Speed Control of PMBLDC Motor with the Help of PI Controller

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ABSTRACT- This paper presents model, scheme and performance assessment of speed control of PMBLDC motor with the help of PI controller. The PI controller is used to control the position of a Permanent Magnet Brushless Dc motor by changing the current flow to control the average voltage and thereby the average current. The speed is regulated by PI controller. Simulink is utilized, with MATLAB (2013a) to get a reliable and flexible simulation. In order to highlight the effectiveness of the speed control method used, the studies are conducted at two different load torques and the corresponding speed regulation is recorded using MATLAB/Simulink. The method proposed suppresses torque oscillations. This drive has high accuracy, high efficiency, silent operation, compact form, reliability, low maintenance, robust operation from near zero to high speed. Most useful applications in of CNC machine.

KEYWORDS Hall position sensors, permanent magnet brushless DC motor, decoder, closed loop speed control, PI controller.

1. INTRODUCTION The economic constraints and new standards legislated by governments place increasingly higher requirements on electrical systems. New generations of equipment must have higher performance parameters such as better efficiency and reduced electromagnetic interference.

Household appliance have traditionally relied on historical classic electric motor technologies such as single phase AC induction, universal motor, etc. These classic motors typically are operated at constant-speed directly from main AC power without regarding the efficiency. Consumers now demand for lower energy costs, better performance, reduced acoustic noise, and more convenience features. Those traditional technologies cannot provide the solutions.

A permanent magnet brushless DC motor (PMBLDC) is a motor that uses permanent magnets to produce the air gap magnetic field rather than using electromagnets. This motor has significant advantages and attracting the interest of researchers and industry for use in many applications. Electronic commutation of stator windings is based on rotor position with respect to the stator winding [1]. A new generation of microcontrollers and advanced electronics has overcome the challenge of implementing required control functions, making the BLDC motor more practical for a wide range of uses [2], [3]. In this method the speed is 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 (PI) controller is used to amplify the speed error and dynamically adjust the PWM duty cycle. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be got by varying the duty cycle of the PWM signal. For low-cost, low-resolution speed requirements, the Hall signals are used to measure the speed feedback.

2. TYPES OF CONTROL TECHNIQUES OF PMBLDC MOTOR

Though various control techniques are discussed in basically two methods are available for controlling PMBLDC motor. They are sensor control and sensor less control. To control the machine using sensors, the present position of the rotor is required to determine the next commutation interval. Motor can also be controlled by controlling the DC bus rail

voltage or by PWM method. Some designs utilize both to provide high torque at high load and high efficiency at low load. Such hybrid design also allows the control of harmonic current [5].

In case of common DC motors, the brushes automatically come into contact with the commutator of a different coil causing the motor to continue its rotation. But in case of BLDC motors the commutation is done by electronic switches which need the rotor position. The appropriate stator windings have to be energized when rotor poles align with the stator winding. The BLDC motor can also be driven with predefined commutation interval. But to achieve precise speed control and maximum generated torque, brushless commutation should be done with the knowledge of rotor position. In control methods using sensors, mechanical position sensors, such as a hall sensor, shaft encoder or resolver have been utilized in order to provide rotor position information. Hall Position sensors or simply Hall sensors are widely used and are popular. Three phase windings use one Hall Sensors each. They provide three overlapping signals giving a 60° wide position range. Whenever the magnetic poles pass near the sensors, they either give a high or low signal, indicating North or South Pole is passing the pole. The accurate rotor position information is used to generate precise firing commands for power converter. This ensures drive stability and fast dynamic response. The speed feedback is derived from the position sensor output signals.

Between the two commutation signals the angle variation is constant as the Hall Effect Sensors are fixed relative to the motor, thus reducing speed sensing to a simple division. Usually speed and position of a PMBLDC motor rotor is controlled in a conventional cascade structure. The inner current control loops runs at a larger with than the outer speed loop to achieve an effective cascade control[6].

Various sensorless methods for BLDC motors are analyzed in [7-17]. [7] Proposes a speed control of brushless drive employing PWM technique using digital signal processor. Speed control of BLDC based on PI controller is explained in. Direct torque control and indirect flux control of BLDC motor with non sinusoidal back emf method controls the torque ripple-free control with maximum efficiency. Direct back EMF detection method for sensorless control is given in. Proposes a novel architecture using a FGPA-based system. Fixed gain PI speed controller has the limitations of being suitable for a limited operating range around the operating point and having overshoot. To eliminate this problem a fuzzy based gain schedule PI speed Controller is proposed in. A new module structure of PLL speed controller is proposed by. A fixed structure controller (PI or PID) using time constrained output feedback is given in. The above literature does not deal with reduction of speed oscillations in PMBLDC drive. This paper deals with control method to reduce speed oscillations. To control a system, by any of these methods can use.

3. BLDC Motor speed control

In servo applications position feedback is used in the position feedback loop. Velocity feedback can be derived from the position data. This eliminates a separate velocity transducer for the speed control loop. A BLDC motor is driven by voltage strokes coupled by rotor position. The rotor position is measured using Hall sensors. By varying the voltage across the motor, we can control the speed of the motor. The speed and torque of the motor depend on the strength of the magnetic field generated by the energized windings of the motor, which depend on the current through them. Hence adjusting the rotor voltage and current will change motor speed.

Commutation ensures only proper rotation of the rotor. The motor speed depends only on the amplitude of the applied voltage. This can be adjusted using PWM technique. The required speed is controlled by a speed controller. This is implemented as a conventional proportional-Integral controller. The difference between the actual and required speeds is given as input to the controller. Based on this data PI controller controls the duty cycle of the PWM pulses which correspond to the voltage amplitude required to maintain the desired speed. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal.

In case of closed loop control the actual speed is measured and compared with the reference speed to find the error speed. This difference is supplied to the PI controller, which in turn gives the duty cycle. PMBLDC motor is popular in applications where speed control is necessary and the current must be controlled to get desired torque. Figure .shows the basic structure for closed loop control of the PMBLDC motor drive. It consists of an outer speed control loop, an inner current control loop for speed and current control respectively. Speed loop is relatively slower than the current loop.

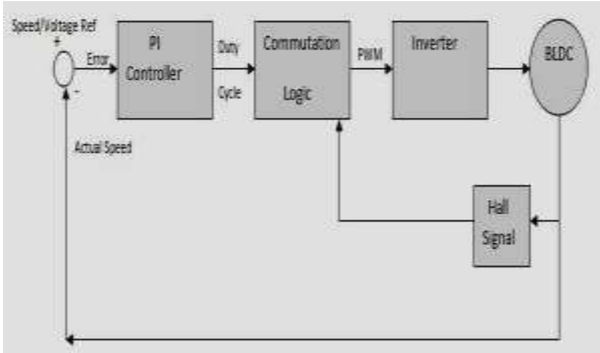

Figure 1: Closed Loop Speed Control

4. Simulation and Results

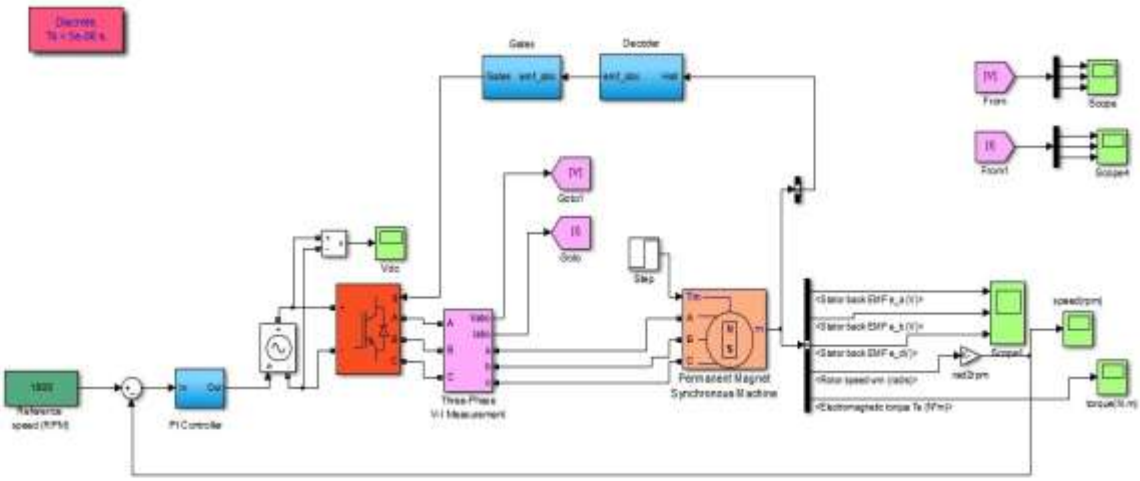

FIGURE 2: Simulink Closed Loop Speed Control of PMBLDC Motor With the help of PI Controller

A decoder is a circuit that changes a code into a set of signals. It is called a decoder because it does the reverse of encoding, but we will begin our study of encoders and decoders with decoders because they are simpler to design. A common type of decoder is the line decoder which takes an n-digit binary number and decodes it into 2n data lines. The simplest is the 1-to-2 line decoder. The truth table is shown below for the decoder or hall sensors

True table of hall sensor					
ha	hb	hc	Emf-a	Emf-b	Emf-c
0	0	0	0	0	0
0	0	1	0	-1	+1
0	1	0	-1	+1	0
0	1	1	-1	0	+1
1	0	0	+1	0	-1
1	0	1	+1	-1	0
1	1	0	0	+1	-1
1	1	1	0	0	0

Table:1 Truth Table of Hall Sensors

True table of switches								
Emf-a	Emf-b	Emf-c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

Table:2 Truth table of Switches

These two tables are used for switching the IGBT's used in universal bridge inverter.

The gate circuit is used to triggering gate pulse for commutation in to the universal bridge inverter. The above truth table shown the EMFs signal are enter in the gate circuit and the signal are compared to the grater then to zero or less then to zero. This signal is throwing to the inverter and inverter is conducting. If the signal is zero the inverter will not conduct and if the signal is one the inverter will conduct.

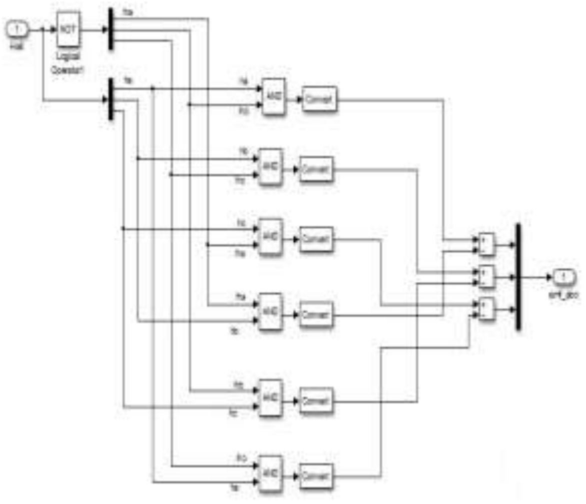

Figure 3: Subsystem of Decoder

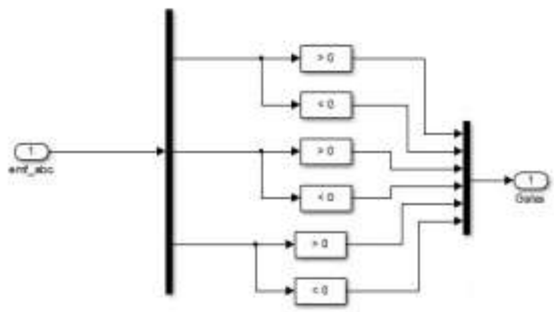

Figure 4: Subsystem of Gates

PI controller is used to compare between the motor speed and reference speed. With the help of the designed circuit parameters, the MATLAB simulation is done and results are presented here. Speeds are set at 1800 rpm and the load torque disturbances are applied at time t=1 sec. The speed regulations are obtained at two different set speeds and the simulation results are shown.

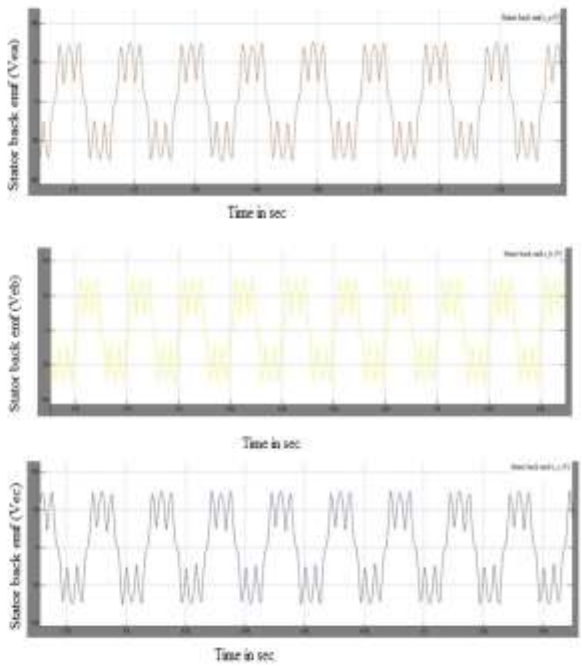

Figure 5: Sinusoidal Back EMF waveforms, when speed is not controlled

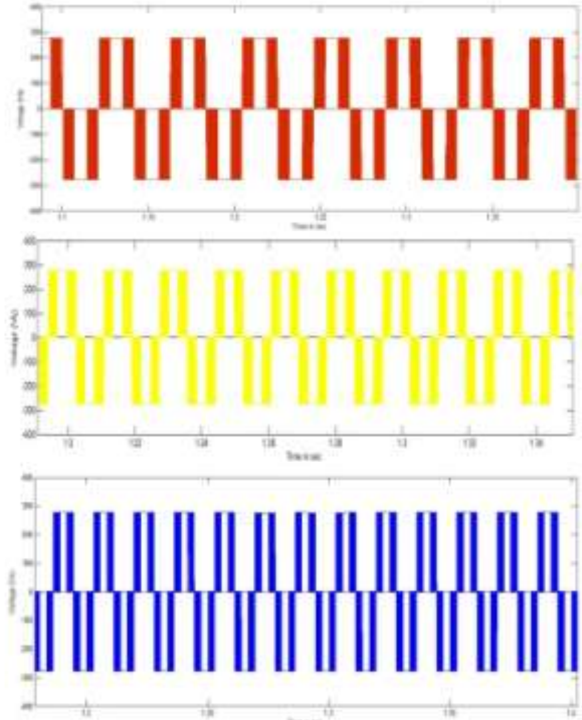

Figure 7: Output Waveforms of phase voltage

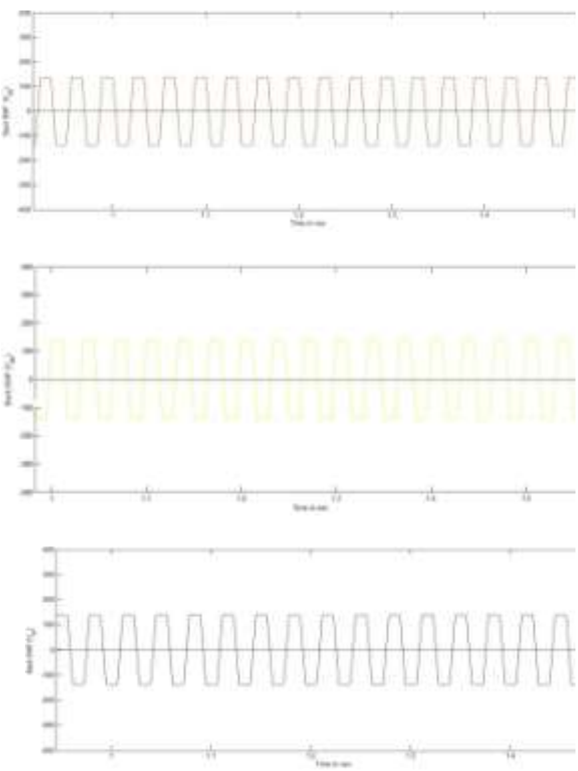

Figure 6: Trapezoidal Back EMF waveform after speed control

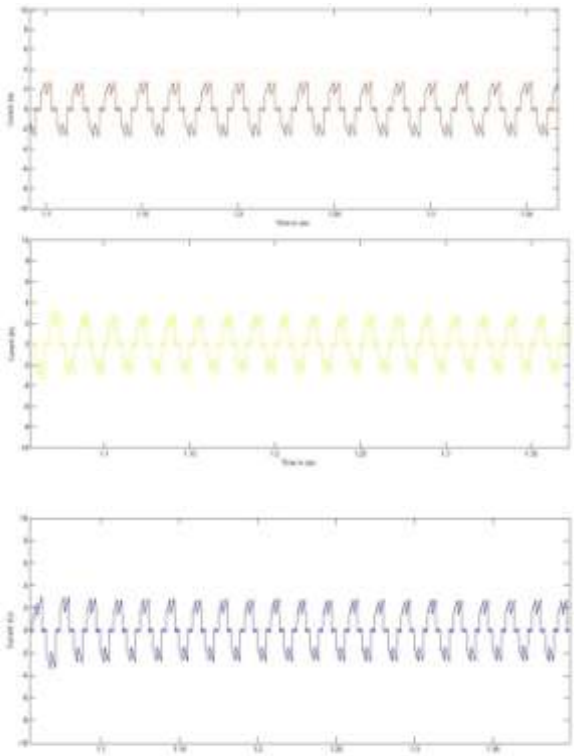

Figure 8: Output waveforms of stator current

When torque is 10 N*m motor speed=2000 rpm at t= 2 sec and Set speed is 1800 rpm.

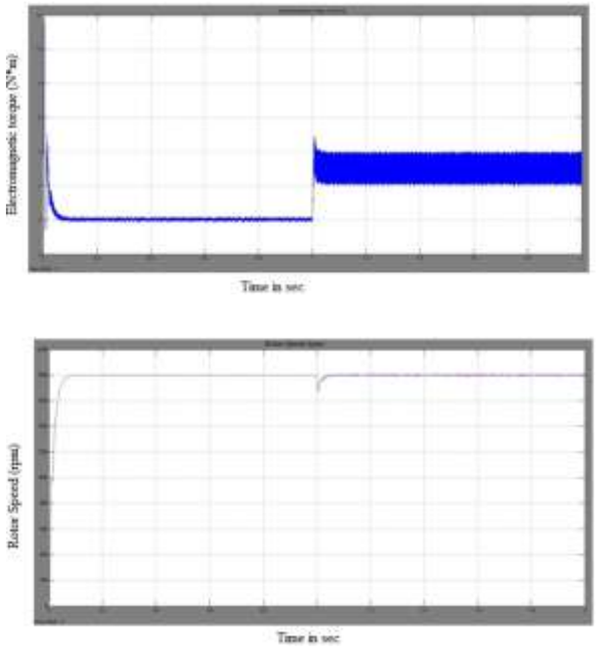

Figure 9: Load Torque Disturbance applied at t= 1 sec, speed 1800 rpm

When torque is N*m motor speed= rpm at t=2 and Set speed is 1800 rpm.

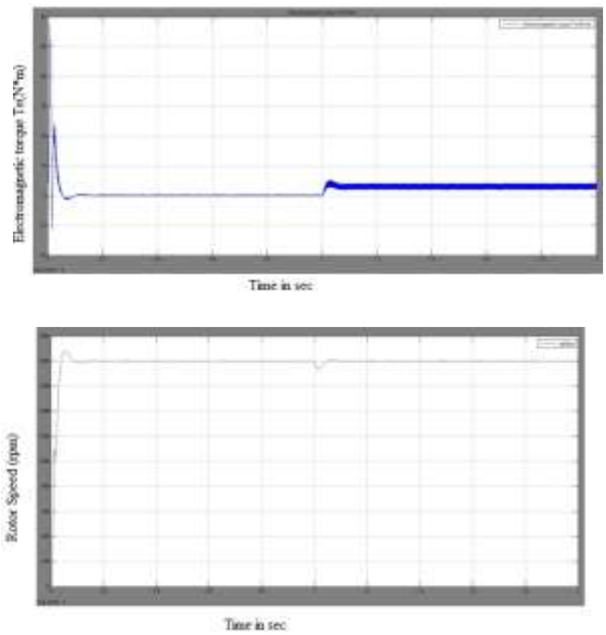

Figure 10: Load Torque Disturbance applied at t= 1 sec, speed 1800 rpm

5. CONCLUSION

Closed loop speed controlled PMBLDC motor is simulated. Feedback signals from the PMBLDC motor representing speed and position are utilized to get the driving signals for the inverter switches. The simulated results shown are at par with the theoretical predictions. The simulation results can be used for implementation of PMBLDC drive. The stator current and the motor back EMFs are discussed under rated condition. All switches work under soft-switching condition, so their power losses are small. The speed oscillations are minimized using closed loop system.

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