BioGecko

Vol 12 Issue 02 2023

ISSN NO: 2230-5807

Controller Modeling and Development for Bldc Motor with Load Response

Shahuraj S. Sable[1], Dr.Ashok kumar Jhala[2]

[1]Research Scholar, Electrical Dept., BHABHA University, BHOPAL, MP, India.
[2]Associate Professor, Electrical Dept., BHABHA University, BHOPAL, MP, India.

Email: [1]Shahurajs@gmail.com, [2]akjhala.35@gmail.com

Abstract

Now because with their simplicity, viability, and high power density, Brush Less DC {BLDC} motor drive system are widely employed in industrial operation purpose. In many position control plants, DC motors predominate, although they require routine brush &commutator maintenance. As a result, BLDC motors are exploited because of their electronic commutation. Sensorless speed controls are two alternative methods used to control the BLDC motor speed. For BLDC motor speed control, many controllers are employed. The most industrial popular controllers are PID and PI. The electrical feature modeling of BLDC motors will be included in this research. This paper shows a MATLAB design for BLDC motor speed Supervise with a simple hand-tuning procedure approach used with thecontroller for tuning.

Keywords:PID / Pi, Bldcm, Commutation, sensorless.

1. Introduction

A BLDC motor was conceived in 1962 to avoid the upkeep of brushes plus commutation of DC motors. BLDC motors are comparable to PMSM motors in terms of construction and hold common DC motor electrical properties. Hall Effect sensors are used by BLDC motors to detect the rotor angle and excite the relevant phase windings. A BLDC motor's stator is powered by an inverter and has three phase windings coiled around it. For the construction of the rotor, materials like alnico, neodymium, magnetite, etc. are employed as permanent magnets. The electrical commutation gives the BLDC motor increased reliability. On the stator, three Hall impact sensors are positioned 120 degrees apart from one another. To achieve continuous operation, the spinning magnet position is detected by hall sensors, which then transmit a feedback signal to the voltage source converter (VSI) to activate the appropriate phase windings. In fact, a range of sensor-based methodologies are used to measure a BLDC motor's speed response. The inverter circuit is driven by a voltage source with controlled output. The inverter that converts voltage sources rotates through 120 degrees [1]. The inverter runs for six cycles. Only the two-phase windings are ever excited, with the rest being unexcited. Short circuit safety is provided by 120° commutation because it doesn't require any additional phase lag. A trapezoidal Wave shape [backemf]& concentrated phase winding of the BLDC motor set it apart from the PMSM motor. It is presented how to simulate a BLDCdrive with back emf sensing mathematically and using Mat lab code [2]. This work illustrates the simple mathematical model & transfer function analysis of BLDC motors. Using a PID/PI controller throughout a variety of load torque variations is the easiest way to supervise speedof BL drive [3][4].

2. MathematicalModeling

The dynamic equivalent networks of {BLDC} Drive appear in the diagram for model input parameter analysis. Now equation for the stator phase input voltage in the motor's stator reference frame is given as follows:

a) The three phases of the motor are symmetric in terms of resistance, inductance, and mutual inductance. They are all constant as well.
b) Due to the non-salient rotor, the rotor reluctance does not alter with angle.
c) Each magnet and accompanying stator winding are perfectly aligned.
d) Since boath magnets and stainless steel have a high resistance, current produced in the rotor was

overlooked.

e) Switches made of semiconductors are perfect.

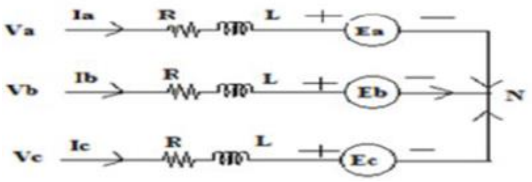


Fig 1: dynamic equivalent networks of a {BLDC} Drive system.

As per above assumption {a} mutual inductance neglected also $l_a=l_b=l_c=l$ this are equal.
The following equation can be used to represent a three-phase BLDC motor:

$v_a= r\, i_a+l\, \{ di_a/ dt \} + e_a$ ……………………………………………………1

$v_b= r\, i_b+l\, \{ di_b / dt\} + e_b$ ……………………………………………………2

$v_c= r\, i_c+l\, \{di_c/ dt\}+ e_c$ ……………………………………………………3

The majority of applications for the motor employ a star connecting without neutral phases, phase voltage is so challenging to determine. Because of this, analysis of line voltage is more practical in Simulink model designs [2]. Even as line voltages are equivalent to the source voltage, the following line voltage equations

$V_{ab}= r\, [i_a- i_b] + l\, [d\, \{i_a- i_b\} / dt]+ [e_a- e_b]$……………………………4

$V_{bc}= r\, [i_b- i_c]+l\, [d\, \{i_b- i_c\} / dt]+ [e_b-e_c]$……………………………5

$V_{ca}= r\, [i_c- i_a]+l\, [d\, \{i_c- i_a\} / dt]+ [e_c-e_a]$……………………………6

The following modified equations are used to remove design problems from the modal by applying the voltage value for current generations v_{ab} and v_{bc} by replacing value of $i_c= -\{i_a+ i_b\}$with equations 4 and 5.

$V_{ab}= r\, [i_a- i_b] + l\, [d\, \{ i_a- i_b\} / dt] + e_a- e_b$ ……………………………7.

$V_{bc}= r\, [i_a- 2i_b]+l[d\, \{i_a- 2i_b\} /dt] + e_b- e_c$ ……………………………8

Trapezoidal Wave shape [back emf] is produced by the way the windings are spread. The PMBLDC motor's operating principle is to electrify the phase pairings which generate constant torque. To create the constant torque, three phase input currents are adjusted to adopt synchronies with trapezoidal back EMF. The back EMF has amplitude that depends on the rotor position.

$E = K_e * d[\theta] / dt$

$E=k_e*\omega$……………………………………………………………11

[K_e - [back emf] constant, where, "ω" - rotor mechanical speed].

In BLDC, instantaneous {back EMF} is expressed as seen in the equation above.

$E_a= f_a[\theta]k_a*\omega$……………………………………………………12

$E_b= f_b[\theta]\, k_b*\omega$……………………………………………………13

$E_c= f_c[\theta]k_c*\omega$……………………………………………………14

"f[θ]" is the rotor electrical position.

A BLDC motor's trapezoidal back-EMF waveform can be written as a unit function in six different ways:

$(\theta)=10<\theta<60^0$ **Mode1**

(θ)=160^o<θ<120^0 **Mode2**

(θ)=−6$^{\theta}$ –

π

120^0<θ<180^0 **Mode3**

(θ)=−1180^0<θ<240^0 **Mode4**

(θ)=−1240^o<θ<300^0 **Mode5**

$f(\theta)$

= 6$^{\theta}$ –

π

300^0

<θ<360^{0}thisis Mode 6

The numerical formulation of back EMF can calculate based from rotor orientation. As a result, the identical 3 back EMF pulses can be produced at any operating speed using speed command with rotor position. Electrical power and rotating speed both affect the electrical torque, T_e. If equation $P_e= e_a i_a+ e_b i_b+ e_c i_c$ is used to replace the electrical power and equations are used to replace the back EMFs, we gate equation torque.

Where T_e-T_l : Mechanical torque transferred to the motor shaft .

$T_e - T_l - K_f\, \omega_m = j\,[\,d\,[\omega_m] / dt]$ 21

Hence speed of the motor is found with the help of above equitation simplifying it.

As $\theta_m= \omega_m$ .The relationship between $\theta_m$and $\omega_m$are as follows: $\theta_m= [P/2]\ \omega_m$

3. Controller

In a factory, a controller has been employed to improve a control system's usual performance. Several types of conventional and non-conventional controllers are used for a variety of applications, such as control of temperature, charge control, etc.

The PI regulating parameters in this model are manually adjusted. The technique of PI controllers is used to control the armature current. Armature current and motor torques are directly correlated. As a result, torque has a big impact on armature current control. The major reason why feedback process is extremely significant task in these systems that is capable of reaching a set-value regardless with disturbances or any deviation in features at any form is because adequate Kp and Ki settings for the speed regulation of bldcm were achieved with manual technique.

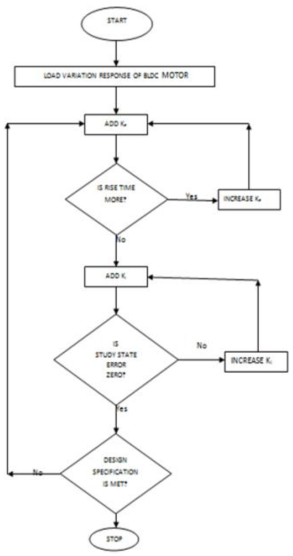


Fig 2: Simple hand-tuning procedure is as follows

Two distinct modes, namely proportional &integral, are used in PI controller computation. Integral approach predicts the response onthe basisof recent error, while proportional mode predicts the response based on the current error. The control element receives a correction from the adjusted total of both modes. Due to its easy design and straightforward structure, a PI controller is frequently utilized in industry. Implementing the PI controller strategy can be done as

$C [s] = K_p[e \{t\}] + K_i / s [e \{t\}]$

4. Matlab/Simulink Model

EstimatedSimulink model of Permanent Magnet BL drive and its speed and position control with PI controller and PWM. With adjusting following values at which the approximate speed is obtained at Kp= 1 and Ki = 1.5.

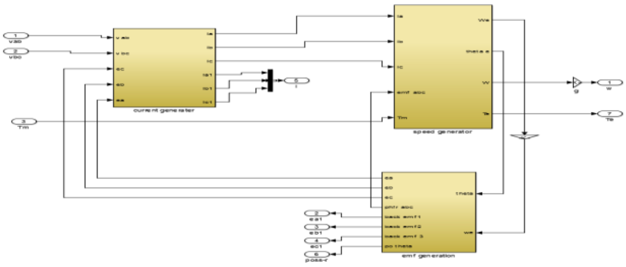


Fig 3:BLDCMSimulinkmodel

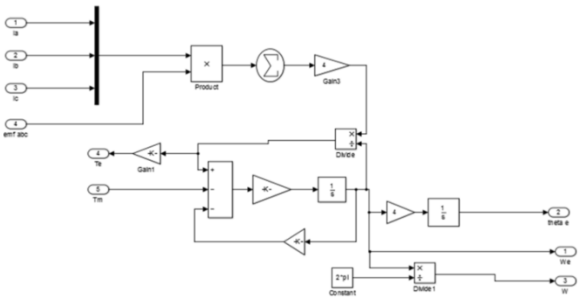
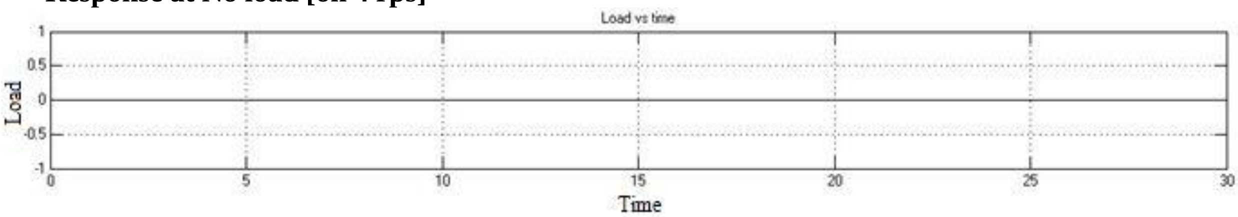


Fig 4: Speed Generation Block of BLDC motor

5. Results and Analysis

When a quick rise in loading or even a drastic drop in rotor velocity is desired, the simulation is performed for a predetermined period of time. This PI control method offers better adaptability as well as faster tracking solution for speed regulation. The current controller directs the current to follow the reference. The electromagnetic thus adheres to the reference value. When in use, the PI control signal follows the reference speed. Fig. displays the simulation results illustrating the operation of the PI guided drive system. Fig. displays the drive system's electromagnetic torque and speed inaccuracy. The drive appears to attain the desired speed in the shortest amount of time.

- **Response at No load [on 4 rps]**



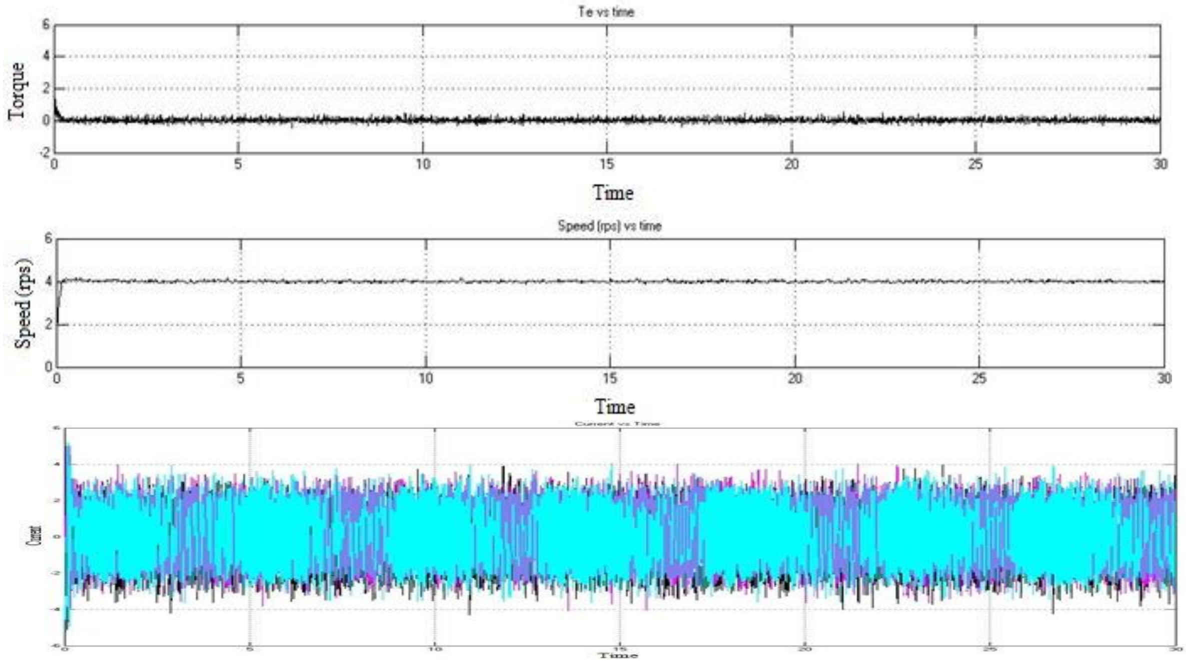


Fig 5: Response at No load [load, electro.mec.torque& speed VS time, current VS time]

- **Response at load and sudden variation on load [0.1,-0.15, 0.2,-0.1, 0.15 sec.]**

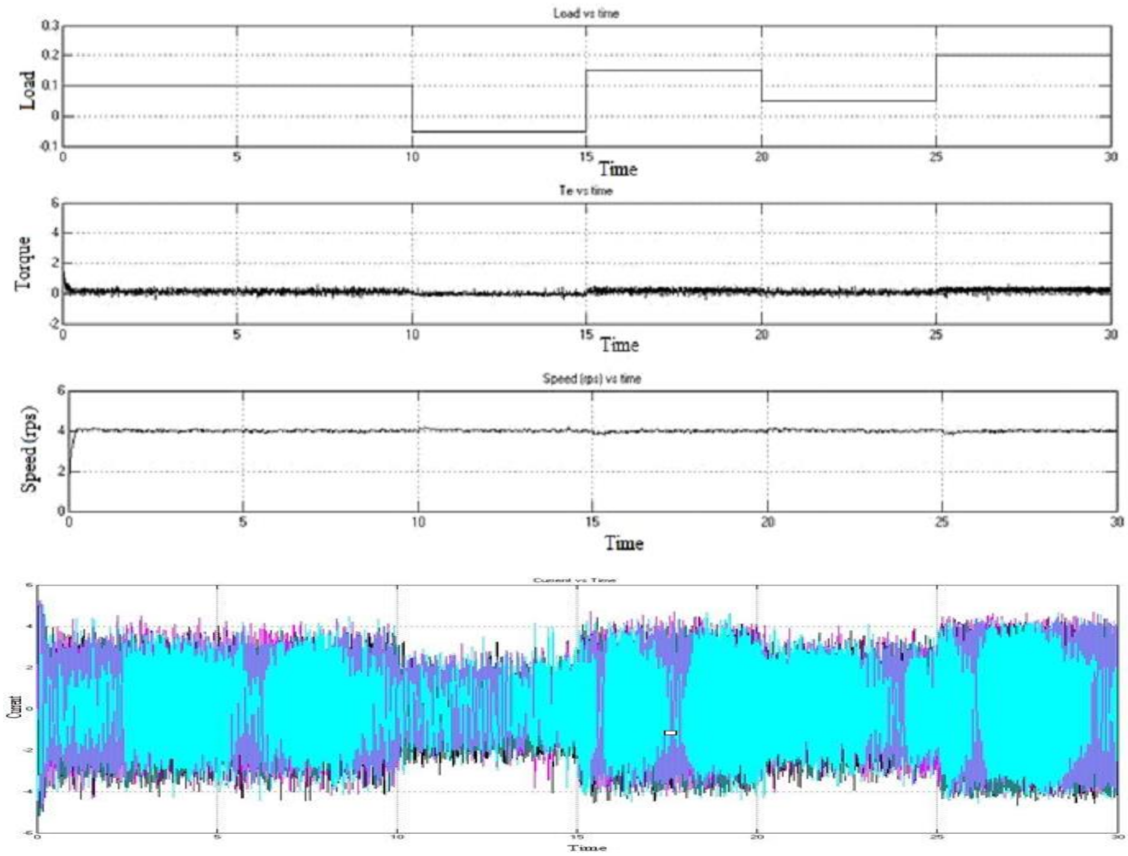


Fig 6: BLDC motor at sudden load varies [load, electro.mec.torque& speed **VS** time, current **VS** time]

ThesettlingtimeforBLDCmodelwithoutcontrolleris0.15secwhereassettlingtimewithPI controller is 0.125 sec. The peak time is also less in case of BLDC Model with PIcontroller which is 0.045 sec whereas the peak time for BLDC model without controller isaround0.1 sec.

6. Conclusions

All of the simulation's conclusions include a theoretical component and can be applied practically. The PMBLDC motor's speed has been controlled with the use of a PI controller, which exhibits excellent control performance and supremacy under disturbances. The motor could operate with no errors and at the correct rate and location as soon as possible.

Future Scope

Speed Control of BLDC motor using fuzzy logic controller, using neural network can be implemented to check the performance of brushless dc motor
Implementation of real time hardware for motor position control is possible.

7. References

1. Jiaxin Chen, "Performance Analysis of a Surface Mounted Permanent Magnet Brushless DC Motor using an Improved Phase Variable Model", China 0197-2618/2007 IEEE
2. Duane C. Hanselman, "Brushless Permanent Magnet Motor Design" Second Edition [Bookos.org], University of Maine, Orono, ME 04469
3. Pramod Pal, Dr. Amit Ojha, "Simulation of Brushless DC Motor for Performance Analysis using matlab/simulink Environment" ISSN: 2321-8169 Volume: 2 Issue: 61564 – 1567
4. HemchandImmaneni "Mathematical Modeling and Position Control of Brushless Dc [Bldc] Motor" [IJERA] pp.1050-1057, Vol. 3, Issue 3
5. E. Kaliappan, C. Chellamuthu "Modeling, simulation and experimental analysis of permanent magnet brushless DC motors forsensor less operation" pp. 499-515 [2012]
6. Atef Saleh Othman Al-Mashakbeh, "Proportional Integral and Derivative Control of Brushless DC Motor", European Journal of Scientific Research, 2009
7. G.Prasad, N SreeRamya, P V.N Prasad, G.Tulasi Ram Das, "Modelling and Simulation Analysis of the Brushless DC Motor by using MATLAB", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-I, Issue-5, October 2012, pp.2l20-2025.
8. Mr.P.Nagasekhar Reddy, "Modelling and Analysis of PI Controller Based Speed Control of Brushless DC Motor Drive", International Journal of Engineering Sciences & Research Technology, September, 2013, pp.2226-2231