Modeling and Simulation of Real Time Electronic Speed Controller of Position Sensorless Brushless DC Motor

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Abstract

Brushless DC (BDC) motors are widely used in aerospace applications because of their high power to weight ratio, low maintenance and reliable operation over long periods of time. These advantages also make them preferred over brushed DC motors for several other applications. But the requirement of an electronic speed controller for commutation and customization for specific applications makes BDC a costly affair. This project presents a low cost and real time electronic speed controller for BDC motors. The motor is started using the motor phase saturation inductance change method. Further control of the motor is established by monitoring the back emf zero crossing as a feedback. In addition, MATLAB simulink based simulations have been performed to analyse the circuit performance under real time input conditions.

1. Introduction

Brushless DC motor (BDC) is an electronically commutated motor where the stator is an electromagnet and the rotor is the permanent magnet. The stator of the BDC motor consists of laminations made of steel or any other suitable material and windings placed in the slots which are cut axially along their inner periphery. One or more coils are placed in these slots and they are Interconnected to make a winding. The permanent magnet of the rotor is selected based on the required magnetic field density. Usually alloys of Rare Earth Alloy metals like Samarium-cobalt, Neodymium etc are employed that have exceptionally high magnetic density per unit volume which enables the rotor to compress further for the given torque, thus improving the size to weight ratio of the BDC motor.[1]

The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive the motor at that speed. In Open loop configuration, the motor is made to rotate at any given speed by controlling the time between switching the sequences. This method is very straightforward and simple to implement but, however, absence of any type of feedback makes this method prone to inaccurate switching especially at higher speeds.

To overcome the problem, closed loop configuration is used where the back-EMF from the three motor phases are continuously monitored for the zero crossing event. This provides for a feedback to switch sequences. The closed loop technique is highly accurate and accounts for any glitches during the operation.

2. Start of the motor without back-emf

As the back-EMF is proportional to speed, a sensorless controller needs a way to find the initial rotor position, for starting the motor and accelerating it to sufficient speed for detection of back-EMF voltage. Start-up is undoubtedly the biggest hurdle any sensorless-control algorithm must overcome. Conventional methods drive a current through the motor windings, forcing the motor rotor into a known position to ensure proper motor start. This can cause up to 180° of (2-pole) motor rotation opposite to the desired direction, adding to acceleration and start-up time.

In this method the position of the rotor is determined based on motor-phase saturation inductance change. The controller generates 6 short, opposing current pulses that drive the motor phases into saturation. The current pulse sequence used to determine the change in saturation inductance is similar to the commutation sequence. The controller calculates the motor rotor position based on the saturation inductance change in each phase.

3. Speed controller circuit

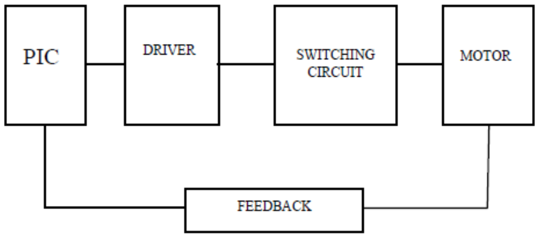


Fig. 1 Block diagram of the speed controller

Description of components:

1) *Microcontroller:* The interrupt-on-change feature is used for the feedback. This is an external interrupt which is triggered when any change is observed on the input. The pins with this interrupt are given the feedback from the comparator (for sensorless).

2) *Driver Circuit*: we need a driver circuit which could provide voltage and current amplification to the signals generated by the microcontroller to match the motor requirements

3) *Switching Circuit*: switch is used to provide sufficient voltage to the motor. So we need a driver to provide required voltage to the input of the switch [2]

4) *Comparator (feedback stage)*
Digital comparator is formed by configuring an OPAMP and controlling the output value by regulating the driving voltage of the OPAMP. The range of values of Back EMF around the zero crossing is found out and is given as the reference voltage at the inverting pin. The non inverting pin is given the feedback from the floating line of the BLDC motor. When the potential of the floating line drops below the reference value, a change in comparator output is noticed. This change in the feedback value from comparator makes the microcontroller switch the commutation sequence

4. Simulation

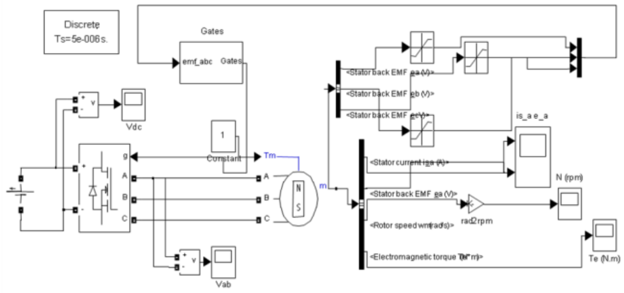


Fig2: Simulation of BLDC in sensorless mode of operation

A.*Gates emf_abc Block*

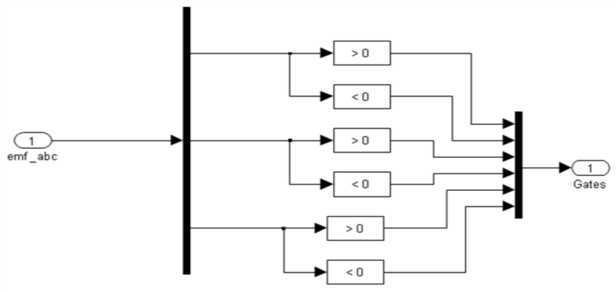


Fig3: subsystem of Gates emf_abc Block in sensorless mode

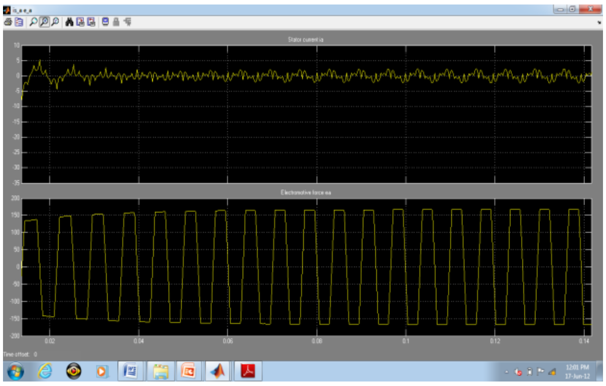
B.*Gates emf_abc module implements the following truth table*

TABLE-I

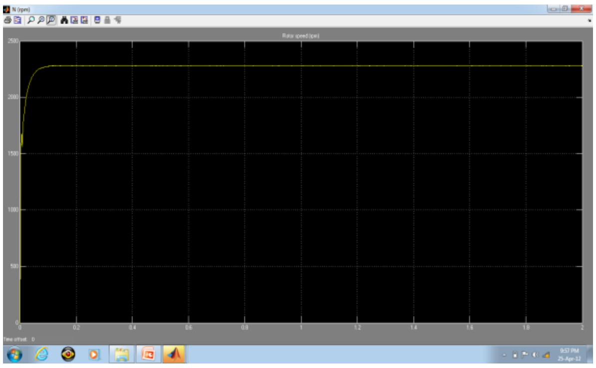
Emf_a	Emf_b	Emf_c	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	+1	0	0	0	1	1	0
-1	+1	0	0	1	1	0	0	0
-1	0	+1	0	1	0	0	1	0
+1	0	-1	1	0	0	0	0	1
+1	-1	0	1	0	0	1	0	0
0	+1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

5.Simulation results

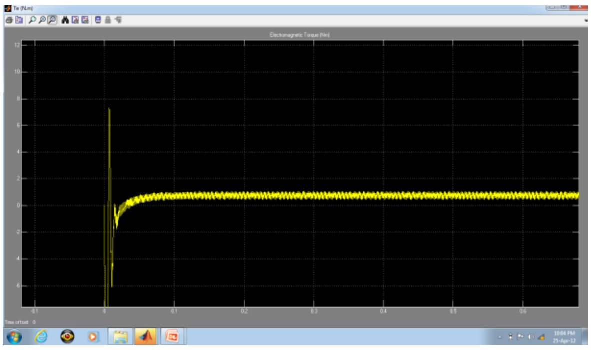
A. *stator current (ia) & back emf (ea)*



B. *rotor speed*



C. *electromagnetic torque (te)*



6. Conclusion

This shows the speed control of position sensorless brushless DC motor. The rotor position is determined by the state of back-EMF. The circuit has been constructed and simulated using Matlab-Simulink and desired results were obtained.

Fig in 5.A shows the Stator current and back EMF generated, Fig in 5.B shows Speed of the motor, fig in 5.C shows the Electromagnetic Torque of the motor. These were the results analyzed using simulation.

7. References

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