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Understanding Proportional Integral Derivative (PID) Controller

[*Last Updated on:* ***13th December 2020, 11:30 Hrs***]

NOTE: Make sure you have covered the Control Systems document before proceeding further.

- Introduction
- So what is this hype for PID all about?
- Variations of PID controllers
  - 1. Proportional Controller aka P Controller
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Introduction

- **Proportional-integral-derivative** (PID) controllers are **widely used** in industrial systems despite the significant developments of recent years in control theory and technology.
- PID is an example of a **closed loop system**.
- They **perform well** for a wide class of processes.
- Also, they give **robust performance** for a wide range of operating conditions and, they are easy to implement using analogue or digital hardware.

So what is this hype for PID all about?

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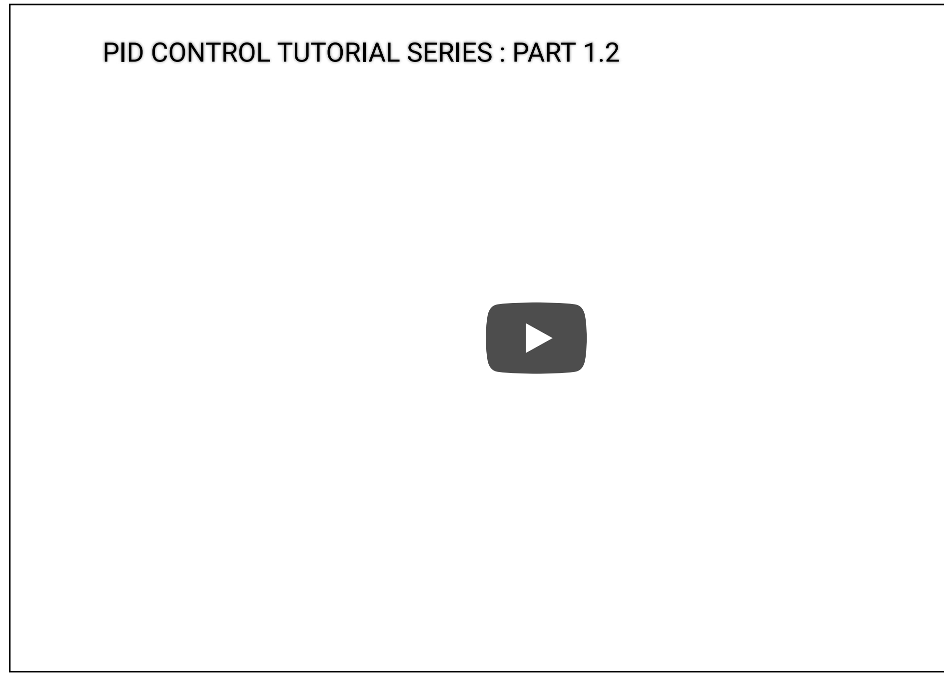
Well, lets look at some videos first.

1. Refer this video from your **beloved eYRC competition host - eYantra**.



2. Refer this video by **Aerospace Controls Laboratory of Massachusetts Institute of Technology (MIT)**.

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NOTE:

- Try watching the videos again to understand as much as possible. It has a lot of important information.
- After you think you have some background about PID start reading below.

To put things in perspective, we will have to go through some definitions.

Variations of PID controllers

1. Proportional Controller aka P Controller

- Proportional controller is mostly used **in first order processes** with single energy storage **to stabilize the unstable process**.
- The main usage of the P controller is to **decrease the steady state error** of the system.
- As the **proportional gain factor K** increases, the **steady state error** of the system **decrease**

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- However, despite the reduction, **P control can never** manage to **eliminate** the **steady state error** of the system.
- As we **increase the proportional gain**, it provides **smaller amplitude** and **phase margin**, **faster dynamics** satisfying wider frequency band and **larger sensitivity** to the noise.
- We can **use** this controller **only** when our **system is tolerable** to a **constant steady state error**.
- In addition, it can be easily concluded that applying **P controller decreases** the **rise time**.
- Moreover, **after** certain value of **reduction on the steady state error**, **increasing K** only **leads to overshoot** of the system response.
- P control also **causes oscillation if sufficiently aggressive** in the presence of lags and/or dead time.

> **Assignment**: Learn about dead time in control systems.

- The more lags (higher order), the more problem it leads. Plus, it directly **amplifies process noise**.
- A P controller consists of only a linear gain Kp. The output of such controller can be simply given as

```
output = Kp * error
```

2. Proportional-Derivate Controller aka PD Controller

- A controller which **changes the input** of the controller to **proportional plus derivative of error signal** is called **PD** controller.
- It is used to **damp the oscillations** that arise because of increasing the proportional constant

```
output = (Kp * error) + (Kd * ((error - previous error)/Δt))

where, Δt is a small duration of time
```

3. Proportional-Integral-Derivate Controller aka PID Controller

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- A controller which **changes the input** of the controller to **proportional plus derivative of error signal plus the integral of the error** is called **PID** controller.
- It is used to **remove the steady state error** which might arise in PD controller.

```
sum_err = sum_err + error
output = (Kp * error) + (Kd * ((error - previous_error)/Δt)) + (Ki * sum_err * Δt)
```

Improving your Controller

- The simple equations stated **may not** always **be enough** to stabilize the system.
- Hence there are **various techniques to improve the performance** of PID controller. These are as follows:
  - Sample Time
  - Derivative Kick
  - On-The-Fly-Tuning Changes
  - Reset Windup Mitigation
  - On/Off
  - Initialization
  - Controller Direction
  - Proportional on measurement
- You can read about these in the **blog by brettbeauregard** here.

NOTE: The above blog is very important to write your code. Make sure you read everything carefully.

References

1. **Feedback Control Systems: A conceptual Approach** by U.A. Bakshi, V.U. Bakshi
2. The series of videos by **MATLAB** will help to grasp the concept of PID in the best way possible You can watch the entire playlist from here.

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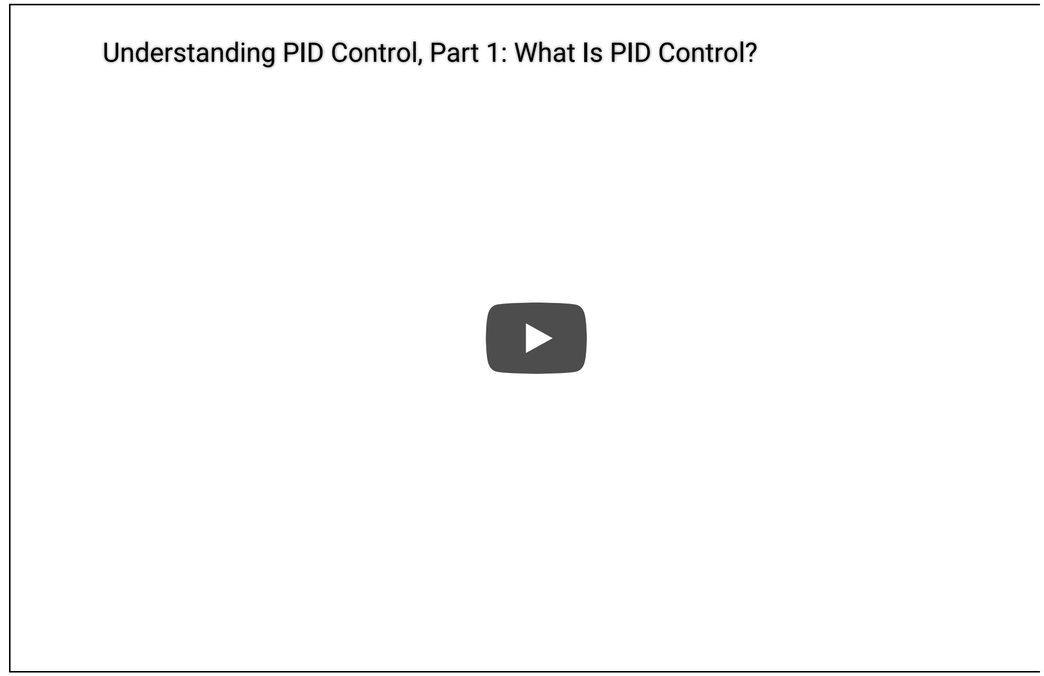

3. This document by **National Programme on Technology Enhanced Learning** will help you ge some great insights about PID. You can download it from here.

ALL THE BEST