Tutorial for PID - Controlled Systems

About the tutorial

This Tutorial should help you to become familiar with PID feedback controlled systems. If you think you are already familiar with certain topics you can enter the tutorial at specific stages using the menu on the left hand side of the screen. Pen and paper would be useful to note down important information.

PID - Controller

The PID – Controller is the most widely used control strategy in industry. It is used for various control problems such as automated systems or plants. A PID-Controller consists of three different elements, which is why it is sometimes called a three term controller. PID stands for:

- **P** Proportional control
- **I** Integral control
- **D** Derivative control.

PID – control can be implemented to meet various design specifications for the system. These can include the rise and settling time as well as the overshoot and accuracy of the system step response.
To understand the operation of a PID feedback controller, the three terms should be considered separately.

Proportional Control

Proportional control is a pure gain adjustment acting on the error signal to provide the driving input to the process. The P term in the PID – controller is used to adjust the *speed* of the system.

Integral Control

Integral control is implemented through the introduction of an integrator. Integral control is used to provide the required accuracy for the control system.

Derivative Control

Derivative action is normally introduced to increase the *damping* in the system. The derivative term also amplifies the existing noise which can cause problems including instability.

PID Transfer Function

If we now look at the general transfer function of a PID-controller, the three terms can be recognised as follows:

$$G_C(s) = K_P\left[1 + \frac{1}{T_i \cdot s} + T_d \cdot s\right] \qquad (1.1)$$

P I D

If we now rearrange that a little we come up with a more conventional transfer function form:

$$G_C(s) = \frac{K_P(T_i \cdot T_d \cdot s^2 + T_i s + 1)}{T_i s} \qquad (1.2)$$

Where:

K_p is the proportional gain
T_i is the integral time constant
T_d is the derivative time constant

Such a controller has three different adjustments (K_p, T_i, T_d) which interact with each other. For this reason, it can be very difficult and time consuming to tune these three values in order to get the best performance according to the design specifications of the system.
The next example illustrates the effect of implementing P, PI, PID control to a system in turn. We will consider how the controller constants are selected later.

Empirical tuning methods (OPZIONALE)

As mentioned before, the set up procedure or tuning of a controller can be tedious. One approach is to use a technique which was developed in the 1950's but which has stood the test of time and is still used today. This is known as the Ziegler Nichols tuning method.

Ziegler Nichols Tuning Method

The procedure is as follows:

1. Select proportional control alone
2. Increase the value of the proportional gain until the point of instability is reached (sustained oscillations), the critical value of gain, $\mathbf{K_c}$, is reached.
3. Measure the period of oscillation to obtain the critical time constant, $\mathbf{T_c}$.

Once the values for $\mathbf{K_c}$ and $\mathbf{T_c}$ are obtained, the PID parameters can be calculated, according to the design specifications, from the following table.

Control	K_p	T_i	T_d
P only	**0.5** K_c		
PI	**0.45** K_c	**0.833** T_c	
PID tight control	**0.6** K_c	**0.5** T_c	**0.125** T_c
PID some overshoot	**0.33** K_c	**0.5** T_c	**0.33** T_c
PID no overshoot	**0.2** K_c	**0.3** T_c	**0.5** T_c

Table 1

These values are not the optimal values and additional fine tuning may be required to obtain the best performance from the system. The selection of the type of PID-control to be applied depends on the application of the system. i.e. a control system for a pressure vessel strongly requires PID-control with no overshoot.

Now work through the following example.

Example

Use the Zeigler Nichols closed loop method to tune a PID-controller for a cruise control system applied in a road vehicle. Fluctuations in the speed are not permitted and cruise speed should be accurate

What type of control is appropriate?

Answer

Assume the transfer function of the road vehicle is:

$$G_p(s) = \frac{40}{2 \cdot s^3 + 10 \cdot s^2 + 82 \cdot s + 10} \qquad H(s) = 1$$

Now form the closed loop transfer function with proportional gain K and increase the gain up to the point of instability. From this, the response K_C and T_C are obtained which enables the calculation of the PID parameters (Table1 above). Apply these to the closed loop transfer function.

Finally obtain the response and compare it with the design specification.

SVOLGIMENTO

1) trovare il valore di un regolatore proporzionale che porti (circa, senza farlo "esplodere", si tratta di un criterio empirico!) il sistema al limite di stabilità: K_c
2) misurare il periodo di oscillazione in condizioni limite: T_c
3) calcolare i valori di T_i, T_d e K_p secondo la tabella soprastante
4) verificare le varie soluzioni