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Applications of Self-tuning Control

Users of self-tuning PID controllers have experienced both challenges and successes.

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Control Engineering

Loop tuning is as much an art as it is a science. A well tuned feedback control loop can quickly and safely eliminate errors between the process variable and the setpoint, but endowing the controller with the necessary balance of aggression and patience requires a certain degree of skill and experience.

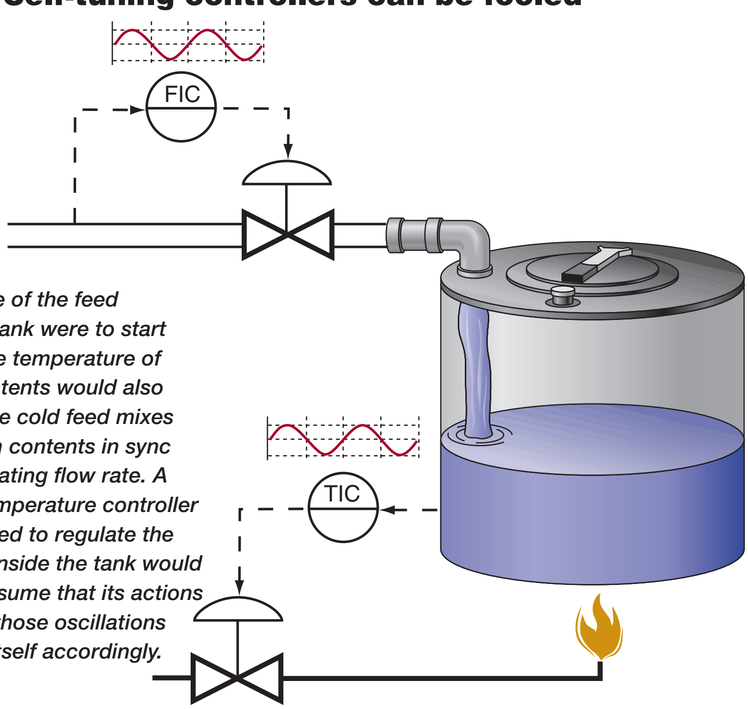
Fortunately, a variety of simple tuning techniques for proportional-integral-derivative (PID) loops have been automated and incorporated into commercial controllers. On-demand "auto-tuning" functions mimic the steps that a knowledgeable control engineer might take to tune a loop when it is first commissioned. On-the-fly "self-tuning" controllers also can continue to update their own tuning constants once the loop is fully operational.

Though both approaches have gained some degree of acceptance among industrial process control users, on-demand auto-tuning has proven to be the more popular of the two. Peter Wellstead is SFI research professor of systems biology at the Hamilton Institute, Ireland, and co-author of the chapter "Self-tuning controllers" in the fourth edition of the Instrument Engineers Handbook (Béla G. Lipták, ed, CRC press, 2006). He explains: "I did do a lot of work on self-tuning controller theory and worked on some commercial self-tuning products in the '80s and early '90s. After this, self-tuning went mainstream." Many controllers have them as standard features now.

"The products that I had a hand in designing seem to have gone one of two ways. For general loop tuning, they are simplified to tuning-on-demand with a test step or pulse doublet, rather than continuously adapting with normal operating data," Wellstead says. "For special loops they have become highly adapted to the particulars of the control system in hand. In this case I notice that the companies that offer systems tuning and diagnostics services for difficult processes almost all have fairly sophisticated self-tuning features that are used by the trained staff of the companies. These are only of value in high value plants, and/or where de-skilling requires outside contractors be used for loop maintenance."

Wellstead adds that on-demand auto-tuning has prevailed because "the instrument company engineers were not happy with the extra mathematical and algorithm complications needed for on-the-fly tuning. Much simpler algorithms could be used. Something that was as necessary as self-tuning became an expected feature on even quite basic loop controllers. End-users also liked the idea of picking their re-tuning points themselves."

Self-tuning controllers can be fooled



If the flow rate of the feed entering this tank were to start oscillating, the temperature of the tank's contents would also oscillate as the cold feed mixes with the warm contents in sync with the oscillating flow rate. A self-tuning temperature controller (TIC) configured to regulate the temperature inside the tank would mistakenly assume that its actions have caused those oscillations and de-tune itself accordingly.

Source: Control Engineering

Challenges

Lew Gordon, principal application engineer at Invensys, agrees that the adoption of commercial self-tuning control technology has been tempered by the technology's shortcomings. "Most advanced DCS platforms include a self-tuning capability. These routines evaluate the current performance of a controller and modify its tuning constants to achieve a desirable transient response following an upset."

However, "this is a difficult challenge," he says. "The adaptor has to assume that any behavior it sees is the result of the changes it makes. As a result, such algorithms can be easily confused by cyclic oscillations that enter the loop through interaction with other variables."

Gordon has personally run in to this problem when trying to control both the temperature and flow rate of a liquid. "Any sustained oscillation in the flow rate would cause temperature variations at the same frequency. A self-tuner on the temperature controller would try, without success, to stop the temperature variation by de-tuning the temperature controller, leading to even worse temperature control. For such reasons, self-tuners need to be applied with close supervision and should not be left unattended for long periods."

Reducing variability

Other users have had much better luck applying self-tuning control technology. The Lubrizol Corporation, for example, has used the self-tuning capabilities of DeltaV InSight from Emerson Process Management to help with the production of various fuel and engine oil additives at their plant in Deer Park, Tex.

Products involving aqueous, organic, liquid, solid, and gas phases are manufactured in batches with differing physical and chemical properties. "It's a fairly complex batch reaction, and it's hard to maintain the consistency that customers demand" says Fred Gregory, Lubrizol's principal engineer and group leader for process improvement. "Anything we can do to make the product more consistent is going to help us compete in the marketplace."

In an effort to reduce the variability in their temperature and pressure control loops, Lubrizol implemented InSight's dynamic loop tuning as a beta test site for Emerson. "What we needed was something that could dynamically tune the system on the fly without an operator or a control engineer going there to initiate an auto-tune for you," says control engineer George Lin.

Bruce Johnson, engineering manager for Lubrizol's Texas facilities adds, "We chose InSight because of its ability to dynamically model a process's gain, dead time, and time constants." It uses learning algorithms embedded right in the controller. "The engineer doesn't have to worry about configuring new technology. He just turns on a switch to enable learning," says John Caldwell, product marketing manager for Emerson Process Management.

Lubrizol was cautious about implementing self-tuning controllers since they knew that operators would only accept the new technology if the plant ran smoothly with no upsets or lost production. Efran Hernandez, process controls engineer for Lubrizol, notes that "there were some concerns from the operations perspective that they needed to be in control," so Lubrizol installed supervisory functions to allow operators to enable or disable the adaptive control technology themselves. But according to Hernandez, "we found out that that was never necessary."

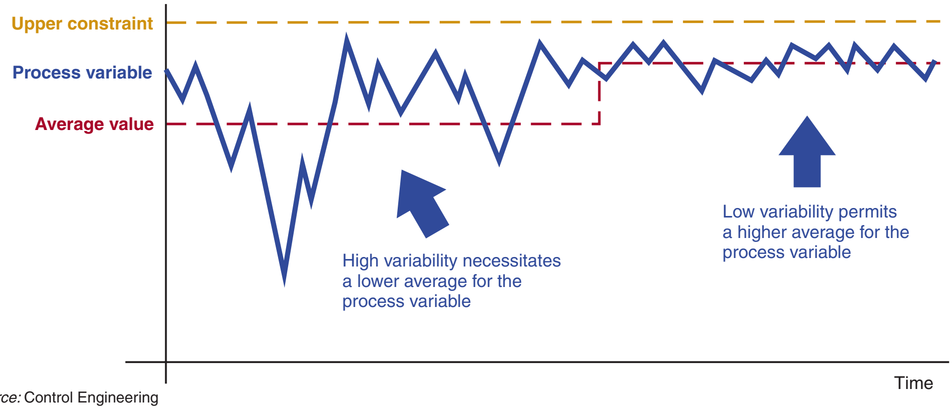
In fact, says Hernandez, "almost immediately after we started collecting data in our beta test, we noticed an improvement in the variability of the loops. Before, every time I looked in our plant historian, many loops were all over the place. After we started using the baseline tuning that Emerson recommended, everything started looking much better."

Process variability was reduced by 25% to 50%. That not only improved the product's consistency, it allowed the reaction to go much faster, which in turn led to an increase in the plant's capacity.

Controlling temperature

On a much smaller scale, self-tuning control has also been also been used to regulate the temperature of an electric glass-blowing furnace and annealer. Chemical engineer turned glass artist Richard Huntrods found that a Fuji Electric PXR Series PID controller did an excellent job of both maintaining the desired temperature and ramping it up and down per his specifications, all without any manual tuning.

Benefits of reducing process variability



Source: Control Engineering

Reducing the variability of a process variable will produce a more consistent product and allow the process to be operated closer to its constraints.

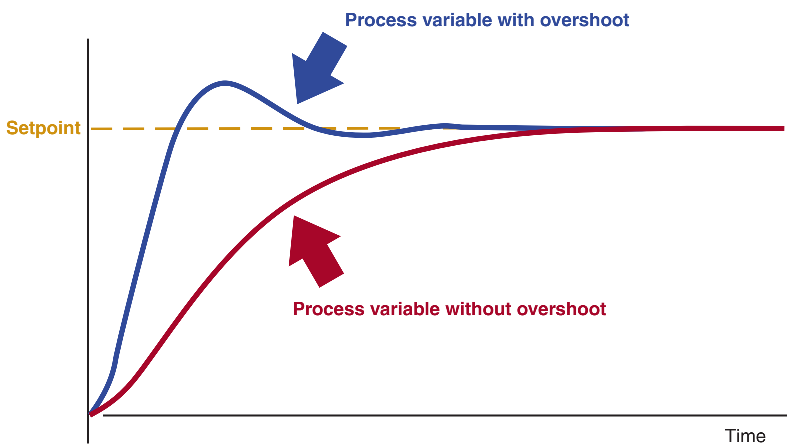
ONLINE

Visit www.controleng.com archives for more on self-tuning control:

"Fundamentals of self-tuning control." July 2007

"Auto tuning control using Zieglar-Nichols" October 2006

Benefits of minimizing overshoot



Source: Control Engineering

Eliminating overshoot can lengthen the time required for the process variable to reach the setpoint, but it also reduces the wear and tear on the actuators that drive the process.

Huntrods replaced a standard PID controller that had not been able to hold the various setpoints he needed at different stages of the cooking, blowing, and annealing process. "The new controller took some time to self-tune, giving me a small scare. After turning the furnace back on, the temperature dropped to around 1,825°F before the controller really kicked in to bring it back to the 1,850°F setpoint."

However, after a day's use, "you could see the controller slowly dial in the right settings," he notes. "When I first turned it on, the temperature often overshot as the setpoint was bumped up every few minutes en route to the final temperature. But by the time the final temperature was reached, the controller's response was within a few degrees."

The self-tuning controller also proved adept at disturbance rejection. Huntrods notes that "one of the problems with blowing glass is you have to open the furnace every ten minutes or so to take a gather of glass out. The performance of the furnace after the door is closed is critical. You need a good response time. The temperature also drops quite drastically when cold glass components are added to the furnace."

But once the controller found a good set of tuning constants, the temperature curve would asymptotically reach the setpoint after a disturbance, rather than overshooting and throttling back. This minimized the temperature response time and lowered Huntrods' operating costs.

"The heating elements are run close to their max, so the PID curve needs to be optimized to avoid overshoot," Huntrods explains. "The Fuji controller knows how much power to apply for how long, rather than simply going to full power when I open the door. This really extends the life of my elements." Heating elements that typically last a matter of months are now going into their third year of operation, he says.

Annealing too

Huntrods also uses a Fuji self-tuning controller for his annealer to keep the temperature at 920°F while he's working. When he's done for the day, he drops the temperature at 100°F per hour until it's room temperature.

Unlike the furnace, the annealer doesn't pass through a series of temperature steps as it warms up, so its response is fairly crude en route to the 920°F setpoint. But as the controller responds to subsequent temperature disturbances whenever the annealer door is opened, the overshoot goes away. "The final response is very quick, but doesn't overshoot," says Huntrods. "The tuning is also very quick."

Huntrods reports that he has encountered conditions that appeared to confuse the Fuji controller. "I once had a situation where the heating elements weren't actually heating the furnace." He's also seen sustained oscillations that he had to terminate manually by turning the controller off then back on again.

Overall, though, Huntrods considers his self-tuning controllers to be worth the investment. In addition to the greater efficiency and lower operating costs, they save him the time and effort that he had previously spent tuning his traditional PID controller manually. He says he'd rather spend that time blowing glass. **ce**

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