The Working Principle of a PID Controller for Beginners

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As the name suggests, this article is going to give a precise idea about the structure and working of PID controller. However going into details, let us get an introduction about PID controllers.

PID controllers are found in a wide range of applications for industrial process control. Approximately 95% of the closed loop operations of industrial automation sector use PID controllers. PID stands for Proportional-Integral-Derivative. These three controllers are combined in such a way that it produces a control signal.

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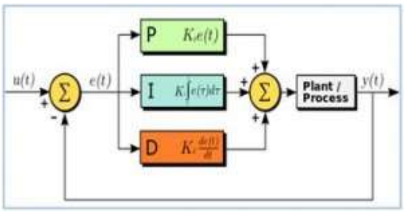


Working of PID controller

As a feedback controller, it delivers the control output at desired levels. Before microprocessors were invented, PID control was implemented by the analog electronic components. But today all PID controllers are processed by the microprocessors. Programmable logic controllers also have the inbuilt PID controller instructions. Due to the flexibility and reliability of the PID controllers, these are traditionally used in process control applications.

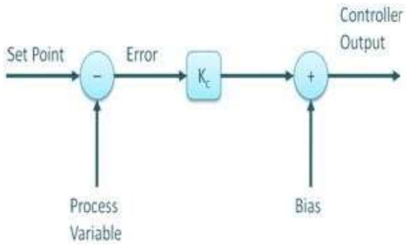
Working of PID Controller

With the use of low cost simple ON-OFF controller only two control states are possible, like fully ON or fully OFF. It is used for limited control application where these two control states are enough for control objective. However oscillating nature of this control limits its usage and hence it is being replaced by PID controllers.

PID controller maintains the output such that there is zero error between process variable and set point/ desired output by closed loop operations. PID uses three basic control behaviors that are explained below.

P- Controller:

Proportional or P- controller gives output which is proportional to current error e (t). It compares desired or set point with actual value or feedback process value. The resulting error is multiplied with proportional constant to get the output. If the error value is zero, then this controller output is zero.



P-controller

This controller requires biasing or manual reset when used alone. This is because it never reaches the steady state condition. It provides stable operation but always maintains the steady state error. Speed of the response is increased when the proportional constant Kc increases.

P-Controller Response

I-Controller

Due to limitation of p-controller where there always exists an offset between the process variable and set point, I-controller is needed, which provides necessary action to eliminate the steady state error. It integrates the error over a period of time until error value reaches to zero. It holds the value to final control device at which error becomes zero.

Integral control decreases its output when negative error takes place. It limits the speed of response and affects stability of the system. Speed of the response is increased by decreasing integral gain Ki.

PI controller

PI Controller Response

In above figure, as the gain of the I-controller decreases, steady state error also goes on decreasing. For most of the cases, PI controller is used particularly where high speed response is not required.

While using the PI controller, I-controller output is limited to somewhat range to overcome the integral wind up conditions where integral output goes on increasing even at zero error state, due to nonlinearities in the plant.

D-Controller

I-controller doesn't have the capability to predict the future behavior of error. So it reacts normally once the set point is changed. D-controller overcomes this problem by anticipating future behavior of the error. Its output depends on rate of change of error with respect to time, multiplied by derivative constant. It gives the kick start for the output thereby increasing system response.

PID controller

PID Controller Response

In the above figure response of D controller is more, compared to PI controller and also settling time of output is decreased. It improves the stability of system by compensating phase lag caused by I-controller. Increasing the derivative gain increases speed of response.

So finally we observed that by combining these three controllers, we can get the desired response for the system. Different manufactures designs different PID algorithms.

Tuning methods of PID Controller

Before the working of PID controller takes place, it must be tuned to suit with dynamics of the process to be controlled. Designers give the default values for P, I and D terms and these values couldn't give the desired performance and sometimes leads to instability and slow control performances. Different types of tuning methods are developed to tune the PID controllers and require much attention from the operator to select best values of proportional, integral and derivative gains. Some of these are given below.

Trial and Error Method: It is a simple method of PID controller tuning. While system or controller is working, we can tune the controller. In this method, first we have to set Ki and Kd values to zero and increase proportional term (Kp) until system reaches to oscillating behavior. Once it is oscillating, adjust Ki (Integral term) so that oscillations stops and finally adjust D to get fast response.

Process reaction curve technique: It is an open loop tuning technique. It produces response when a step input is applied to the system. Initially, we have to apply some control output to the system manually and have to record response curve.

After that we need to calculate slope, dead time, rise time of the curve and finally substitute these values in P, I and D equations to get the gain values of PID terms.

Process reaction curve

Zeigler-Nichols method: Zeigler-Nichols proposed closed loop methods for tuning the PID controller. Those are continuous cycling method and damped oscillation method. Procedures for both methods are same but oscillation behavior is different. In this, first we have to set the p-controller constant, Kp to a particular value while Ki and Kd values are zero. Proportional gain is increased till system oscillates at constant amplitude.

Gain at which system produces constant oscillations is called ultimate gain (Ku) and period of oscillations is called ultimate period (Pc). Once it is reached, we can enter the values of P, I and D in PID controller by Zeigler-Nichols table depends on the controller used like P, PI or PID, as shown below.

Zeigler-Nichols table

PID Controller Structure

PID controller consists of three terms, namely proportional, integral and derivative control. The combined operation of these three controllers gives control strategy for process control. PID controller manipulates the process variables like pressure, speed, temperature, flow, etc. Some of the applications use PID controllers in cascade networks where two or more PID’s are used to achieve control.

PID Controller Structure

Above figure shows structure of PID controller. It consists of a PID block which gives its output to process block. Process/plant consists of final control devices like actuators, control valves and other control devices to control various processes of industry/plant.

Feedback signal from the process plant is compared with a set point or reference signal u(t) and corresponding error signal e(t) is fed to the PID algorithm. According to the proportional, integral and derivative control calculations in algorithm, the controller produces combined response or controlled output which is applied to plant control devices.

All control applications don't need all the three control elements. Combinations like PI and PD controls are very often used in practical applications.

Application of PID Controller: Closed Loop control for a Brushless DC motor

We hope we have been able to provide basic yet precise knowledge about PID controllers. Here is a simple question for you all. Amongst the different tuning methods, which method is preferably used to achieve an optimum working of PID controller and why?

You are requested to kindly give your answers in the comment section below.

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Sudheer Kumar Says: REPLY

at

It was very helpful , simple and clear . Can you please explain with examples like PI , PID tuning how to vary P , I & D values it would be more helpful.

Tarun Agarwal Says: REPLY

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