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Comparison of Tuning Methods of PID Controllers for Non-Linear System

[1]Sachinkumar Hiremath, [2]Nalini.C.Iyer, [3]Raghavendra.M.Shet

Department of Instrumentation, B .V Bhoomaraddi College of Engineering and Technology Hubli -580031

***Abstract*: Modern days have seen vast developments in the field of controller's .There are various controllers developed these days with various different specifications. But the only drawback is that, there is no fixed method for the tuning of these controllers, which is necessary for controlling of the system based on the variation of the input or for the changes in the system. In order to overcome this drawback, in this paper we have compared various tuning methods of PID controller for non-linear system. As a non-linear system we have taken the dc motor as a system. For the particular DC motor controller transfer function has been determined and control parameters such as Proportional Gain, Integral Time and Derivative time are identified. They are numerous methods of developing a Proportional Integral and Derivative (PID) Controller, amongst them some methods are adopted in this paper and Comparisons of Time Domain specifications of those controllers has been carried out.**

***Keywords:* PID controller c, Ziegler Nichols method, Tyres Luyben Method, damped oscillation method.**

1. INTRODUCTION

Proportional Integral and Derivative (PID) Controllers are one of the most widely used controllers in Process and Control Industries because of their characteristics such as simple design, easy to use and robustness. Ziegler and Nicoles introduced a PID controller tuning in the early 1940s and it is the basic controller that is used in Industries and Research purposes till now. Some of the PID Controllers are mentioned in this paper with their characteristics. PID Controller is designed by obtaining the closed loop transfer function of a process. In this paper, the Transfer function of the DC motor is determined. Using the Process Transfer function, the dead time, Gain, Time constant are calculated using bode plot analysis and hence by using those parameters controller parameters such as Proportional Gain, Integral Time, Derivative Time are determined. Then Transfer function of the PID Controller is obtained [1].

If A(t) is the Transfer function of PID Controller then,

$$A(t) = Kp * e(t) + Ki\int e(t) + Kd * \frac{d}{dt}e(t)$$

….. (1)

Where,

KP is the Proportional Gain

KI is the Integral Gain

KD is the Derivative Gain

The characteristics of PID Controller is that

- It predicts the future errors and hence provides better performance.
- It reduces offset.
- It has less overshoot compared to Proportional Integral Controller.
- It has faster response.

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Vedika V. Patki *et.al* [3] presented the paper on the augmented Ziegler-Nichols method for the tuning of the PID controller. From which we can have adopted the method of Ziegler Nichols method of tuning.

Kiam Heong Ang *et.al* [4] presented the paper on analysis of PID controller and its stability using the control system analysis technique. In this they have .In this they have adopted a software based approach to analyze the PID controller.

K Smriti Rao.*et.al* [6] have published a paper on comparative study of P, PI, PID controller with respective to VSI-fed induction motor to control the speed of it. In general, the principle of operating a three phase IM indicates that the speed of the motor is directly related to the frequency of the supply.

Auto-Tuning of PID controller is mainly use to increase the performance of the system [5]. The proportional integral derivative (PID) controller is the most dominant form of automatic controller in industrial use today. A practical difficulty with PID control technology is a lack of industrial standards, which has resulted in a wide variety of PID controller architectures.

From the survey made it is evident that by comparison of the various tuning code we can easily auto tune the PID controller [6]–[10].To set the critical gain and the finding the individual gain is the critical part of this experiment.

The Organization of the paper is, section 1 describes the introduction with the highlighted view of an objectives of the work which is be Carried out in this paper. Section 2 is based on Methodology of this paper also discussed the block diagram and describes the performance evaluation of system. Section 3 deals with the Experimental results and discussion. Section 4 deals with the conclusions

2. PROPOSED METHODOLOGY

The proposed work is focused on implementation of auto tuning of the process controllers using the traditional Ziegler Nichols (ZN) method, Tyres-Luyben (TL) Method and Damped Oscillation (DO) method. As per these methods the detailed steps for tuning of the controllers are explained below.

2.1 OBTAINING THE TRANSFER FUNCTION AND FINDING THE CRITICAL GAIN:

As we are taking the input as the DC motor we take the transfer function of the system and then find out the closed loop transfer function of the system.

The Transfer function of the DC motor taken is

TF=1/(1000s^3+300s^2+100s+1)

…2.1

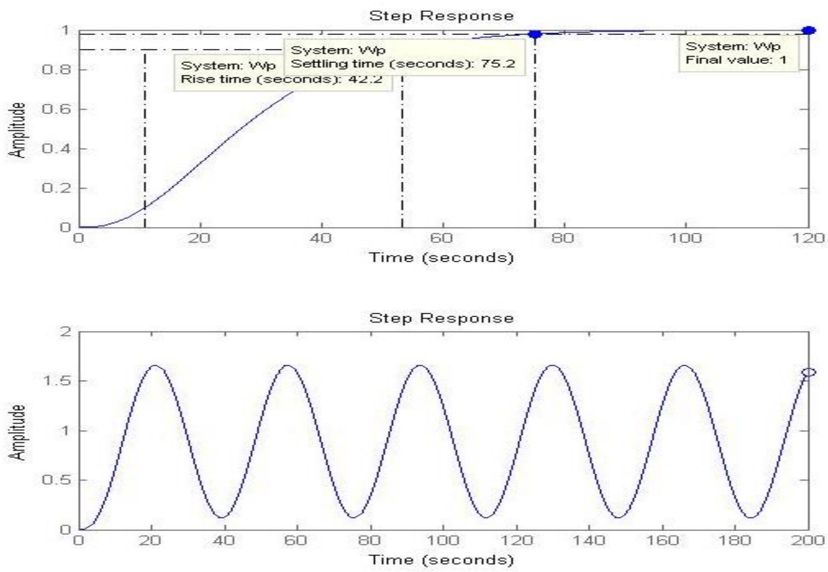

Fig.1 Input response of the transfer function of DC motor

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Then based on the determined transfer function we do bode analysis and plot the graph, from which we come to know about the gain margin, phase margin, gain crossover frequency and phase crossover frequency. Then finding the critical gain as we take into consideration that the gain margin got will be equal to the critical gain.

2.2. FINDING THE INDIVIDUAL GAINS AND TIME DELAY'S OF PROCESS CONTROLLERS:

Now as we already found the critical gain (Kc) and crossover frequency value (Pu) this helps us to find the individual gain of the process controllers. From the following table we find the individual gains

Table 1: Showing the individual gains for different tuning methgods.

Type Of tuning	Kp
ZN method	0.59*Kc
TL method	0.313*Kc
DO method	0.59*Kc

After finding the gains then we find the time delays of the process controllers by following table

Table 2: Showing the time delays of the process controllers.

Type of tuning	Ti(sec)	TD(sec)
ZN method	.5*Pu	0.12*Pu
TL method	2.2*Pu	0.16*Pu
DO method	Pu/6	Pu/1.5

2.3 FINAL IMPLEMENTATION OF THE PROCESS CONTROLLERS:

Now as we have already calculated the gains and the time delays, now it's time to implement the controllers. Based on the equations,

$$A(t) = Kp * e(t) + Ti \int e(t) + Td * \frac{d}{dt} e(t) \quad (2.3)$$

From the above mentioned equations the respective controllers are implemented and are auto tuned.

3. EXPERIMENTAL RESULTS

The results are tested for the transfer function found and the values got for the Individual gains and their time delays are as follows

Table3: Showing the obtained values for the individual gains and time delays of the process controllers.

Type Of tuning	Kp	Ti(sec)	TD(sec)
ZN method	4.7	18.2	4.4
TL method	2.504	79.90	5.812
DO method	4.74	6.05	24.213

Now based on the individual gains obtained the output for all three process controllers are as follows

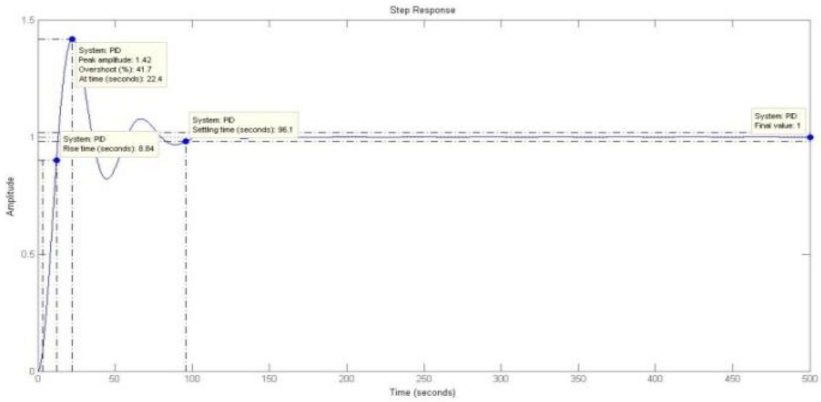

Fig.2 Output response of the Ziegler-Nichols tuning of PID controller.

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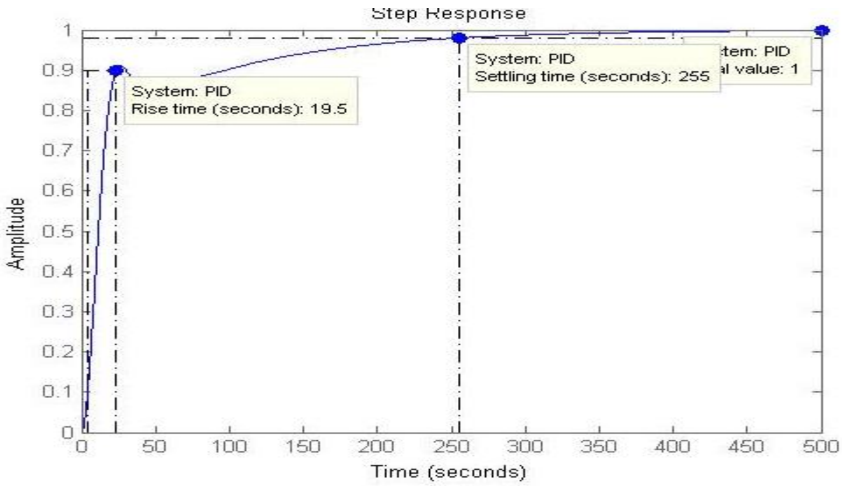

Fig.3 Output response of the Tyreus-Lybuen method tuning of PID controller.

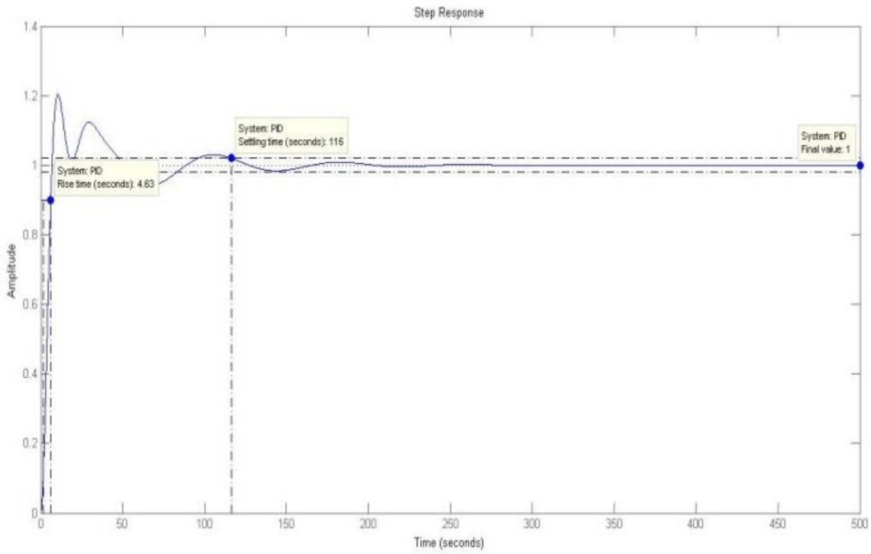

Fig.4 Output response of the Damped oscillation method tuning of PID controller

From the above figures of the output of all the process controllers the obtained values for the settling time ,rise time and the final value are mentioned in the below table

Table4: Showing the obtained values for the rise time, settling time and the final value of the various tuning methods of PID controllers.

Type Of tuning	Rise time(sec)	Settling time(sec)	Final value
ZN method	8.86	95.7	1
TL method	19.5	255	1
DO method	4.63	166	1

4. CONCLUSION

The proposed work consists of different options of controllers for the auto tuning of the process controllers. Summarizing we can say that the PID auto tuning process is one of the best method for the auto tuning of the controllers based on the comparison of the results obtained during the design process. As controlling the system is one of the biggest challenges in today’s scenario the proposed is one of the best solution for it.

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