How to Manually Tune a Three-Mode PID Controller
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As the marketplace changes, we are finding that more and more companies are outsourcing their technical resources or eliminating engineers from their staffs entirely. Gone are the days of manufacturing facilities filled with engineers available to take on every technical issue in the plant and ensure that the instrumentation is operating at its peak efficiency.

You may be one of the operators now responsible for keeping the process running as well as taking care of the instrumentation. The ability to manually tune a process loop is an art that is quickly becoming scarce.

Many of the new controllers on the market today are vastly more advanced than the units that were sold 20 years ago. The controllers of today have many types of auto-tuning algorithms, fuzzy-logic overshoot, disturbance and hunting-suppression routines to keep the most unruly loops under control. Even with this horsepower, there are some loops that will just not be tamed with these automated methods. This is when the skills to tune a loop manually are necessary. If you are new to the instrument shop, have been given the responsibility of the process loops running smoothly or just need a refresher, this information will help.

Temperature and Profile Recorders

Most universal temperature and profile controllers on the market provide an “auto-tuning” function as a standard feature. Auto-tuning is a function whereby the controller automatically measures the process characteristics and calculates the best PID parameters for optimum control. Auto-tuning will set optimum PID parameters in most applications. However, there are processes such as pressure and flow where the auto-tune is not effective. The auto-tuning routine should always be attempted first. If an auto-tuning error occurs or if no improvement in control is observed, the controller must be tuned manually.

Before we get started, there are a few things we should define first. Cycle time is the total length of time for the controller output to complete one on/off cycle. Cycle time is used when a controller output is configured for time-proportional PID
and is typically a relay or voltage pulse output. The percentage of the cycle time during which the output is ON is the same as the output calculated by the PID. This is the value labeled “Out or Output” on the controller display. If output display value is 50% and cycle time is set at 20 seconds, the output would be on for 10 seconds and off for 10 seconds. Reducing the cycle time results in faster cycling and finer control, and it also reduces the life of the final control element. This parameter typically is set after auto-tuning or during the manual-tuning process after the dead time has been calculated.

Many loops tuned with auto-tune may not perform properly or appear to oscillate when they are actually tuned properly. Unless the cycle time is set properly, the loop will never reach its full potential.

Proportional Band
The proportional band (P) is the range over which the output is adjusted from 0-100%. P is expressed in % of the full operating span of the controller and is centered on the setpoint assuming the manual reset is set at 50%. For example, an operating range of 0-1000 degrees with a P of 5% would equal a P of 50 degrees straddled 25 degrees above and below the setpoint.

Integral Action
Integral action (I), also known as reset, is added to proportional action to overcome the offset or error from the setpoint. It responds to the error signal of the feedback system just as proportional action does, but it responds to the magnitude of the error by summing it over time and adjusting its effect on the proportional band over time. A large change in the load on a system will cause the process variable (PV) to experience a large deviation from the setpoint. If a heavy load is placed into a hot preheating furnace, the temperature of the furnace will drop before the control system can increase the output to add more energy to the furnace and the load. The proportional action alone may not be enough to recover from the disturbance in a timely manner, especially if the temperature is within the P. As the error between the setpoint and PV becomes smaller, the position of the final control element gets closer to the point required to maintain a constant value.

Derivative Action
Derivative action (D), also known as rate action, responds to rapid changes in the error signal. It will anticipate the rise or fall of the PV and automatically adjust the P to minimize overshoot or undershoot. Derivative action makes additional adjustments to P relative to the rate of change of the error signal. When the PV is steady, D is zero. When the value of the PV is changing rapidly, the derivative signal is large. The derivative signal has a major effect on the output of the controller. In this way, a larger control signal is produced when there is a rapid change in PV. In turn, the final control element receives a larger input signal. The
net result is a faster response to load changes, and overshoot/undershoot is limited or prevented.

**Tuning Loops with Dead Time**

Dead time is defined as a measurable time delay, in minutes or hours, before a response in the PV is observed due to an output change. Most ovens and furnaces fall into this category. This method of tuning is best done with a recorder connected to the control because the influence of proportional setting changes can be easily seen and the dead time measured.

Begin by setting the PID parameters to the following:

- P at 5%
- I at 0%
- D at 0%

Start the furnace, which should be run at a setpoint that will allow the PV to stabilize, with an output being generated between 25% and 75%.

**Setting Proportional Band**

With the integral and derivative turned off, the PV will stabilize with a steady-state deviation, or offset from setpoint. A properly set P will oscillate on an output or setpoint change (disturbance) and settle out to steady-state condition in what is called ¼-wave decay. If the PV oscillates continually, increase the value of P from 5% to some larger number until the PV settles to a steady state. Note whether or not there are regular cycles at this temperature by observing the measurement on the display or the recorder. A cycle, or oscillation, may be as long as an hour, so the recorder would be the preferred method to monitor the PV.

If there are no regular cycles in the process on an upset, divide the proportional band by two. Narrowing P leads to tighter control. Allow the process to stabilize and check for oscillations. If oscillations are not detected, continue to divide by two until oscillations are obtained. Fine tune – increase or decrease the P setting – until the process oscillates and then reaches steady state, just as Figure 2 shows.
Setting Integral Time (Reset)

The integral should be set at five times the dead time. Dead time is defined as that period between an output change and a noticeable change in the PV. Assume a PV of 200 degrees, the process is in manual at 25% and the control is stabilized. Increase the output by 50% to drive PV to a new setpoint of 250 degrees. If after two minutes the PV begins to climb, we have determined the dead/lag time is 120 seconds. Integral is set as seconds per repeat. Therefore, the integral would be set at 600 seconds.

Setting Cycle Time

At this point, the cycle-time value can be determined if your process is using time-proportional PID with either a relay or voltage pulse output. A good rule of thumb is the cycle time should be set for one-quarter of the dead time. So, using the above example of 120 seconds for dead time, the cycle time should be set around 30 seconds. This is not a hard, fast rule. Values less than 30 will have no effect on PV but can cause unnecessary wear on the final control element. Values much larger than 30 can introduce some cycle-time oscillation into the process at steady state.

Derivative

Derivative is usually set at one-quarter of integral. Therefore, if integral is set at 600, the derivative would be set at 150 seconds.

Tuning Fast Loops

Fast loops are defined as having little or no dead/lag time. A small or large change in output triggers an immediate change in PV. When manually tuning a fast loop, it is usually found desirable to configure the instrument as a two-mode, PI controller. Derivative, an overshoot/undershoot-suppression function, by its nature contributes to instability in a fast-control loop. Most pressure and flow loops fall into this category.

Begin by setting the PID parameters to the following:

- P at 100%
- I at 0%
- D at 0%
Start the process, which should be run at a setpoint that will allow the PV to stabilize, with output being generated.

**Setting Proportional Band and Integral Terms**

With integral and derivative turned off, the PV will stabilize with a steady-state deviation, or offset from setpoint. If PV oscillates, increase the value of P from 100% to some larger number until PV reaches steady state. To set the integral in seconds per repeat, start with an integral of 20 seconds. If PV begins to oscillate, make “I” weaker by increasing the value of “I” from 20 seconds to some larger number until PV reaches steady state. If the response is sluggish or the offset diminishes slowly, strengthen the “I” action by reducing the value of “I” from 20 seconds to some smaller number until PV reaches steady state.

Yokogawa’s new UTAdvanced was designed as a result of the knowledge obtained in Yokogawa’s 50-plus years of experience in the control market. Significant changes in the marketplace are demanding that control instrumentation be easier to use and at the same time more capable. Multiple auto-tuning algorithms and features as well as world-class overshoot and hunting suppression allow the UTAdvanced to control demanding processes. Yokogawa accomplishes this by balancing an easy-to-use controller with the power to handle your most challenging applications. **IH**

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Additional related information may be found by searching for these (and other) key words/terms via BNP Media SEARCH at www.industrialheating.com: fuzzy logic, proportional band, integral action, derivative action, PID controller

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