4.1 PROPORTIONAL INTEGRAL CONTROLLER

The proportional controller commonly known as PI controller is an essential part of the Industrial Automation and Control system. It is a closed-loop feedback control mechanism that aims to adjust the process variable by manipulating the variable based on the error between the setpoint and the process variable. It strikes a balance between quick response to deviations and long-term error elimination. Tuning the controller allows adjustment to meet the desired value.

roportional Integral Controller

PI controller or Proportional controller is a combination of Proportional controller action and Integral controller action which is designed to regulate a process variable based on its setpoint and manipulated variable. Also, it can be identified as a combination of proportional and integral controllers.

Proportional Controller: Proportional Controller in electronics engineering continuously adjusts the output based on the current error signal. The p term or proportional term calculate the current error from the setpoint and the current manipulated variable output. It generates a control signal to regulate the error.

$$Co(t) \propto e(t)$$

$$Co(t) = Kp \cdot e(t) \qquad \text{-----------(i)}$$

Where,

Co(t) = controller output at time T,

e(t) = error at time t(SP-PV),

Kp = tuning constrains for proportional action.

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Integral Controller : In Integral Controller, the I term or Integral term actuates the past error over time and generates a control action to eliminate the accumulated steady-state error. It ensures that even small errors are eventually corrected. It eliminates offset but can lead to sluggish responses and overshooting if too aggressive.

This is represented as :

It can be represented mathematically as :

$$Co(t) \propto \int e(t)\,dt$$

$$Co(t) = Ki \,.\, \int e(t)\,dt \qquad \text{-----------}(ii)$$

Where,

ki = tuning constrains for integral action,

others are same as equation number (i).

- Proportional Plus Integral Controllers with Equation
- Till now we have seen the definition of a Proportional Integral controller. Now time to understand the mathematical formula behind it. We can represent a PI controller in mathematical expression from the definition. And from that a block diagram is made for better understanding the working of a PI controller. Below is the elaboration of equation and diagram of a PI controller.

Mathematical Expression of PI Controller

From equation number (i) and (ii) we can write by adding both of them,

$$Co(t) = Kp \cdot e(t) + Ki \cdot \int e(t)\,dt \qquad \text{----------(1)}$$

This equation indicates that PI controller works like a simplified PI controller without a derivative action.

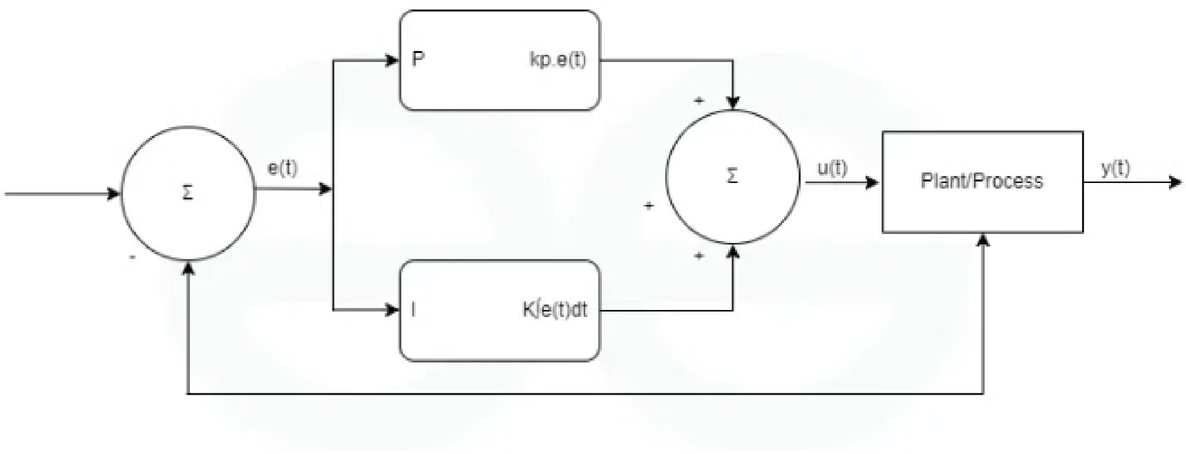
Taking laplace in both side of the equation,

$$L\{Co(t)\} = Kp.Le(t) + Ki.L\{\int e(t)\,dt\}$$

The Laplace transform of the integral term is expressed using the property $L\{\int f(x)dx\} = (1/s).L\{f(x)\}$

$$L\{Co(t)\} = Kp.L\{e(t)\} + Ki.(1/s).L\{e(t)\}$$

Block Diagram of PI Controller



Explanation of the Block Diagram

A Proportional controller operates in step by step manner to regulate a control system. It starts by calculating the error, which is the difference between the desired setpoint and current process variable. The proportional(P) part of the controller multiplies this error with proportional gain(Kp) and generates an immediate action. which is directly proportional to the error.

The Integral(I) part computes the cumulative sum of past errors by integrating gain(Ki). The two components P and I are then added together to determine the control output, which is applied to the system. This output adjusts the ultimate output of the system by minimizing the error over time and maintain the setpoint.

Applications of Proportional Integral Controller

- PI controllers are often used in temperature control systems, such as ovens, furnaces, and HVAC systems.
- PI controllers are used in motor control applications to control speed and position.
- In robotics, PI controllers are used to control the movements and positions of robot arms and manipulators.
- PI controllers are an essential part of the flight control systems in aircraft.
- PI controllers can be used in audio systems for applications like noise cancellation.
- PI controllers are used in medical devices, such as infusion pumps and respirators, to regulate parameters like drug delivery rates or patient ventilation.

Advantages

- It responses fast as compared to other controllers like PD controller or PID controller.
- PI controller enhance system stability.
- They eliminate steady state error.
- PI controllers are versatile to use in various system.

Disadvantages

- PI controller may not suitable for highly dynamic or complex system.
- In some cases it can produce overshoot before settling.

- Proper tuning can be challenging for a PI controller.
- PI controller might not be the best choice for rapidly changing setpoints.