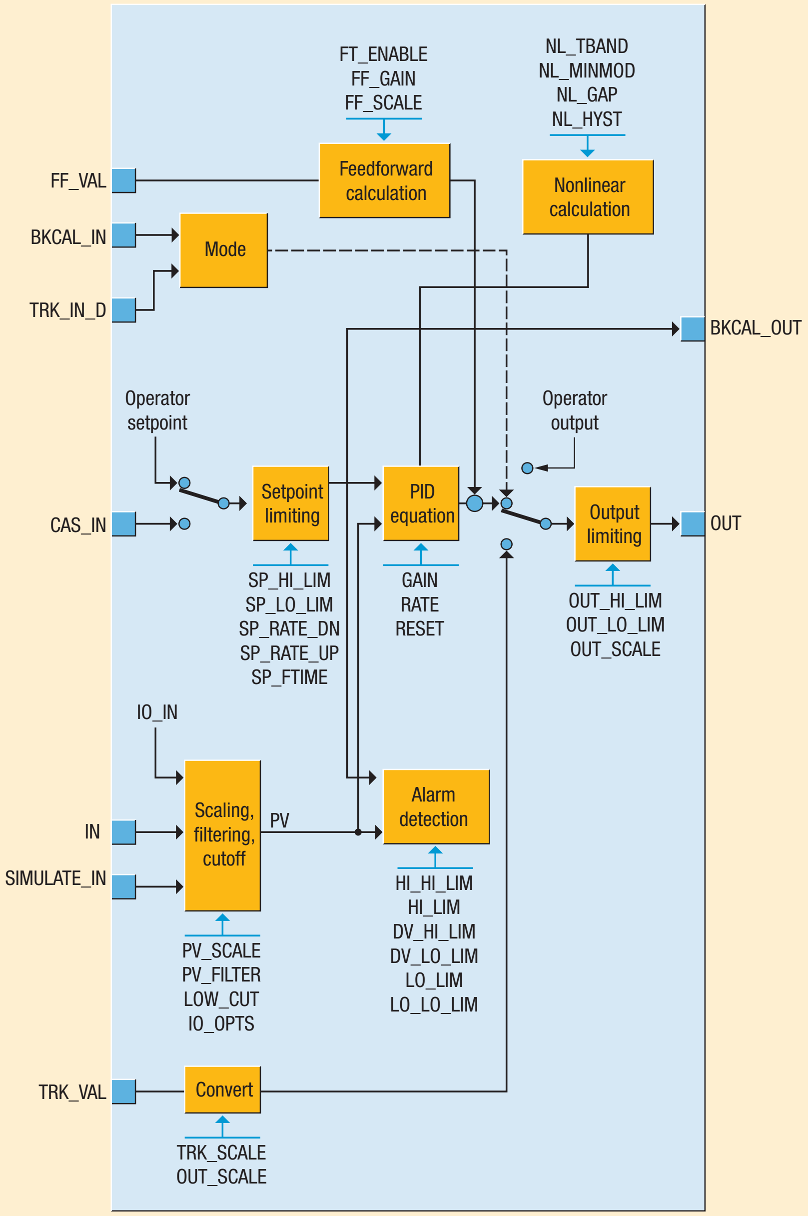
That's where the I and D terms come in. The integral term (I) reduces the effect of process disturbances, effectively by causing some of the control action to be driven by an averaged, not instantaneous, measured variable divergence signal. Equally, if divergence from setpoint is great – as in start-up – remedial control action will be increased (which may need moderating, using functions such as overshoot control and so-called anti reset wind-up).

Meanwhile, the derivative (D) term helps the controller to respond to the rate of change away from (or towards) setpoint – effectively shaping the system's response to help it smoothly and rapidly return the measured variable to its setpoint.

It's the precise balance of P, I and D 'gains' that enables not only steady-state stability, but the desired process dynamics around your parameter setpoint, as specified by the process engineers. Notwithstanding the existence of several other options beyond the scope of this feature, the beauty of the modern automatic equivalents of the Ziegler and Nichols tuning method – which mostly involve briefly 'bumping' (disturbing) the process, watching its behaviour and plugging in P, I and D values best able to deal with the findings – is that relatively little knowledge of the process is required.

Or so you would think. And you certainly don't need to construct a mathematically precise process model. Unfortunately, however, all such tools can only provide generalised guidance. What we need to remember is that, in some cases – for example, exothermic reactions that can rapidly run out of control, vessels that are required to buffer fluids for downstream processes, burner management where gas pressure is critical for flame stability, or reactions where products must not overheat – there may be good reasons to tweak the recommended PID controller configuration. That's where your engineering knowledge of both PID control itself and of the plant/process you are working on comes into its own.

PID function block schematic diagram



Modern PID function blocks are comprehensive beasts, with several configurable ancillary controls

on the one hand, our plant maintenance role means we're likely to be clued up about the process and, on the other, we understand the limitations (in terms of accuracy and repeatability) of our valves, actuators, pumps etc, required to effect final control.

As Andrew Riley, one of a team of consultants on advanced control at process instrumentation giant Emerson, says: "Very often it's the plant actuators or valves that cause process variability, not the control tuning itself. You move them and nothing happens. Part of any loop tuning is, of course, getting the PID right, but a big part is also checking out the quality of the instrumentation and field actuators."

Just so, and he continues: "Also, when you get that equipment part right, in many cases you still need an engineer between the auto-tuner and setting the live controller." Why? Because a PID controller must reject disturbances, control to setpoint and not upset any downstream units it influences. Quite simply, auto-tuning software cannot easily know how important each of these factors is. For example, reactors often need to be controlled to within tenths of a degree, but there are few external disturbances. On the other hand, a steam main normally needs much less accurate temperature control, but must stay stable during large disturbances, such as plant trips.

Automation limits

"Emerson and others produce software that monitors loop performance, and works out a process model and 'ideal' PID coefficients. On some, there's even a switch to auto-implement those settings. However, I've never known anybody go that final stage. It's good to know the recommendations – and you need to take note, because they also tell you how bad your loop performance is, in terms of energy efficiency, product variability etc. But you need the engineer's feel for the process to get the right balance."

There's everything to play for here. Riley recounts that loop surveys (conducted in-house or using external experts) often reveal significant potential for improvements. "The point is, you don't have to requisition expensive capital equipment and you don't have to wait for a plant shutdown to do this. With a little training, these kinds of projects often provide payback in a few months," he advises.

And one final thought: for the more adventurous among you, advanced (model-based, predictive) control, which used to be the preserve of the refining and petrochemical plants because of its sheer cost, is now much cheaper. So far, that has meant advanced control on, say, a single distillation column or perhaps the spray driers in a pharmaceutical facility. But the time may yet come when controls more sophisticated than PID are routinely available.

For now, however, Riley agrees that PID is still best for stable regulatory control – for several good reasons. "PID controllers automatically linearise the flow characteristics of control valves, for example, whereas model-based controllers typically sit on top of the PID scheme, so assume linear characteristics. Also PID controllers work on a second-to-second basis to ensure process stability, whereas the model-based control layer is designed for overall optimisation – pushing stable conditions slightly off to somewhere more profitable. That's a different job entirely."