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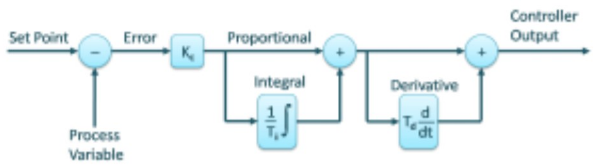
PID Controller Algorithms | Control Notes

5~6분

Manufacturers of PID controllers arrange the Proportional, Integral and Derivative modes into one of three different controller algorithms or forms. These are called the Interactive, Noninteractive, and Parallel forms. Some controller manufacturers allow you to choose between different forms as a configuration option in the controller software.

Interactive

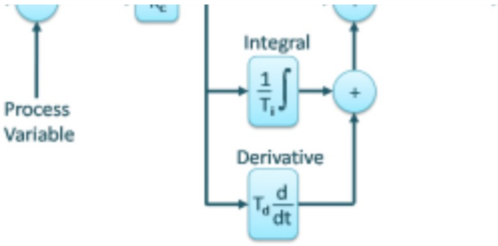


Interactive Form

$$CO = K_c\left[E + \frac{1}{T_i}\int E \cdot dt\right] \times \left[1 + T_d\frac{d\cdot}{dt}\right]$$

The oldest arrangement of the P, I, and D control modes is called the Series, Classical, Real, or Interactive form. The original pneumatic and electronic controllers had this form and it is still found it in some controllers today. The Ziegler-Nichols PID tuning rules were developed for this form.

Noninteractive



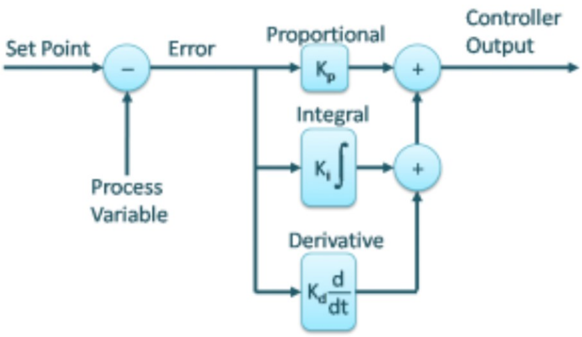
Noninteractive Form

$$CO = K_c\left[E + \frac{1}{T_i}\int E \cdot dt + T_d\frac{dE}{dt}\right]$$

The Noninteractive form is also called the Ideal, Standard or ISA algorithm. Most PID tuning rules, including the Cohen-Coon and Lambda tuning rules were designed for this form.

Note: If no derivative is used (i.e. $T_d = 0$), the interactive and noninteractive forms are identical.

Parallel



Parallel Form

$$CO = K_p \times E + K_i\int E \cdot dt + K_d\frac{dE}{dt}$$

Many academic textbooks discuss only the parallel form of PID controller, and don't mention the others. The parallel form is also used in some DCSs and PLCs. This algorithm is simple to understand, but not intuitive to tune. The reason is that it has no controller gain that would normally affect all three control modes. Instead, it has a proportional gain that affects only the proportional mode. Adjusting the proportional gain should be supplemented by adjusting the integral and derivative settings at the same time. I try not to use this controller algorithm if possible. In some DCSs it has an alternative option, but not always.

Significance of Different Forms

The biggest difference between the different forms is that the Parallel form has a Proportional-only Gain (Kp), while the two other forms have a Controller Gain (Kc). Controller Gain affects all three modes (Proportional, Integral and Derivative) of the Series and Ideal forms, while Proportional Gain affects only the Proportional mode of a Parallel controller.

This difference has a major impact on the tuning of the controllers. All the popular tuning rules (Ziegler-Nichols, Cohen-Coon, Lambda, and others) assume the controller does not have a parallel form, and therefore has a Controller Gain. To tune a Parallel controller using any of these rules, the Integral time has to be divided and derivative time multiplied by the calculated Controller Gain.

The second difference between the forms is the interaction between the Integral and Derivative modes of the Interactive form. This, of course, is only of significance if the Derivative mode is used. In most PID controller applications, Derivative mode is not used. Equations have been developed for converting tuning settings between Ideal and Series controller algorithms.

Units of Measure of Tuning Settings

Another very important difference between controllers lies in the units of measure of the tuning settings. There are three differences.

1. Most controller types (e.g. Honeywell Experion, Emerson DeltaV, ABB Bailey) use Controller Gain, while some (e.g. Foxboro I/A, Yokogawa CS3000) use Proportional Band (PB). The conversion between the two is easy once you know which one is being used: PB = 100% / Kc.

2. Many controllers (e.g. Honeywell Experion, Foxboro I/A) use minutes as the unit for Integral and Derivative modes, but some controllers (e.g. Emerson DeltaV, ABB Bailey) use seconds.

3. Most controllers use Time for their Integral unit, while some (e.g. ABB Bailey) use Repeats/Time. These are reciprocals of each other.

The first controller I ever tried to tune used Proportional Band, but at the time, I had never heard of this concept. Needless to say, when I entered my calculated Kc of 1.2 into its PB setting, the loop became wildly unstable. It did not take me long to realize that I should read up on PID controllers before trying to tune one again.

Other Differences

Beyond the differences mentioned above, controllers also differ in the way the changes on controller output is calculated (positional and velocity algorithms), in the way Proportional and Derivative modes act on set point changes, in the way the Derivative mode is limited/filtered, as well as a interesting array of other minor differences. These differences are normally subtle, and should not affect your tuning.

When tuning controllers, always find out which PID form the controller has and which units it uses.

Stay tuned!

Jacques Smuts – Author of the book Process Control for Practitioners