

# Design of a Closed Loop Speed Control for BLDC Motor

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**ABSTRACT:** The present work deals with speed control of BLDC motor in which an Inverter is controlled using PWM techniques and checked the performance of sinusoidal PWM and Space Vector PWM schemes and simulated to produce the desired dynamic and static speed-torque characteristics. The speed can be controlled in a closed loop by measuring the actual speed of the motor. The error in the set speed and actual speed is calculated. A Proportional plus Integral plus derivative (P.I.D) controller can be used to amplify the speed error and dynamically adjust the PWM duty cycle. The developed speed control scheme is verified through Matlab/simulink

**KEYWORDS:** Speed controller, feedback loop, Brushless dc (BLDC) motor drive, SPWM, SVPWM, Hysteresis current control

## I. INTRODUCTION

The construction of BLDC appears like inside –out Permanent Magnet DC motor (PMDC) .In a PMDC motor the stator is a permanent magnet and the rotor has the windings, which are excited with a dc current. The current in the rotor winding is reversed to create a rotating or moving electric field by means of a mechanical commutator and brushes. On the other hand, in a BLDC motor the three phase windings are on the stator and the rotor is a permanent magnet. Hence it is inside-out PMDC motor.

The Brushless DC motor (BLDC motor) drive is a combination of an ac machine, a solid state inverter, and electronic control circuitry and rotor position sensors. The speed –torque characteristics of this drive is drooping nature just similar to a conventional dc motor.

The PMSM has a sinusoidal back-EMF and requires sinusoidal stator currents to produce constant torque while the BDCM has a trapezoidal back-EMF and requires rectangular stator currents to produce constant torque. There is a slight variation among the modeling of PMSM and BLDC motors. The PMSM is very similar to the standard wound rotor synchronous machine except that it has no damper windings and field excitation is no required as they are permanent magnets. Hence the d-q model of the PMSM can be derived from the well-known [4] model of the synchronous machine with the equations of the damper windings and field current dynamics removed and it is well known that the transformation will make.

In the present paper implemented the state space model of BLDC motor in a-b-c reference frame and performed detailed examination of torque behavior and speed control. Firstly the modeling is done by developing suitable blocks in MATLAB/Simulink and various blocks like torque, rotor position, speed, trapezoidal induced back EMF, phase currents, phase voltages are obtained.

The Speed control of BLDC motor is carried out in a closed loop by measuring the actual speed of the motor. The error in the set speed and actual speed is calculated. A Proportional plus Integral plus derivative (P.I.D) controller can be used to amplify the speed error and dynamically adjust the PWM duty cycle.

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## II. PRINCIPLE OF OPERATION

To understand the operation of BLDC motor, consider a three-phase BLDC motor with only three coils. To make the motor to rotate the coils are excited (or energized) in a predetermined sequence to get uniform torque. The direction of current in stator coils determines the orientation of magnetic field and based on current direction, the magnetic field attracts and rejects the permanent magnets of rotor. The method of reversing current flow in stator coils and thereby the magnetic field at right point of time and in right sequence to rotate the rotor is known as commutation. In three-phase BLDC motor, there are six commutation states and they have been repeated in a sequence for every mechanical rotation of rotor. One sequence (i.e. six states) for every electrical cycle of rotation. A four-pole BLDC motor consisting two electrical cycles of rotation [1]-[3].

The inverter, rotor position sensors and electronic control circuitry imitates the commutation in a conventional dc motor therefore; this method of commutation is called as electronic commutation

## III. MODELING OF BLDC MOTOR

The BLDC motor has been modeled using stator phase currents, phase voltages, speed, and rotor position as state variables of drive system. The following model of BLDC motor is based on a few assumptions, such as iron and stray losses are neglected and induced currents in the rotor due to stator harmonic fields are being neglected.

First model equation from Phase-A of stator winding is

$$\frac{di_a}{dt} = \frac{1}{L-M} [v_a - R_s i_a - k_p \omega_m e_a(\theta_r)]$$

In the above equation L, M are self inductance and mutual inductance of stator winding respectively. Where  $R_s$  is stator resistance per phase. Similarly for Phase –B and C are as below

$$\frac{di_b}{dt} = \frac{1}{L-M} [v_b - R_s i_b - k_p \omega_m e_b(\theta_r)]$$

$$\frac{di_c}{dt} = \frac{1}{L-M} [v_c - R_s i_c - k_p \omega_m e_c(\theta_r)]$$

Now model equation contributing electromechanical energy conversion in the motor is as follows,

$$\frac{d\omega_m}{dt} = \frac{-B}{J} (\omega_m) - \frac{1}{J} (T_e - T_l)$$

Hence

$$T_e = \frac{P}{\omega_m} = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega_m} = T_a + T_b + T_c$$

$$T_e = \frac{2(k_p \omega_m)I}{\omega_m} = 2 * k_p * I$$

This equation further modified as

$$T_e = k_t * I$$

Where  $k_t$  is called as torque constant and the equation is just similar to separately excited brushed dc motor when flux is constant.

Now governing equation of rotor position is as follows

$$\frac{d\theta_r}{dt} = \frac{P}{2} [\omega_m]$$

Where P is the number of poles.

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The variation of back EMF values with respect to rotor position is as shown below

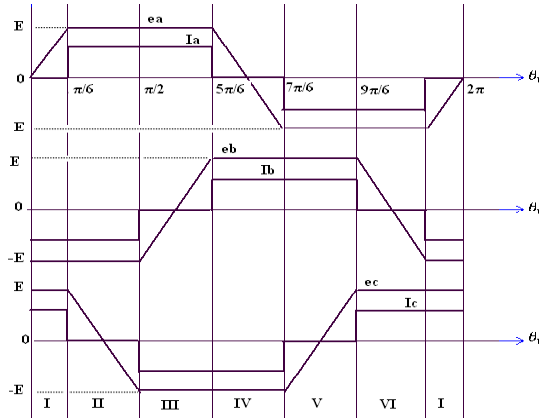


Fig.1 back-EMF variation with rotor position

## IV. DYNAMIC SIMULATION

The overall block diagram implemented in MATLAB is described in Fig.2 and it consisting various functional blocks such as back-EMF, speed-torque, hysteresis block and inverter blocks etc with Sinusoidal PWM and Space Vector PWM techniques [1],[2].

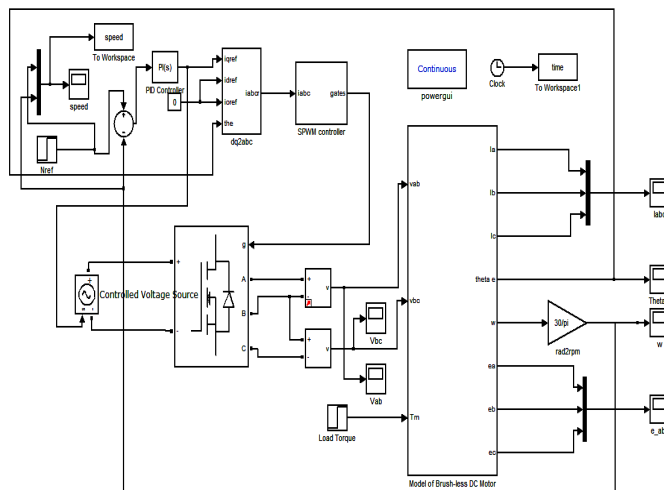


Fig.2 (a) Sinusoidal PWM technique.

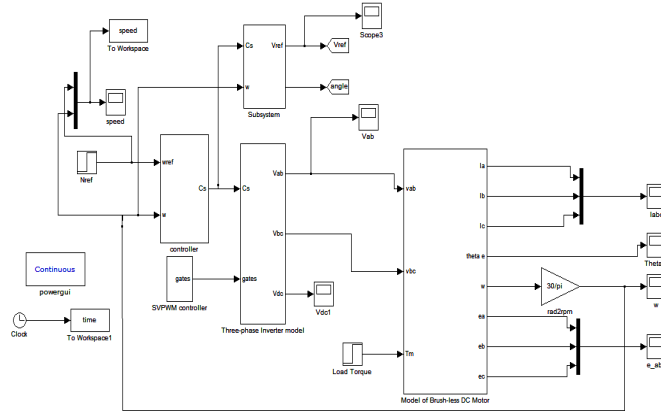


Fig.2 (b) Sinusoidal PWM technique

## V. SIMULATION RESULTS

The following figures representing simulation results for sinusoidal PWM technique and Space Vector PWM technique.

Fig.3 (a) (b) and (c) shows the speed performance, torque wave form and Back –emf of SPWM scheme and Fig.4 (a) (b) and (c) shows the speed performance, torque wave form and Back –emf of Space Vector PWM technique.

Torque ripples very high at dynamic conditions for BDLDC motor when it is run by using Sinusoidal PWM technique as

Compared to Space Vector PWM and similarly the same is happening with regard to speed performance.

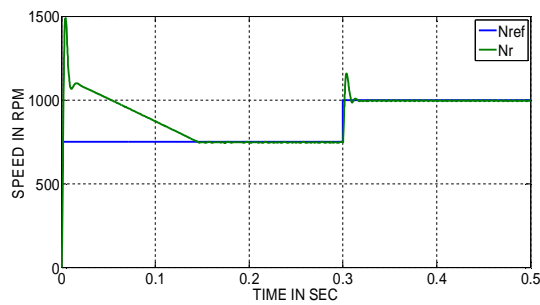


Fig.3 (a) speed versus time

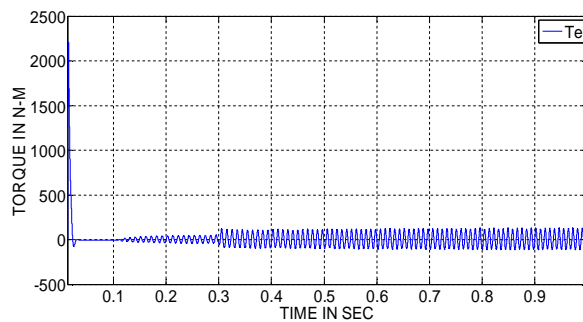


Fig.3 (b) torque versus time

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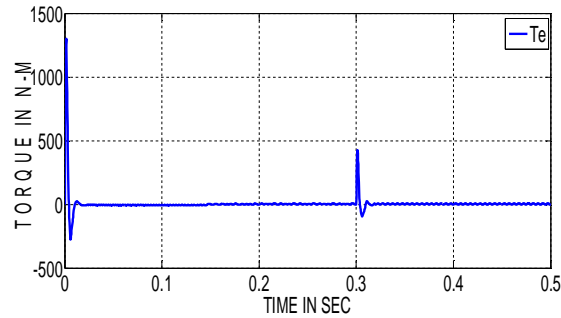


Fig.3 (c) Back-emf wave form

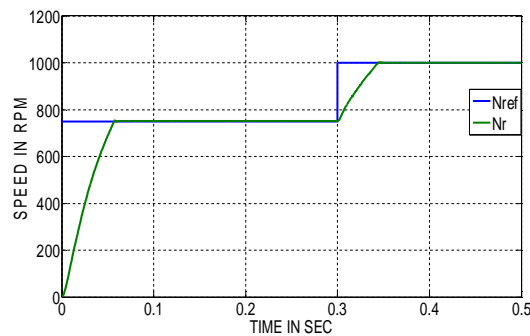


Fig.4 (a) speed versus time

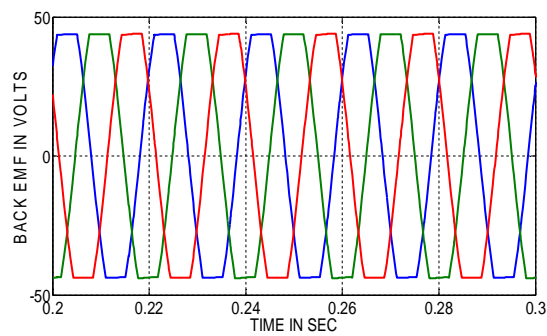


Fig.4 (b) Torque versus time

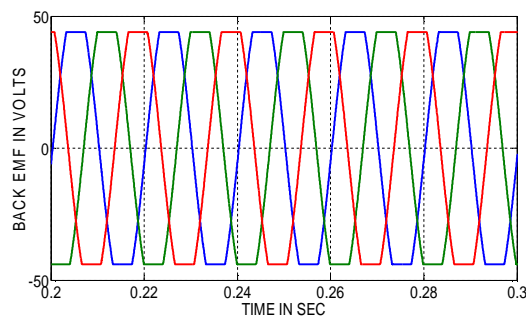


Fig.4 (c) Back-emf wave form

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## VI. CONCLUSION

The simulation results reveal that the fluctuations in speed and torque are less when the Space Vector Modulation strategy is implemented in the BLDC motor. Thus it can be concluded that the overall performance of a motor drive system is improved when Space Vector Modulation technique is used in the drive system.

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