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Tuning of PID Controller by Ziegler-Nichols Algorithm for Position Control of DC Motor

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Abstract
As the technology is growing the new applications are coming into existence, which needs both speed control as well as position control for better and efficient performance. We have many speed control techniques such as armature voltage control, field control etc. In addition to these control techniques for better performance of the systems we need to design an algorithm, which is helpful for DC position control. The advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity. For adjusting gain constants of PID (Proportional-Integral-Derivative) control with Ziegler-Nichols (ZN) based algorithm probably a stochastic method of approach of genetic algorithm was implemented which will give more optimal results when compared with the results obtained with untuned PID controller. This tuned PID controller is used for position control of DC motor for better performance. This work is carried through MATLAB/SIMULINK environment.
Keywords: DC motor, PID controller, Position control, stochastic methods, Ziegler-Nichols, Genetic algorithm.

1. Introduction

Now a days many applications find the usage of DC motors as it provides excellent speed control for both acceleration and deceleration with effective and simple torque control. They are portable and well suited to special applications, such as industrial tools and machinery that is not easily run from remote power places.

With the growing technology, the new applications find the use of both speed control as well as position control for better and efficient performance. In addition to the existing control techniques, we introduce a genetic algorithm, which helps in the position control of DC motor. For this we make use of control techniques such as controllers, feedback networks and compensation techniques. This will lead to automatic control of position of the DC motor without manual interference.

This paper presents the most common classical controller tuning method i.e. Ziegler-Nichols technique in short ZN which provides an effective starting point for controller tuning. Tuning rules work quite well when you have an analog controller, a system that is linear, monotonic, and sluggish, and a response that is dominated by a single-pole exponential "lag" or something that acts a lot like one. Using this algorithm to perform the tuning will result in the optimum controller.

2. Model of DC Motor with Position Control

We consider a DC shunt motor as shown in Fig. 1. DC motors have the field coil in parallel with the armature. The current in the field coil and the armature are independent of one another. This results in excellent speed and position control. Hence DC motors are typically used in applications that require five or more horsepower. The block diagram for position control is shown in Fig .2.

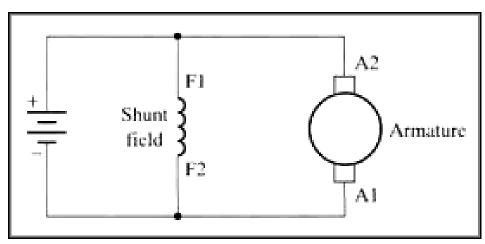

Fig 1. DC shunt motor

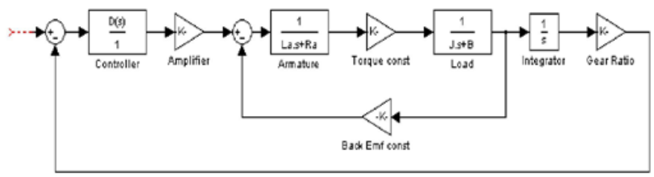

Fig 2. DC Position control system

Design of a control algorithm for a DC position control system to meet a set of requirements and to study the performance of the system under the various non-linearities and parameter variation is the present problem. The DC position control system to which controller is designed is shown below with all its parameters.

K_a (Amplifier gain) = 4.1545 V/V
R_a (Arm resistance) = 3.086 Ω
L_a (Arm inductance) = 0.01 H
K_t (Torque constant) = 0.0952 N-m/A
K_b (Back emf cont.) = 0.0952 V/ (rad/sec)
J_m (MI of motor) = 2.119e-5 Kg-m^2
B_m (friction coefficient) = 47.5e-5 N-m/ (rad/sec)
$B = B_m$ = 47.5e-5 N-m/ (rad/sec)
J_l (MI of load) =227.272e-5Kg-m^2
J (Eqt MI of motor and load) $=J_m+n^2 J_l$=4.1804e-5Kg-m^2
n (Gear ratio) = 1/10.5
K_s (Sensitivity of error detector) = 1V/rad.

Using the above parameters, simplifying by block reduction techniques and rounding off the constants whenever necessary for simplification gives following simplified diagram.

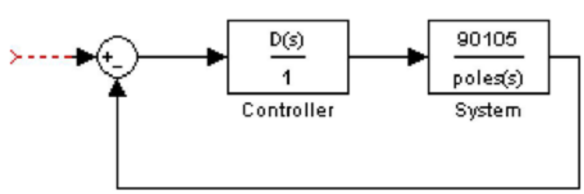

Fig .3. Simplified block diagram

Suppose that the load shaft in our application is subjected to extraneous torque due to environment conditions. This torque will displace the load shaft from its desired position. Therefore our K_V should be sufficiently high and let a peak overshoot of 20% is required then if we convert these specifications into frequency domain we have the following specifications.

$\Phi M > 45.59^0$

GM>12db

$M_r < 1.71$ db.

Along with these some practical constraints can be imposed, as output current of amplifier should be less than 5A.

3. PID controller and Ziegler-Nichols Method

The block diagram shown in Fig .4 illustrates a closed-loop system with a PID controller in the direct path, which is the usual connection. The system's output should follow as closely as possible the reference signal.

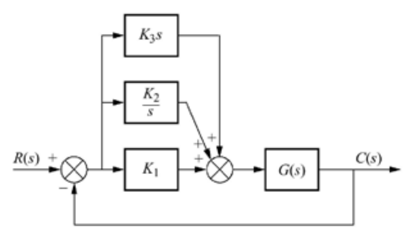

Fig .4 Block diagram of PID-controller

There are several methods fro tuning a PID loop. The most effective methods usually involve the development of some form of process model, then choosing P, I, and D based on dynamic model parameters. Manual tuning methods can be relatively insufficient, particularly if the loops have response times on the order of minutes or longer.

The best tuning method for the PID controller was given by Ziegler and Nichols, which was now accepted as standard technique in control systems practice. Both techniques make prior assumptions on the system model, but do not require that these models are specifically known. Ziegler-Nichols formulae for specifying the controllers are based on plant step responses.

PID controllers are probably the most commonly used controller structures in industry. They do, however, present some challenges to control and instrumentation engineers in the aspect of tuning of the gains required for stability and good transient performance. There are several perspective rules used in PID tuning. These rules are by and large based on certain assumed models. The Ziegler-Nichols algorithm used for providing tuning of a DC position control is shown in Fig .5.

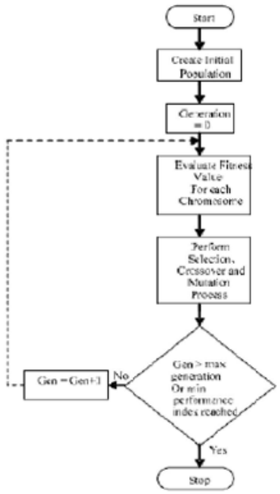

Fig .5 Genetic Algorithm

The method targets plants that can be rendered unstable under the proportional control. The technique is designed to result in a closed loop with 25% peak overshoot. This is rarely achieved as Ziegler and Nichols determined the adjustments based on a specific plant model. The steps for tuning a PID controller are as follows:

Using only proportional feedback control:

1. Reduce the integrator and derivative gains to 0.
2. Increase K_p from 0 to some critical value $K_p=K_{cr}$ at which oscillations occur. If it does not occur then other method has to be applied.
3. Note the value K_{cr} and the corresponding period of sustained oscillation, P_{cr}.

The controller gains are specified as follows

PID type	**K_p**	**$T_i=K_p/K_i$**	**$T_d=K_d/K_p$**
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$P_{cr}/1.2$	0
PID	$0.6K_{cr}$	$P_{cr}/2$	$P_{cr}/2$

4. Results and Discussion

By executing the matlab program with tuned controller parameters we obtain a step response shown in Fig .6, which has a settling time of roughly 40ms, which is less than 16% overshoot and it has no steady-state error. So now we know that if we use a PID controller with

K_p=17,
K_i=600,
K_d=0.15,

All our design requirements will be satisfied.

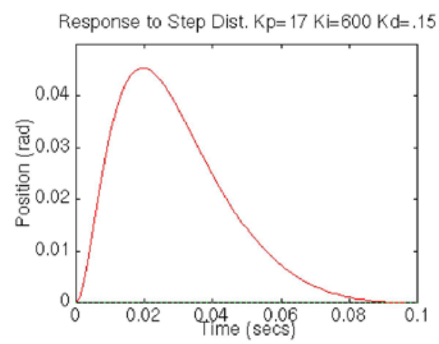

Fig .6 Step Response

The simulations are run with different non-linearities and gain parameters are known. Using these parameters a matlab code is designed to implement Nichols method and the results are obtained as following.

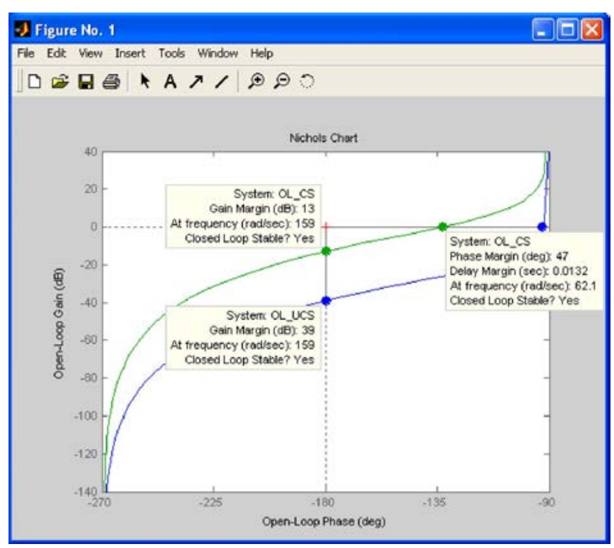

Fig .7 Nichols chart for open-loop system with controller

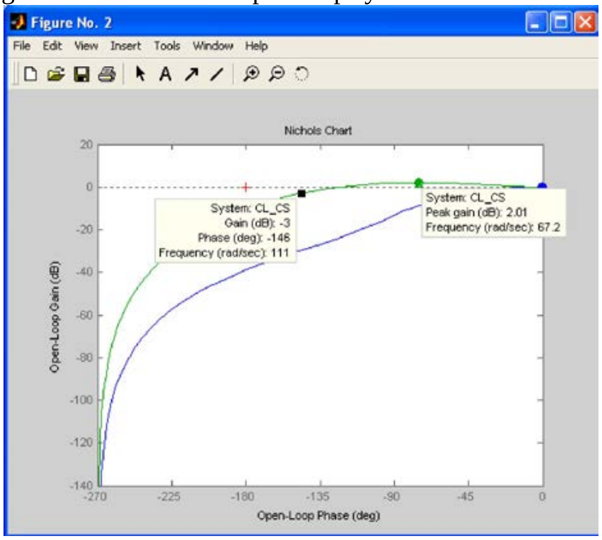

Fig .8 Nichols chart for closed-loop system with controller

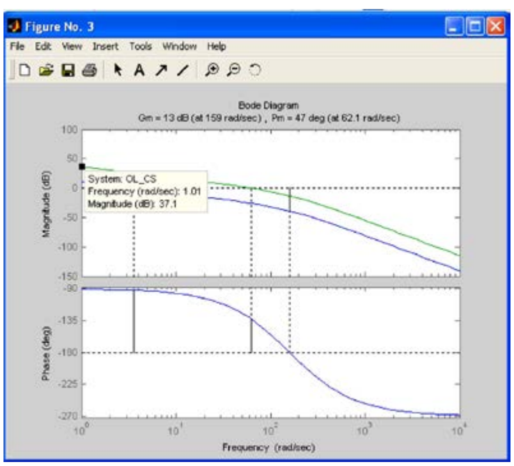

Fig .9 Bode plot for Open-loop system with controller

So our controller is satisfying all the requirements. Here we are meeting all the through some cost we are paying in the form of speed of the response. Now if we have a lead compensator, we can speed-up the system but it has adverse effect on the current output of the amplifier.

4. Conclusions

In this paper PID controller is tuned using Ziegler and Nichols technique to control the position of dc motor. Our aim is to increase the dynamic performance of the system output like settling time, rise time and maximum overshoot. This technique helped in the case of lag compensator but a Genetic algorithm would increase the accuracy and solve the problem. Genetic algorithm system has good steady state responses and performance indices.

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