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PERFORMANCE ANALYSIS OF BLDC MOTOR SPEED CONTROL USING PI CONTROLLER

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ABSTRACT

Many industrial applications uses brushless dc motor because of its high speed range, high torqueand higherefficiency. Speed control of BLDC motor is the fundamental approach for manyapplications. This paper presents modeling and simulation of speed control of BLDC motor by PI controlling technique. Speed control of BLDC motor is done by designing a closed loop feedback control system using PI controller technique.The proposed approach is seen to be more advantageous as it has easy implementation, stable convergence characteristics and good computational efficiency.

Keywords: BLDC motor, modeling and simulation, PI controller.

I. INTRODUCTION

Increase in energy prices has demanded for variable speed permanent magnet motor drives[1]. BLDC motor is nothing but a permanent magnet dc synchronous motor.Adjustable Speed Drives are used in many application in which there is mechanical equipment powered by motors; the drives provide extremely precise electrical motor control, doing so utilizes only the energy required, rather than having a motor run at constant (fixed) speed and utilizing an excess of energy. Since motors consume a majority of the energy produced, the control of motors, based on demands of loads, increases in importance, as energy supplies become ever more strained.

Brushless DC motor is an electronically commutated motor. Brushed DC motor develops a maximum torque when stationary, linearly decreasing as velocity increases. Also for the BLDC motor a linear relationship is observed between current and torque, voltage and speed.

Some limitations of brushed DC motor is overcome by brushless DC motor, as they include higher efficiency and lower susceptibility to mechanical wear, high torque to weight ratio, more torque to wattratio (i.e. increased efficiency), increased reliability, reduced noise, longer lifetime(no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference.

Also BLDC motors find applications in every segment of the market such as industrial control, automations, aviation and so on. Applications demand high-speed control accuracy and good dynamic responses. From the control point of view PI controller offers the simplest and yet most efficient solution to many real-world control problems [2]. PIcontroller possesses the simple structure and robust performance in a wide range of operating conditions [3]. With the help of PI controlling parameters the speed and armature current of BLDC motor is controlled and regulated.

This paper discusses about modeling and speed control techniques of BLDC motor using PI controller. The performance of speed control of BLDC motor is verified through simulation analysis on MATLAB Simulink platform. Section I and II discusses about introduction and modeling of BLDC motor respectively. The speed control technique and and simulation analysis is discussed in section III and IV respectively

II. MATHEMATICAL MODELLING OF BLDC MOTOR

The standard wound dc synchronous motor and BLDC motor are very similar accept that for BLDC motor excitation is provided by the permanent magnet and not by the field winding. Rotor is made up of permanent magnets. The BLDC motor modeling is done based on its dynamic equations[3]. The physical parameters of our system are:-

- Motor inertia of the rotor.
- Motor viscous friction constant
- Electromotive force constant
- Motor torque constant
- Armature resistant
- Armature inductance

Characteristics equations for BLDC motor are given as follows:

$T = Kt\, \Phi\, Ia$(1)

Where torque is proportional to the armature current of the motor,

The back emfEb is directly proportional to the speed of the motor, given as-

$Eb = Kb\, \Phi\, \omega$ (2)

$T = \frac{Jdw}{dt} + B\,\omega$(3)

$V = \frac{LdIa}{dt} + IaRa + Eb$ (4)

Where the parameters of the bldc motor modeling equations are.

V = Terminal voltage in volts,

Ia = Armature current in amp,

L = Armature inductance in hennery,

Eb = Back emf of motor in volt,

Ra = Armature resistance in ohms,

$\frac{dIa}{dt}$ = Rate of change of armature current in amp/sec,

ω = Speed of motor in rad/sec,

T = Motor torque in Nm,

Kt = Torque constant,

For speed control of bldc motor armature current controlling is required. Current control loop is thus shown in the

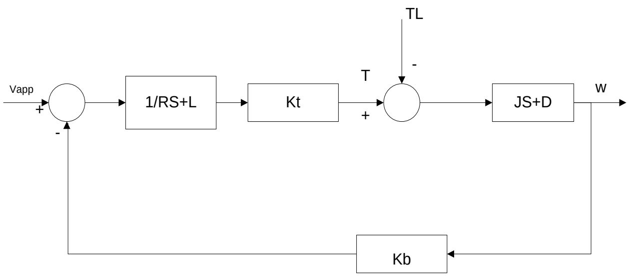

Fig 1.BLDC Motor Block Diagram

The transfer function for BLDC motor speed control model is given as:

$$\frac{\omega(s)}{Vapp(s)} = \frac{Kt}{L.J.S^2+(L.D+R.J)\,S+Kt.Kb} \quad (5)$$

The simulation model Parameter values are given in table 1:

Parameters	Values and units
R	1.69 ohms
L	6.6 micro henry
J	0.4 Kg sq.mt/ rad
Kb	23.489
Kt	1.10285

Table 1: Parameters of the Motor Simulation Model

III. IMPLEMENTATION OF PI CONTROLLERS

PI controller is the most widely used in closed-loop control system. It works on the error generated from the difference between the reference speed and the actual speed. PI parameters Proportional gain Kp, Integral Gain Ki affects system's overall performance. Thus we are needed to select the proper gain parameters. Selecting the proper gain parameters is termed as tuning of PI parameters. Tunning of PI parameters is a difficult task. These tuning of PI parameters is been done by manual tuning, Ziegler-Nicholas tuning and Cohen-coon tuning. Recently several optimizing techniques are also developed for PI parameters tuning process.

Following are the effects of the PID parameters:

1) System rise time will be reduced by Kp, it provides faster response in variable load condition.

2) Steady state error will be reduced by Ki, hence the motor speed is pushed near to the reference speed.

3) Settling time and overshoot will be reduced by Kd, hence provides faster response.

PID controller works on the following equation:

$$U(t) = Kp\; e(t) + Ki \int e(t)dt + Kd\frac{de(t)}{dt}$$

IV. IMPLEMENTATION OF BLDC-PI CONTROLLER

In this paper manual tuning method for PI controlling parameters is applied. The armature current regulation is done by PI controller technique. Armature current is directly proportional to the torque of motor. Thus armature current is closely regulated by the torque. TheKp and Ki values for current controlling of BLDC motor is set from the motor variable parameters as armature current, armature resistance, armature inductance.

The suitable Kp and Ki values for the speed control of bldc motor obtained by manual technique are-

Kp = 0.00449

Ki = 1.14975

V. SIMULATION

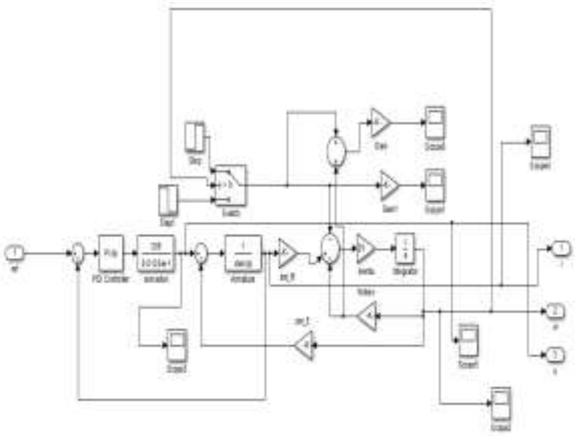

Fig 2.BLDC Motor Current Controlling Block Diagram

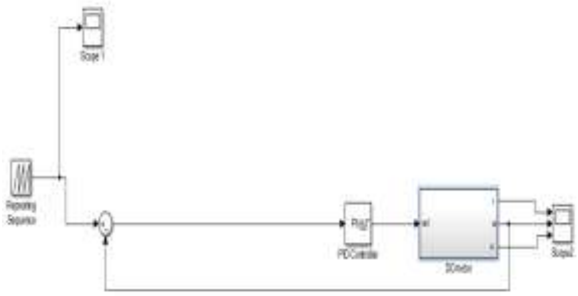

Fig 3.Speed Control Simulation Block For BLDC Motor

VI. SIMULATION RESULTS

The reference speed signal given as follows:

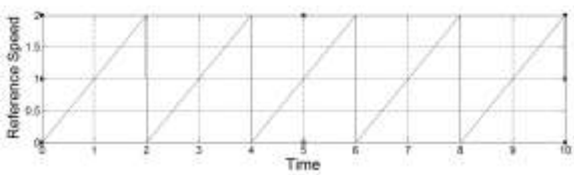

Fig 4: Reference Speed Signal

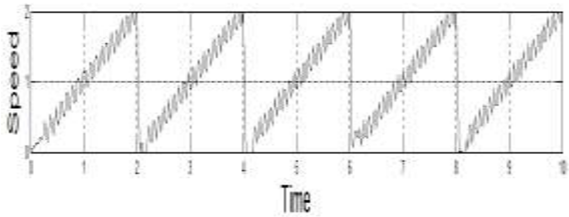

Fig 6: Output Speed Signal

VII. CONCLUSION

In this paper speed controlling technique of BLDC motor by PID controlling parameters is presented. Obtained through simulation of BLDC motor, the results show that the proposed controllercan perform an efficient search for the PID controller.

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