

The effects of pid controller on an automobile manufacturing plant

Amaechi Chineke

Computer Engineering Department Micheal Okpara University of Agriculture Umudike, Abia State, Nigeria

Abstract

Proportional –Integral – Derivative (PID) controllers have had great impact in the automobile manufacturing industry. It is a key component in the control of industrial robots used in automobile manufacturing plants. Automation of car manufacturing plant based on PID has greatly increased production, lowered cost, increased safety, quality and reliability. However the success of PID has improved the industrialization of more intelligent and advanced control strategies. This paper briefly discussed the basics of PID control, its impact in the car manufacturing plant and the challenges in the optimization of PID performance.

Keywords: PID Controller, Robotization, Chasis, Automation, Plant

1. Introduction

Despite all the progress in advanced control, the Proportional-Integral-Derivative (PID) controller remains the most popular controller. Any stable system can be controlled with an integrating controller; performance can be increased by adding proportional and derivative action.

PID controllers come in different shapes: as stand-alone components, as elements of distributed control systems, or embedded in instruments and systems. PID control is used everywhere- in cellular phones, vehicles, process control, heating, ventilation, air conditioning, machine tools, and motor drives. Many PID controllers are found in cars, for example, in engine, cruise, and traction control. PID control is also embedded in instruments like atomic force microscopes and adaptive optics. Because of their widespread use, it is difficult to precisely estimate the number of control loops that are installed each year, but an educated guess is that it is in the billions (1).

The annual output of automobiles is in tens of millions units a year. A key tool in automotive production is automation, especially the use of industrial robots. It is well known that industrial robot manipulators are predominantly equipped

with PID controllers. In the highly competitive automotive manufacturing market, companies are looking to machinery and automation. As the dominant control structure, PID controllers have greatly impacted the automotive manufacturing industry.

2. PID Controllers

The PID controller is probably the most widely- used type of feedback controller. PID controllers are undoubtedly the most employed controllers in industry ^[1]. PID stands for Proportional- Integral-Derivative, referring to the three terms operating on the error signal to produce a control signal.

The desired parameters/conditions for a closed loop system are normally achieved by tuning the system to the inherent conditions without specific knowledge of a plant model. Stability can often be ensured using only the proportional term. Pure proportional action will result in control offset ^[2]. The PID controller produces an output signal comprising three terms- one proportional to error signal, another proportional to integral of error signal and the third one proportional to the derivative of error signal ^[3]. Figure 1 presents the PID controller in its expanded form.

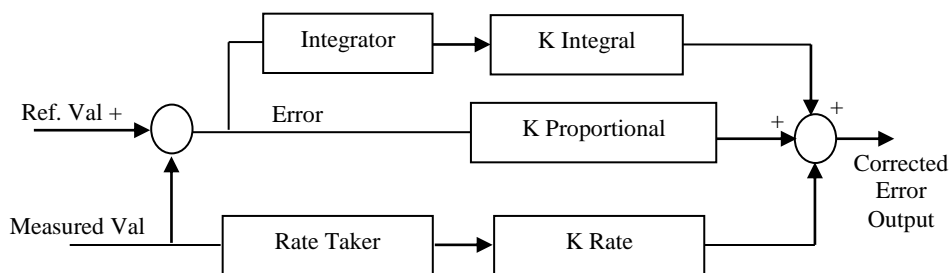


Fig 1: Block Diagram of PID Controller

PID control may be achieved in continuous time domain by computing an error term such as ^[3].

$$V(t) = K_p e(t) + (K_p/T_i) \int e(t) dt + K_p T_d (d/dt) e(t) \quad \dots (1)$$

$$\text{Or} \\ V(t) = K_p e(t) + K_i \int e(t) dt + K_d (d/dt) e(t) \quad \dots (2)$$

Where; $V(t)$ = Total Corrected Error,

K_p = Proportional Gain,

T_i = Integral Time,

T_d = Derivative Time,

K_i = Integral gain = K_p/T_i ; and

K_d = Proportional Gain = $K_p T_d$.

The proportional control stabilizes the gain but produces a steady state error. The integral control reduces or eliminates the steady state error. The derivative control reduces the rate of change of error.

Proportional (See figure 2)

Proportional control gives a change in output that is proportional to the derivation of the process variable from the set point. The range over which the output is adjusted from 0 to 100% is called the proportional band. The proportional

band is express as a percentage of the engineering range. When proportional-only control is used, manual reset is required [2]. In the figure the manual reset is get to 50%. This means that when the process variable is ‘at set point’ the control output will be 50%. Adjusting the manual reset value has the effect of shifting the proportional band up and down. This has the effect of changing the control output when the process variables is ‘at set point’. The proportional control stabilizes the gain but produces a steady state error.

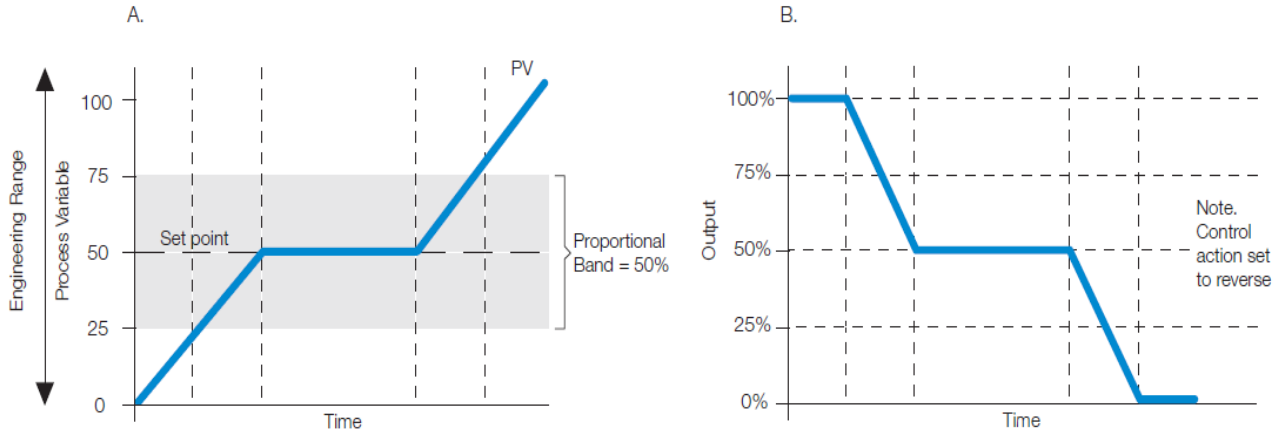


Fig 2: Proportional Action (Source [2])

Integral (See figure 3)

Due to limitations with proportional-only control, which appear as an offset between the process variable and the set point, it is often necessary to introduce an integral action. If an offset is present, the integral action will continue to change the control output in the same direction as the proportional action, until the offset or error is removed.

The integral action is expressed as the time taken for the output to change (due to the integral action) by the same amount that it changed due to proportional action, when a constant deviation is present. Figure 3B shows the effect that a 20 second integral action would have on the control output. The integral control reduces or eliminates the steady state error.

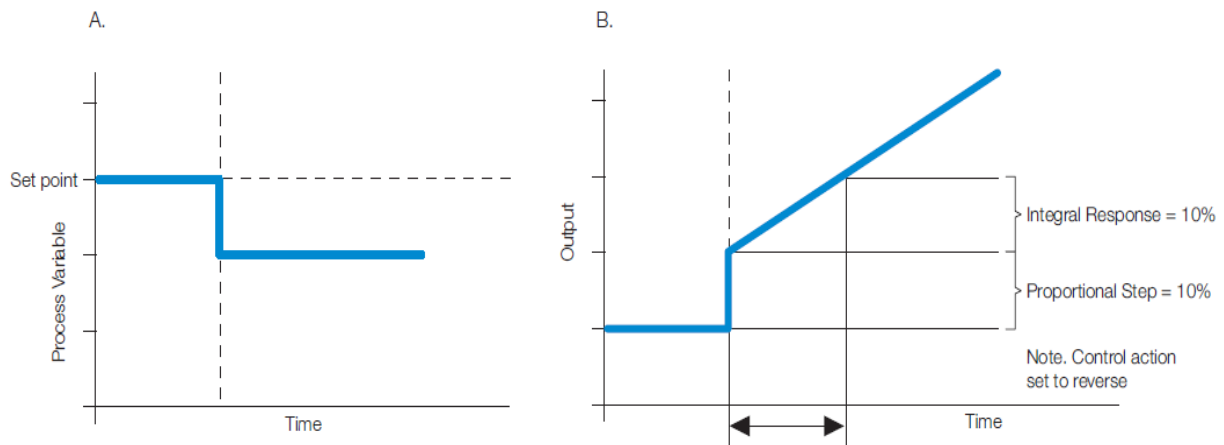


Fig 3: Integral action (Source [2])

Derivate (See figure 4)

Derivative action can be used with proportional control, with or without integral. It has the effect of making changes to the control output, dependent on the rate of change of the process variable. The amount of effect that derivative action has on the output is dependent on its setting. Derivative action is set as a time constant and has the following effect on the control

output. Taking only the proportional part of the output as shown by the lower line on figure 4B, the controller calculates forward to find out what the output will be due to the proportional action after the derivative time period. This change in output shown on the diagram as Y% is then added to the current control output values as derivative action X%. The derivate control reduces the rate of change of error.

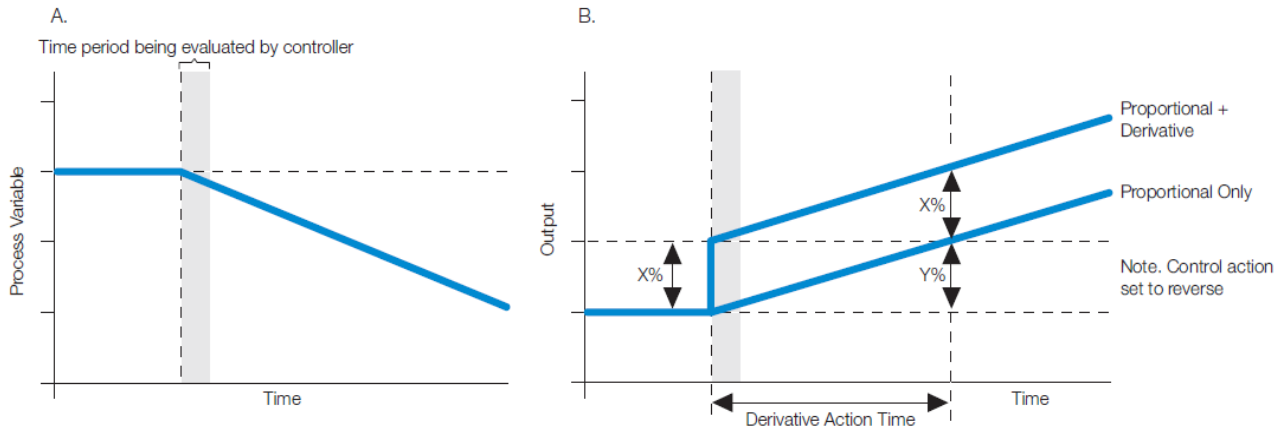


Fig 4: Derivative action

3. PID Controller in the Automotive Manufacturing Plant

PID control is an old and widely used technology. The PI controller dates back to the era of steam engines. It has survived two paradigm shifts: from mechanical to analog, then to digital implementation. Over the years, more advanced control schemes have been introduced but the PID controller is still the dominating choice in a multitude of applications [4].

PID controllers have greatly influenced the growth of the modern automated automotive industry. Annual output of automobiles is in tens of millions into a year. A key tool in modern automotive production is the industrial robot. One of the most impactful aspects of industrial robot is control. The

precise control open each degree of freedom of a robotic arm is a great challenge in implementing industrial work. The reference [5] noted that a discrete PID control technique is being used to replace too complex electronic circuitry, which would greatly reduce the cost and size of the controller. Industrial robots are naturally equipped with classical PID controllers [6]. PID controllers have made great impact in the robotization controllers of many aspects of the car manufacturing process. PID are the dominant control structure in automotive plant assembly robots, spot welding robots, paint spraying robots, materials handling robots etc. An educated guess is that a typical automotive manufacture plant can contain thousands of PID loops.

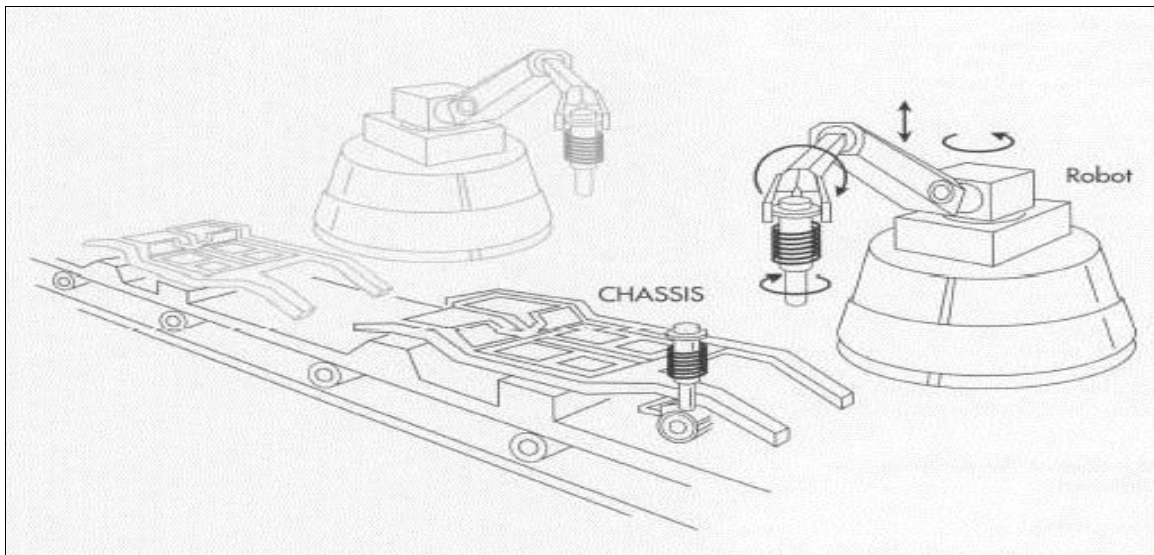


Fig 5: Assembly line robot carrying out welding and placing components onto the chassis

On automobile assembly lines, much of the work is now done by robots rather than humans. In the first stages of automobile manufacture, robots weld the floor pan pieces together and assist workers in placing components such as the suspension onto the chassis

The benefits offered by robot deployment compared to traditional manual welding include improved superior quality and uniformity, better hazardous safety and quality-of-work life, enhanced quality of product and process rationalization [7].

Automotive assembly demands repeatability, precision, variety of motion, sophisticated gripper devices and sometimes compound gripper mechanisms in which the gripper plays an active and primary role in one of the assembly steps, besides simply holding pieces of the parts. The benefits offered by robots in assembly include saving labour cost and accomplishing task with robustness, efficiently and according [8].

The benefits offered by robots in spray coating include removal of operators from hazardous environment,

consistency of finish, lower energy consumption, greater productivity and reduced coating material usage ^[9].

4. Challenges in Monitoring and Optimizing PID Loop Performance.

Maintaining optimum PID control loop performance is important for stable operations, reliable response to typical upsets, and efficient unit operations. Poor regulatory control performance can increase operator work load, promote highly variable and unreliable operation, impact plant safety, and some cases, result in shutdown.

The ability to drive economic benefits from continuous operations at unit constraints is dependent on having optimum PID regulatory control in place ^[10]. Maintaining regulatory control performance for several hundred PID loops can be very time consuming and technically intensive for industrial control engineer or instrument technician.

Though Recent Developments in Identification technology and increasing computation capabilities offer several new opportunities for overcoming the challenges associated with continuous monitoring, and assessments PID control loops, the challenges are still industrially impactful and still present opportunities for research innovations on PID control. Most industrial facilities no longer tune PID loops with manual calculations, but use tuning and loop optimization software. These software packages gather data, develop process model, suggest optimal tuning, and even develop tuning by gathering data from reference changes. The drawbacks: software is somewhat costly and involves some training ^[10]. Hence more intelligent, cost effective systems are necessary for the advancement of the benefits of PID controllers in the automotive manufacturing industry. Further the adaptive tuning of PID has yet to be fully industrialized.

5. The Impeding Impact of the Success of PID Controllers.

The industry has historically recognized the importance of control in order to have a successfully functional manufacturing facility.

The preferred control strategy in most control application in automotive plant is the implementation of PID loops. However, there are a number of features of manufacturing process that are not explicitly treated by PID controllers. Many development of modern advanced control theory have been designed to deal with these characteristics, but the industry have been quite slow or reluctant to apply such tools. This fact led many observers to state that there is a “gap” between control theory and practice.

The lack of coordination between academic and industrial research has a number of root causes. The need to obtain a quick and clearly economic solution to plant automation control problems drives the automotive industry too widely and continue to use PID controllers. Perhaps its simplicity and prevalence in the plant’s control structures meant that the industry has been slow to fully industrialize more intelligent and advanced control techniques.

6. Conclusion

PID has had enormous impact on the automation strategies employed in automotive manufacturing plant. The benefits of this impact is greatly realized in its use as the dominant control structure in industrial robots used at the automotive placement onto vehicle chassis, spot welding on the assembly

line, spray painting, and other assembly and material handling operations. This has greatly reduced the cost of operations, increased safety, reduced product variability and generally advanced the profitability of the automobile manufacturing industry.

Optimally addressing the issue of performance monitoring and optimal automated tuning of PID using more intelligent means technique will greatly increase its impact on the automobile industry.

However one of PID negative impacts is its importance of the industrialization of more intelligent and advanced control structure for use in the auto industry. Nevertheless intelligent modification of PID optimally addresses the use of intelligent tuning which will make the next generation of PID controller to get smarter and will contribute to be the main work point of the auto manufacturing plant.

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