Comparative Analysis of P, PI and PID Controllers for Speed Control of PMBLDC Motor using MATLAB/SIMULINK

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Abstract- This paper is on comparative analysis of proportional (P), proportional-plus-integral (PI), proportional-integral-derivative (PID) controller. This is done by considering the example of permanent magnet brushless d.c motor (PMBLDC). These Controller are subjected to the forward path of PMBLDC drive to get the desired performance of the parameters of its speed response. Performance parameters are rise time, peak overshoot, steady state error e.t.c. A good controller should have reduced overshoot, less steady state error and less rise time. The output response should be as approximate as the input. Here MATLAB/SIMULINK is used to model the motor and implementation of controllers.

Keywords- Permanent Brushless DC Motor (PMBLDC), P controller, PI controller, PID Controller.

1. INTRODUCTION

PMBLDC motor is one of the type of motor which is constructionally similar to a.c synchronous motor and its characteristics are similar to ordinary d.c motor. PMBLDC motor is getting popular in recent year because of its high efficiency, high starting torque, and smooth operation and less maintenance. This motor has wide application in industries, instrumentation, aerospace, and robotics. Ordinary dace motor has commutation through brushes which is inefficient but in PMBLDC motor electronic commutation takes place with the help of VSI inverter which is very efficient.

PID Controller is used in different process industries in order to get desire response. It is a block in control system which takes error signal as input and gives an output which affects the dynamics of the system. This output is an actuating signal to system which reduces the difference between the desire response and actual response.

PID controller in initial days are pneumatic controllers, even though all the experimentation by Zigler and Nichols were carried out with pneumatic controllers, these controller are slow therefore after the advent of electronics devices and operational amplifiers digital PID controllers came into importance. In digital PID controller the controller parameter can easily adjusted, as a result they can be change without removing any hardware.

In this paper digital PID controller is used, MATLAB has a block name PID in simulink which we have used. By just double clicking on this block we get a window having parameters of PID, by adjusting these parameters PID is converted to P PI and PID controller. These P PI PID controllers are then simultaneously placed in forward path of PMBLDC model and different speed response curves are than compared.

1. PMBLDC MOTOR MATHEMATICAL MODEL

As the name PMBLDC shows that this motor having the advantages of D.C motor but the demerits like brush is eliminated , it has three phase stator winding and permanent magnet rotor . The stator is energized in sequence for the motor to rotate. To get correct sequence hall sensors are used, they sense the rotor position and give accordingly output. In this paper permanent magnet synchronous machine block of simulink is used to implement the PMBLDC model. Parameter of PMBLDC motor used in this paper is as follow:

Stator phase resistance (R): 2.8750 ohm
Stator phase inductance (L): 8.5 mH
Flux linkage established by rotor magnet: 0.175 V.S
Voltage constant: 146.607(v/ rpm)
Torque constant: 1.4(Nm/amp)
Pole pair: 4
Nominal torque: 3 Nm

Fig:1 Three phase bridge inverter network for PMBLDC

Above fig:1 shows the equivalent circuit of three phase full-bridge power network for PMBLDC Motor drive. The characteristics equation of a PMBLDC motor is given below:

\[ V_a = R_i(t) + E_a + L \frac{di_a(t)}{dt} \]  \hspace{1cm} (1)  
\[ V_b = R_i(t) + E_b + L \frac{di_b(t)}{dt} \]  \hspace{1cm} (2)  
\[ V_c = R_i(t) + E_c + L \frac{di_c(t)}{dt} \]  \hspace{1cm} (3)  

Where  
\( L \) - armature inductance(H)  
\( R \) - armature resistance(OHM)  
\( V_a, V_b, V_c \) - stator phase voltages (V)  
\( i_a, i_b, i_c \) - stator phase currents (A)  
\( E_a, E_b, E_c \) - motor back emf (V)  

Back emf of motor in each phase is 120degrees electrical shifted from each other and back emf is a function of rotor position and speed. Equation of each phase emf is given below:-

\[ E_a = K_w f(\theta_e)w \]  \hspace{1cm} (4)  
\[ E_b = K_w f(\theta_e - 2\pi/3)w \]  \hspace{1cm} (5)  
\[ E_c = K_w f(\theta_e + 2\pi/3)w \]  \hspace{1cm} (6)  

Where  
\( K_w \) – back emf constant per phase  
\( \theta_e \) – rotor angular position in electrical Degree  
\( W \) – rotor speed  

Relation between mechanical and electrical degree  
\[ \theta_m = \frac{2}{P} \theta_e \]  \hspace{1cm} (7)  

Where  
\( P \) – no. of pole  
\( T_e = \frac{(E_a i_a + E_b i_b + E_c i_c)}{w} \) \hspace{1cm} (8)  
\( T_e - T_i = Jw/dt + Bw \) \hspace{1cm} (9)  

Where
\( T_e \) – total electromagnetic torque (Nm)
\( T_l \) – load torque (Nm)
\( J \) – inertia of the rotor shaft (Kgm\(^2\))
\( B \) – friction constant (Nms. Rads\(^{-1}\))

\[
M(s)=K_p E(s)                        \quad (10)
\]

Where

\( M(s) \) - actuating signal
\( E(s) \) - error signal
\( K_p \) - proportional gain constant

The demerits of P-controller is that it exhibits a permanent residual error known as offset error. A high value of \( K_p \) reduces error but it effect stability

**3.2 PI controller:**

The control action of PI controller is defined by
\[
M(s)= (K_p + K_i/s). E(s) \quad (11)
\]

Where

\( K_i \) - integral constant
This controller has advantages of both P and I controllers, it increases speed of response and reduces offset error created by P controller, as this controller is increasing the order of the system so when it connected to higher order system it create stability problems. The block diagram of PI controller is shown above.

3.3 PID controller:
The control action of PID controller is defined by the below equation.

\[ M(s) = (K_p + K_i/s + sK_d). E(s) \]  

The block diagram of PID controller is shown below.

where

\[ K_d \text{= derivative constant} \]

PID controllers are most widely used in industries because of the reduced number of tuning parameters and these parameters can easily change without changing any hardware.

3. SIMULATION MODEL AND RESULTS

Simulation parameter-
Integrator type: Runge-Kutta, ode4
Sample time: 5e-6 (set automatically by model)
Stop time: 0.2 sec
Fig: 6 speed response of motor without PID

Fig: 7 speed response of motor with P controller

Fig: 8 speed response of motor with PI controller
4. RESULT

<table>
<thead>
<tr>
<th>parameters</th>
<th>P controller</th>
<th>PI controller</th>
<th>PID controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise time</td>
<td>Increases</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Peak overshoot</td>
<td>Decreases</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Steady state error</td>
<td>Increases</td>
<td>Decreases</td>
<td>Decreases</td>
</tr>
<tr>
<td>stability</td>
<td>Worse</td>
<td>Worse</td>
<td>Better(if K_d is small)</td>
</tr>
</tbody>
</table>

5. CONCLUSION

Performance of three phase PMBLDC drive system using without PID, P, PI and PID controllers are evaluated. It is shown through broad simulations that the performance of PID controller is better than P and PI. The performance of motor drive can be enhanced by using optimal parameters of controller through different techniques.

REFERENCES


