Birzeit University
Faculty of Engineering & Techonology
Department of Electrical & Computer Engineering
ENEE4302-Control Systems

"PID Control Systems"

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Abstract

This experiment aimed to examine and study the behaviour of proportional, integral, and derivative action controllers and their impact on system response. It was found that the proportional control action reduces the steady state error and improves the speed of the response. On the other hand, the system is subjected to losing stability if the proportional gain is increased to a high level. Besides, the integral action was observed to eliminate the steady state error but it reduced the response speed and deteriorated the stability. Furthermore, the derivative action was used to eliminated the oscillations, overshoot, and to improve the stability of the system response. The approach followed in this experiment was based on tuning the controller's gains to finally have the desired response characteristics in terms of transient and steady state behaviour.

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Acronyms and Abbreviations

TF	Transfer Function
SSE	Steady State Error

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Chapter 1

Introduction

A close loop control system (feedback control system) shown in Figure 1[1] is a control system use to measure, monitor, and control the output of the system in order to achieve the desired and most accurate output by comparing it with the actual output. There are many techniques used to improve the transient response of any close loop system, which are Proportional Controller (P), Proportional Integral Controller (PI), Proportional Derivative Controller (PD), and Integral Derivative Controller (PID).

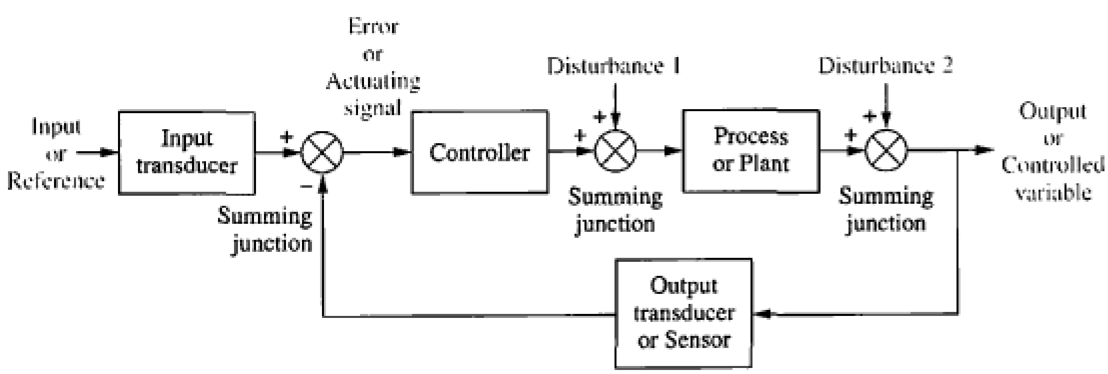

Fig. 1.1: Closed Loop System

- Proportional Controller (P):

Proportional Controller is usually used in first order systems, is improving the system mainly by decreasing the steady state error, this error has an inverse relationship with proportional gain factor K, when k increase the steady state error will decrease.

- Proportional Integral Controller (PI):

Proportional Integral Controller is used for decrease the study state error it , on the other hand it does not have a significant effect on the over shoot and transient, it is used in area when the speed of the system is not an issue.

- Proportional Derivative Controller (PD):

Proportional Derivative Controller is used for increasing the stability of the system by improving control since it has an ability to predict the future error of the system response. In order to avoid effects of the sudden change in the value of the error signal, the derivative is taken from the output response of the system variable instead of the error signal.

- Integral Derivative Controller (PID)

P-I-D controller has the optimum control dynamics including zero steady state error, fast response (short settling time), no overshoot, and higher stability. The necessity of using a derivative gain component in addition to the PI controller is to eliminate the overshoot and the oscillations occurring in the output response of the system.

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Chapter 2

Procedure and Discussion

2.1 Simple Closed Loop Proportional Control

The closed loop proportional control with three lag -unit process was connected and the proportional band was set to 100%. The set value control potentiometer was adjusted and the measured and deviation values' readings were taken as summarized in table 1:

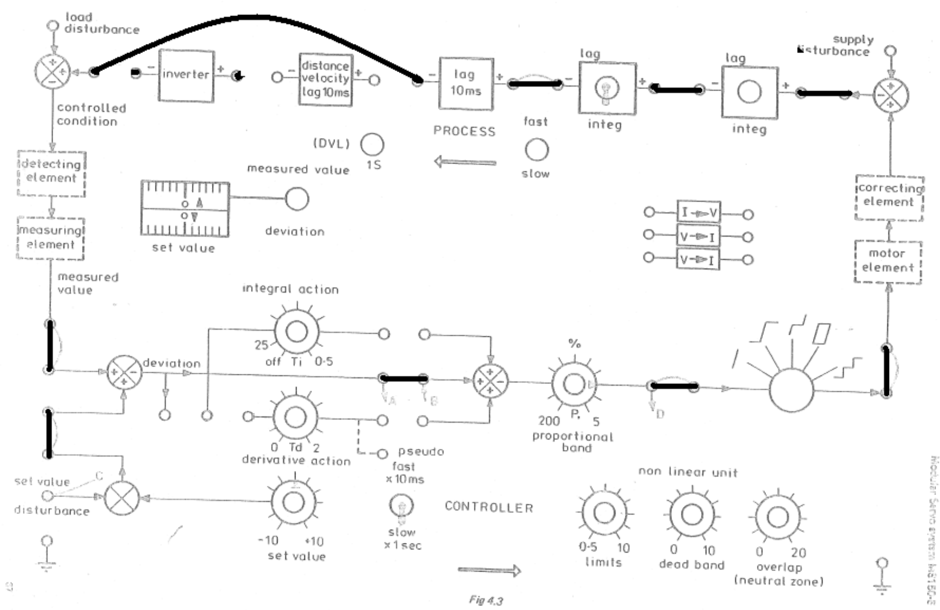

Fig. 2.1: Simple Closed Loop Proportional Control Panel

Table1 :Measured and deviation values without disturbance .

Set values (V)	Measured Values (V)	Deviation (V)
2	2	0
4	3	-1
6	5	-1
-2	1	1
-4	-3	1
-6	-5	1

A voltage of 1.5Vdc was applied to the load disturbance socket and the measurements in table 2 were taken :

Table 2: Measured and deviation values for disturbance of 1.5V

Set values (V)	Measured Values (V)	Deviation (V)
2	2	0
4	3	-1
6	5	-1
-2	-1	1
-4	-3	1
-6	-5	1

It was noticed from table 1 and 2 in results part that load disturbance does not have a big effect on the measured value and the deviation, this is not almost correct because it was expected to have other value for the measured value and the deviation since the load disturbance increase the measured value and decease the deviation.

Questions:

1-NO, because there are three lag units acting as integrators in the time domain ,so there will be time delay.

2- Because there in an error which made the measured value less than the input value due to having proportional P control only, the steady state error is not eliminated.

3- a desired value is set , the difference between the desired or reference set value and the actual or measured value is propagated through a proportional band controller whose output is proportional to the generated error (actuating signal) , this proportional value is then fed to the process which is here a three-lag unit process .

4- The disturbance decreased the deviation (error) and increased the measured value.

The set disturbance is inverted.

5- With the disturbance the measured value (the set value on the meter) is higher than the case without the disturbance as appears in the tables above.

2.2 Proportional Control System Response

The same closed loop proportional control circuit was connected, a square wave signal of 5Vp-p and 2Hz was applied and the measured value signal was observed using oscilloscope.

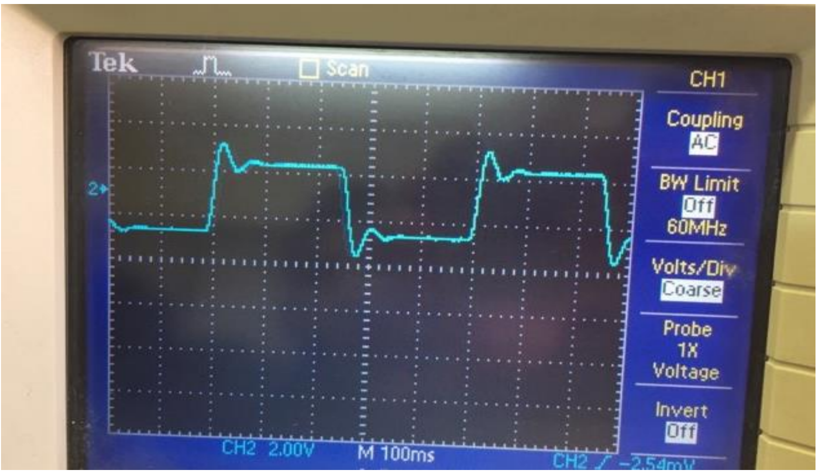

Fig. 2.2: Measured Response of P-Controller

Fig. 2.3: Deviation Signal of P-Controller

➢ With P.B gain = 50%

Fig. 2.4: Measured Response of P-Controller with Gain =50%

Fig. 2.5: Deviation Signal of P-Controller with Gain =50%

➢ With P.B gain = 50%

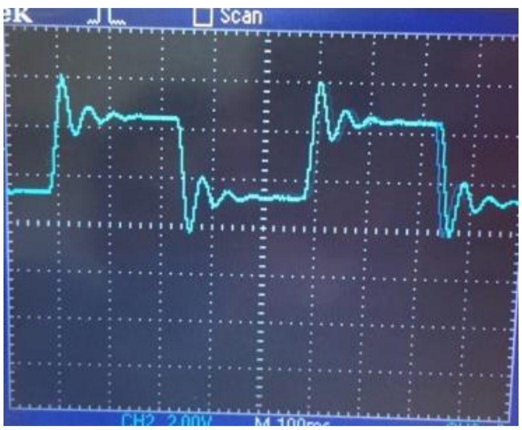

Fig. 2.6: Measured Response of P-Controller with Gain =30%

Fig. 2.7: Deviation Signal of P-Controller with Gain =30%

The obtained results show that changing controller gain can change the closed loop system dynamics. As the value of gain increases, the overshoot and the speed of the response increases and the steady state error becomes smaller but not eliminated. If the gain is increased to higher level, the response will no longer be stable.

2.3 Proportional Plus Integral Control System

The closed loop proportional plus integral control circuit was connected, a square wave signal of 5V-p-p and 2Hz was applied and the measured value signal was observed using oscilloscope.

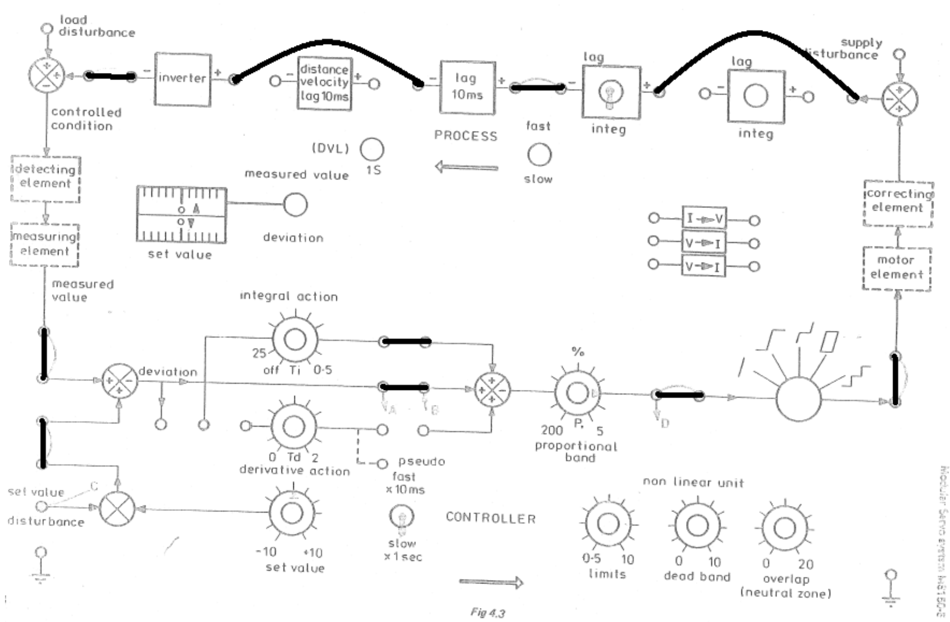

Fig. 2.8: PI Controller Circuit Panel

For 2-lag units: the proportional band gain was adjusted to 50% , At Ti of 10: the response was observed as in figure below :

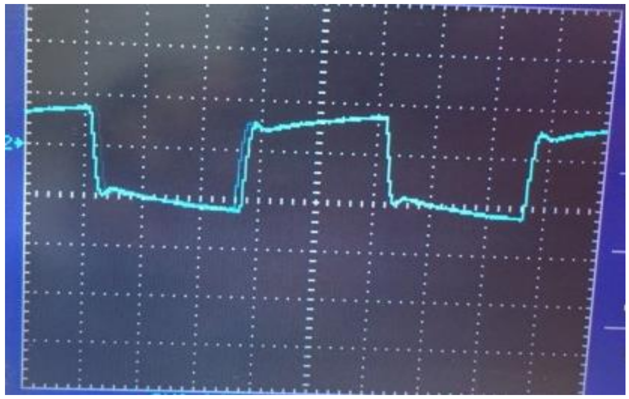

Fig. 2.9: Response of PI Controller for 2 Lag units at gain =50% and Ti of 10

- For Ti = 0.7:

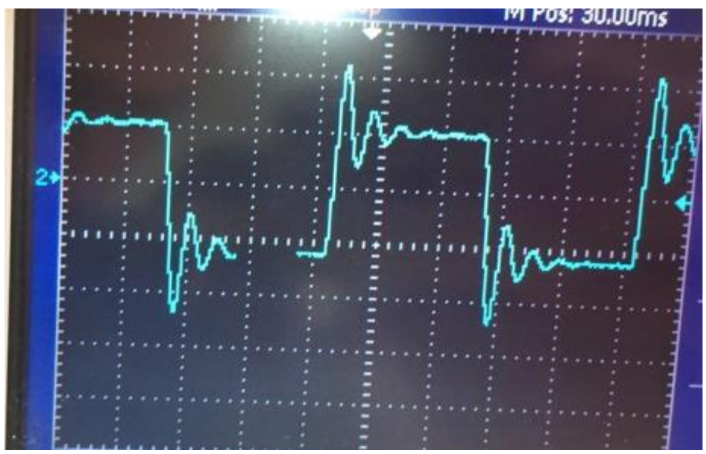

Fig. 2.10: Response of PI Controller for 2 Lag units at gain =50% and Ti of 7

- For a process of 3-lag units , Ti = 10:

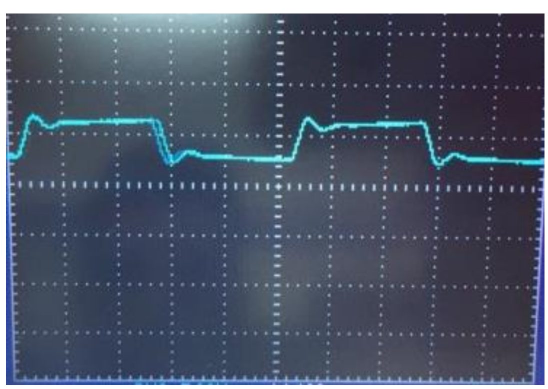

Fig. 2.11: Response of PI Controller for 3 Lag units at gain =50% and Ti of 10

Ti=2.5 :

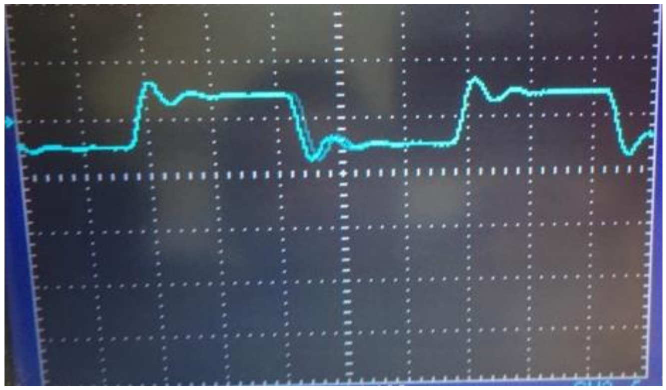

Fig. 2.12: Response of PI Controller for 3 Lag units at gain =50% and Ti of 2.5

It was shown that the PI controller eliminated the steady state error and reduce it to zero, and the effect of the lag units on the delay of the signal was observed as well.

2.4 Proportional Plus Derivation Control System

The integral action was replaced by the derivative action as in figure 13, and the same procedure was followed as in part 2.3.

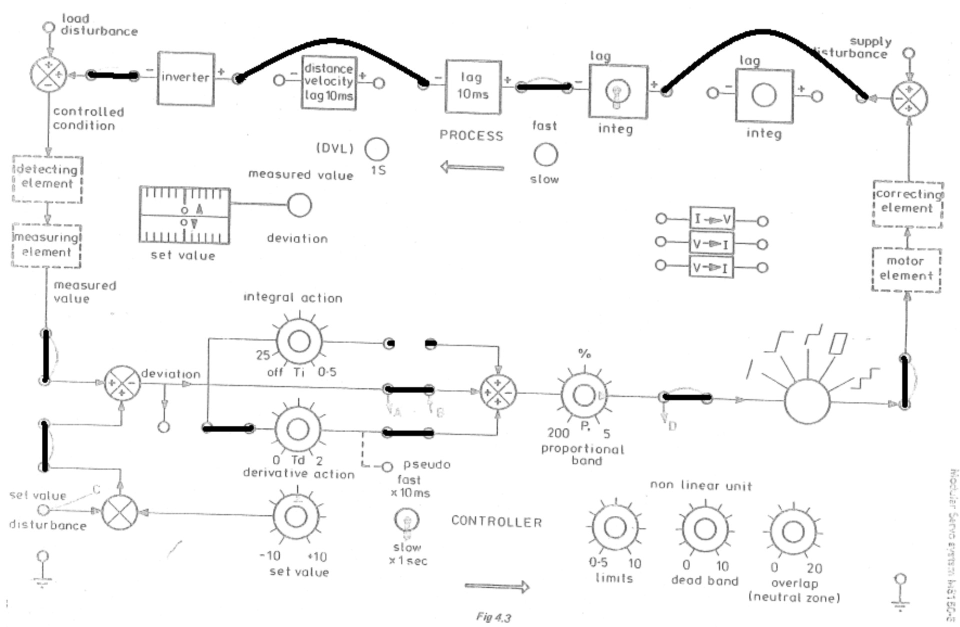

Fig. 2.13: PD Controller Circuit Panel

For 3-lag units: Td= 1:

Fig. 2.14: Response of PD Controller for 3 Lag units at gain =50% and Ti of 1

Td= 1.5:

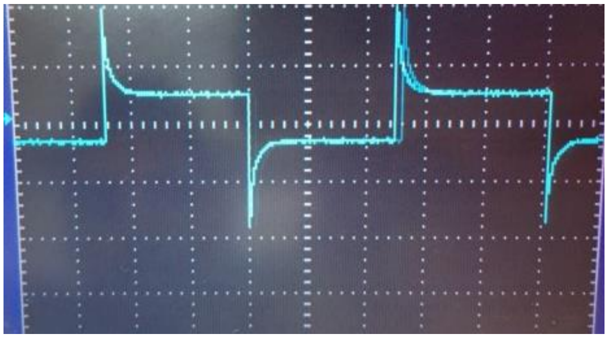

Fig. 2.15: Response of PD Controller for 3 Lag units at gain =50% and Ti of 1.5

For 2-lag units : Td= 1 :

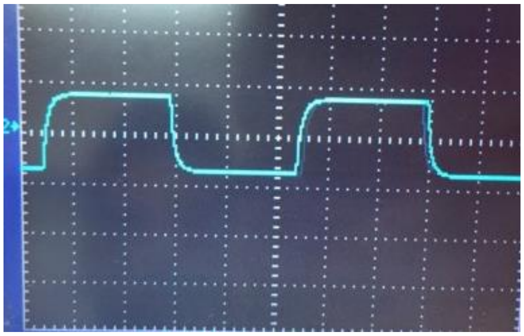

Fig. 2.16: Response of PD Controller for 2 Lag units at gain =50% and Ti of 1

For 2-lag units : Td= 1.5 :

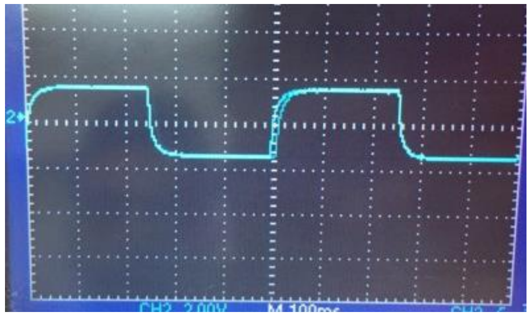

Fig. 2.17: Response of PD Controller for 2 Lag units at gain =50% and Td of 1.5

It was noticed that proportional derivation control mainly used to deal with the number of oscillation (over shoot), also it decrease the settling time (speed up the system) and the steady state error.

2.5 PID Control System

The PID controller closed loop system in figure below was connected; the P.B gain was adjusted to 50%. The gains of integrator and derivative actions were tuned until the response reached desired characteristics of zero steady state error and no overshoot.

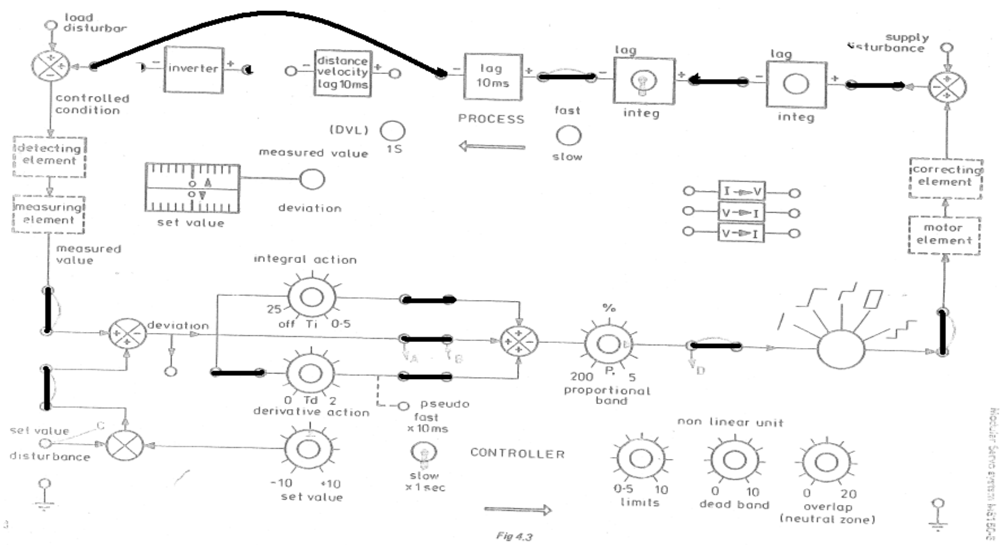

Fig. 2.18: PID Controller Circuit Panel

Response at Td= Ti= 1 .

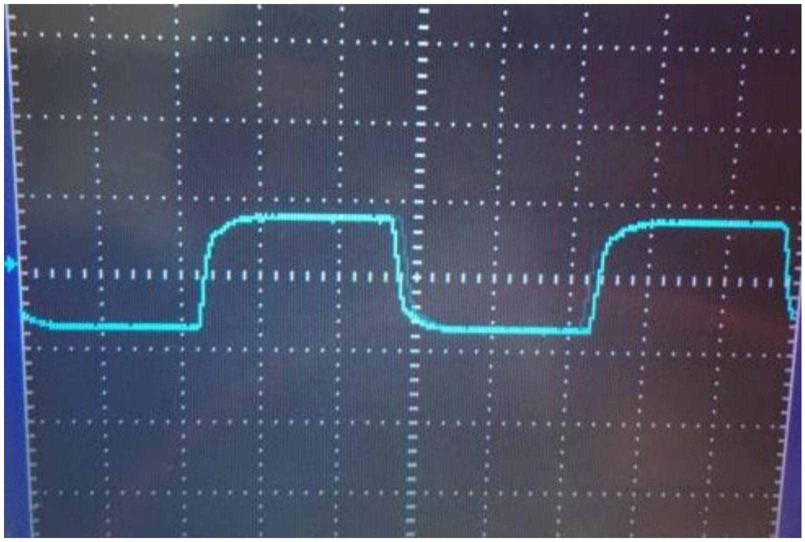

Fig. 2.19: Response of PID Controller at gain =50% and Ti=Td= 1

Questions:
The three effects below are related:
1- Steady state error decreases but not much.
2- Settling time decreases.
3- Number of oscillations is reduced by the derivative action.

The effect of one controller action while others are constant: Changing derivative action affects the response as shown below; when the derivative gain is reduced, the oscillations, overshoot, and the settling time increase, the steady state error is also effected, since the derivative action eliminates the oscillations this makes the error gets smaller at times when the error was high without D control

Fig. 2.20: Effect of Changing Derivative Action.

. PID controller is the optimum control which can achieve a zero steady state error, short settling time (short rise time), less over shoot, and more stability.

Conclusion

This experiment has examined three different types of controllers, P, PI, PD, and PID. The proportional control has some advantages as increasing response speed, and increasing response accuracy. However, P control does not eliminate steady state error and thus the PI controllers is needed to achieve that since the integral action drives the error to zero by proper tuning , the disadvantage of adding integral action is negative effect on system stability and speed of the response. The PD controller is used to increase the stability of the system by improving control since it has the ability to predict the future error of the system response.

The PID controller was found to have all the necessary dynamics , it improves steady state accuracy due to having an integrator , and improves the transient and stability due to having derivative action as well as enabling increase in gain and decrease in integral time constant Ti which increases the speed of the controller response. Therefore, for high order processes, it is recommended to use this type of linear controllers.

References

[1] Beards C.F., Vibrations and Control System. Ellis Horwood, 1988.

[2]Bennett S., A History of Control Engineering. 1800-1930. IET. 142−148, June 1986.