International Research Journal of Engineering and Management Studies (IRJEMS)
Volume: 03 Issue: 05 | May -2019 ISSN: 2395-0126

BLDC MOTOR CONTROL USING SENSORED COMMUTATION

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Abstract: Brushless DC (BLDC) motor is gaining a lot of popularity in industries and in commercial applications. A simple BLDC motor control algorithm for low cost motor drive applications using Arduino has been created and presented in this project. Proposed design will allow the user to rotate the motor either clockwise or anticlockwise direction. The rotor position will be sensed by the Hall Effect sensor. The Hall Effect sensor will give feedback to the controller circuit. The controller circuit will tell which two windings are energised at every instant through MOSFET switching. Through the sensing circuit, we will vary the duty cycle of the potentiometer which will either increase or decrease the speed of the BLDC motor as per requirement. The complete design consists of Arduino circuit, driver board, 3 phase half bridge inverter (MOSFET), BLDC motor, potentiometer and Hall Effect sensors. Our main concern is this project is to control the speed of brushless dc motor using hall sensors. In BLDC motor control three pairs of MOSFETs are connected in a bridge structure, each pair governs the switching of one phase of motor. When the motor rotates, two windings are energised at a time. Here the 3 bit digital output from the hall sensor is fed to the controller to sense the rotor position. A0 pin is connected to the potentiometer which helps in PWM switching. By using this PWM switching the speed control will be better. We aim to control speed by an Arduino Controller with comparator LM399 using sensing part.

Keywords: Hall Effect sensors, H bridge Inverter, Rectifier

I .INTRODUCTION

Brushless DC (BLDC) motors have gained popularity because they are electronically commutated. Conventional DC motor comprises of brushes resting on the commutator due to which the windings gets energised in the stator (armature) of a DC motor. The electronically commutated BLDC motor delivers more efficiency over DC motors. It improves efficiency to about 20 to 30%. The electric motors consumes about 40% of world's electricity, the usage of BLDC motor will reduce the electricity consumed increasing its efficiency. The BLDC motor requires no maintenance. It delivers high performance ,efficiency and power as compared to corresponding DC motor efficiency, performance and power is reduced due to wear and tear, causing poor brush contact, arcing(spark) between the brushes and the commutator dissipating energy, and dirt reduces electrical conductivity. BLDC motors can be made smaller, lighter and noiseless for a given power rating which further increases their popularity in automobiles; electrical and electronics industries. Other features of BLDC motors include good speed versus torque characteristics, noise free operation, and wide speed ranges. The demerit of BLDC motors is that it is complex and it's not economical. As it is electronically commutated it needs supervision of control circuits that the coil is energized at the correct time to get accurate speed and torque control It also ensures that the motor runs at higher efficiency. This sector is rapidly increasing and it offer a wide range of highly-integrated BLDC motor driver circuit, power MOSFET bridge with either external or internal controllers to reduce the complexity of the design process which also reduce the cost of the components. This project explains how we can control the speed of the BLDC motor using Hall Effect sensors.

II. Working Principle: BLDC motor is electrically commutated to transform electrical energy to mechanical energy. Current flowing through the winding generates a magnetic field in the presence of a permanent magnet generates a force on that winding and reaches a maximum when its conductors are placed at 90° to the permanent magnet. If the numbers of coils are increased then the motor output gets increased and power output gets smother. BLDC motor overcomes the requirement of mechanical commutator. BLDC motor has a reversed setup the energized coils (electromagnet) becomes the stator and the permanent magnets becomes the rotor. The stator is made of steel laminations .They are slotted axially in order to accommodate an even number of windings along its inner periphery. Rotor has permanent magnets to move between North and South poles. The below figure showcases the example of a common magnet arrangement in which two magnet pairs are coupled directly to the rotor.

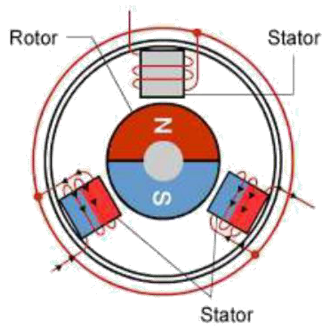

Fig-1.1 BLDC MOTOR WORKING

III. Theory: Stationary windings are energized which moves permanent magnet. A rotating magnetic field is produced when the winding are commutated in a controlled sequence. Stator produces a rotating magnetic field which causes the rotor to revolve at the rated frequency. These motors can be operated in two phases as well as three phase. The current is being applied sequentially to the three-phase BLDC motor using H-Bridge power MOSFETs. At any instant, one pair of MOSFET is switched on. Pulse-width modulation (PWM) is used for switching the high side MOSFET. The input DC voltage is converted into a modulated driving voltage using PWM. The start-up current is limited and it gives precise control over speed and torque characteristics.

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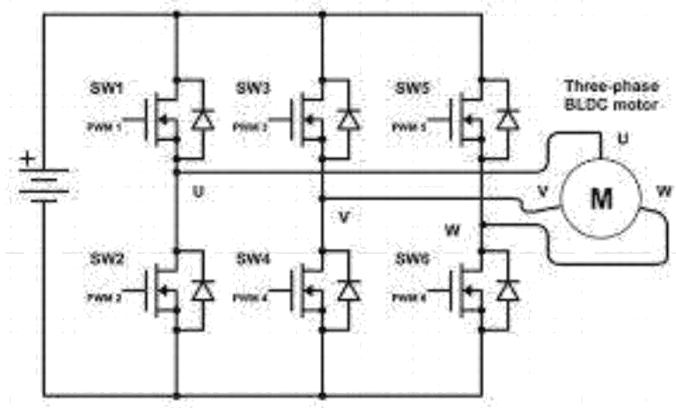


Fig-1.2 H BRIDGE INVERTER

SCHEMES:

The control schemes used for electronic commutation are:

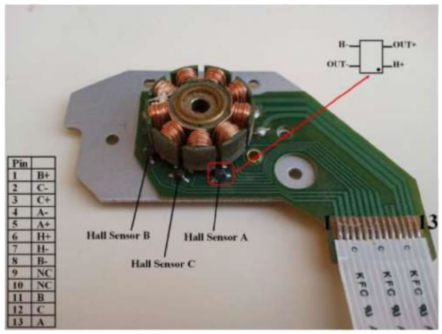
1. Trapezoidal control.
2. Sinusoidal control.
3. Field-oriented control.

One of the simplest techniques is the trapezoidal control. Two windings are being energized (one being as high and the other being as low) while the other winding remains floating at that instant. Stepped commutation causes the torque to ripple during low speeds in Trapezoidal method. The torque ripple can be reduced using the Sinusoidal method. The driving current in each of the three coils varies sinusoidally at 120° from each other resulting into improved power output. The current angle between the rotor and stator flux is always 90° in the Field-oriented method. During high speeds, the technique is the efficient. There is no torque ripple. During low and high speeds, a smother and accurate motor control can be achieved.

The MOSFET H-bridge must operate in a defined sequence to get efficient performance. The switching sequence is decided by the positioning of the rotor magnet and the energized stator windings. To complete one electrical cycle BLDC motor requires six commutation steps. The number magnets-pairs on the rotor is used for determining the number of mechanical revolution per electrical cycle. For one mechanical revolution, two electrical cycles are required.

MOSFET SWITCHING:

The positional feedback is given through three Hall-effect sensors that are embedded in the stator and are arranged at 120 degree. Hall-effect sensor is combined with a switch is used for sensing. It generates either a logic "high" (for north magnetic pole) or "low" (for the South Pole). The Hall-effect sensors and MOSFET switches is used for determining the sequence of commutation. When one of the sensors is triggered by one of the rotor's magnetic poles a voltage pulse is generated. The below figure describes the sequence of commutation of a three-phase BLDC motor that is driven anti-clockwise. Hall Effect sensors are mounted at position at "a", “b” and “c". For each step in the commutation process there is one winding that is driven high by the MOSFET Bridge while one is being driven as low and the third is left floating in the commutation sequence. In the figure, U is high (N pole) V is low(S pole) and W is used as floating. The rotor moves anti-clockwise and produces a resulting magnetic field. One winding will be repelled by one permanent magnet and attracted by the other winding. In the second stage U winding will remain high while V winding switches to float and other winding switches to low causing the rotation of the magnetic field and therefore rotating the rotor with it. Two electrical cycles are needed to complete one mechanical rotation of the rotor.



I had 4 pin hall effect sensor so I added an analog comparator LM339 to each of the sensor outputs (+ve and -ve) which are connected to the inputs (inverting and non-inverting). Finally, three outputs are obtained from three Hall Effect sensors as shown in fig above.

<u>FEEDBACK FROM THE HALL SENSOR:</u>

- BLDC MOTOR.
- HALL EFFECT SENSOR.
- ARUDINO.

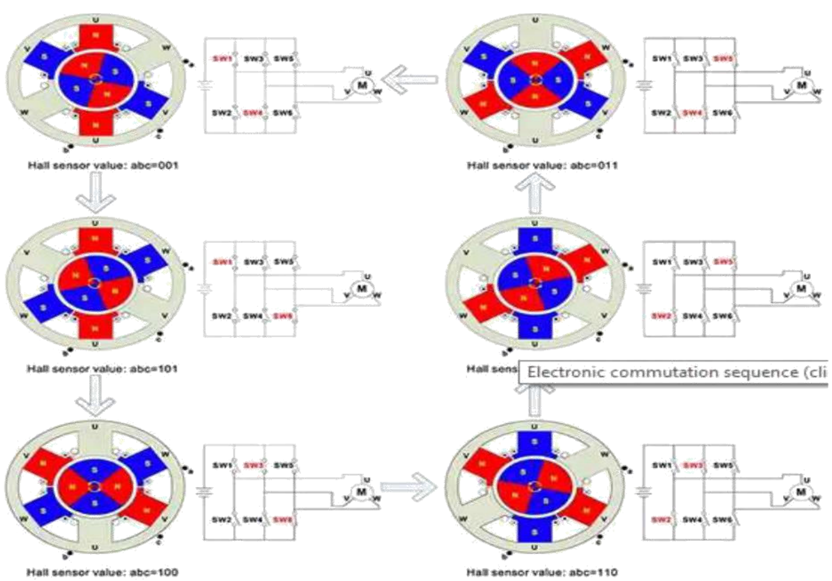


Fig-1.3 MOSFET SWITCHING

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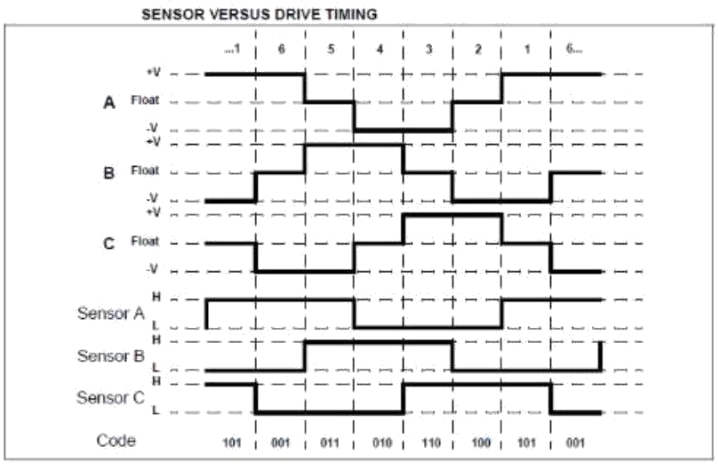

Fig 1.4 SENSORED OUTPUT FOR REQUIRED MOTOR DRIVE VOLTAGES FOR PHASE A, B, C

Phase	Sensor C	Sensor B	Sensor A	C High Drive	C Low Drive	B High Drive	B Low Drive	A High Drive	A Low Drive
6	0	0	1	0	1	0	0	1	0
4	0	1	0	0	0	1	0	0	1
5	0	1	1	0	1	1	0	0	0
2	1	0	0	1	0	0	1	0	0
1	1	0	1	0	0	0	1	1	0
3	1	1	0	1	0	0	0	0	1

Fig 1.5 CONTROL OF 3 PHASE BRIDGE

COMPONENTS:

1. 500 mA Transformer
2. Connectors
3. Optocouplers (SFH9301)
4. Electrolytic Capacitor
5. Heat Sink
6. MOSFET (IRFP250N)
7. Diode (IN4007)
8. Resistor
9. Transistor (CL100)

SENSORED BLDC CONTROL WITH ARDUINO CIRCUIT:

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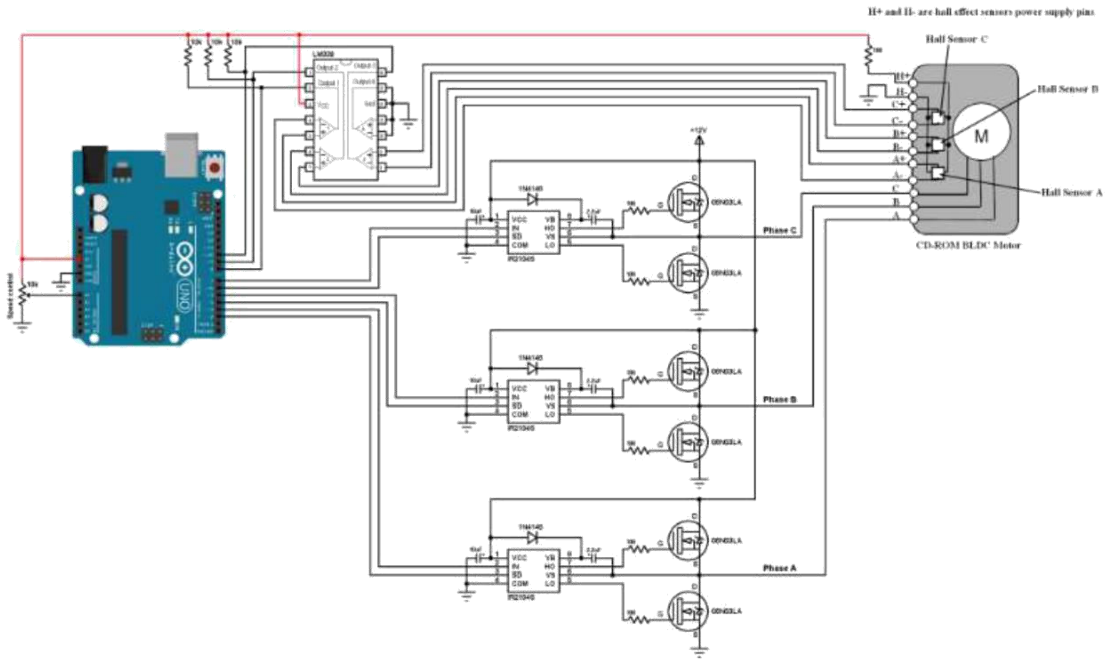
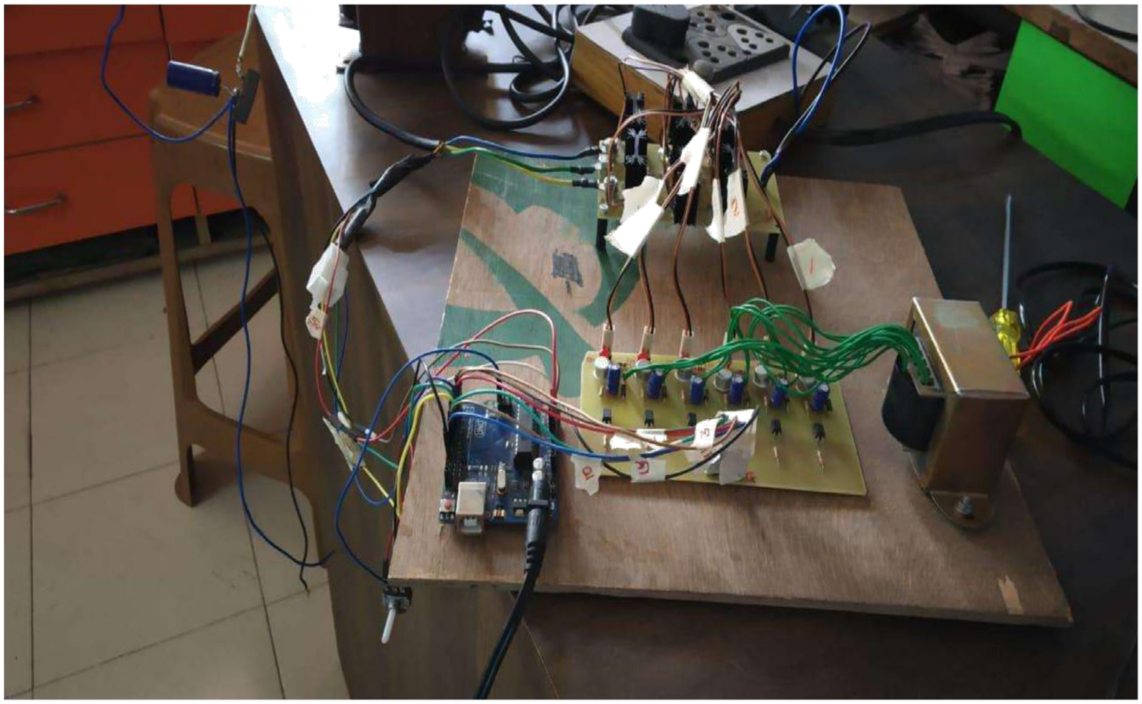


Fig 1.6 SENSORED BLDC CONTROL WITH ARDUINO CIRCUIT

In the circuit there are three gate drivers IC, each one is used to drive one high side mosfet and one low side mosfet, the switching between the high side mosfet and the low side mosfet is done according to the control lines which are: IN and SD.

The potentiometer is used to control the BLDC motor speed, it is controlled using PWM technique which is done on high side only. If at any time there is one active high side mosfet and one active low side mosfet that means always there is one active PWM pin.

IV. Model:



CONCLUSION

BLDC motors demands precise control, adding complexity and cost to the motor's circuitry. But, they offer higher performance by reducing power losses, increasing reliability, reducing space, and weight of the final circuit is more than its offset. The integrated BLDC motor drivers control circuits significantly reduces the difficulty in the design process and adds to the flexibility so that the designer can design as per the given application.

The speed control of brushless DC motor is done by an Arduino Controller with comparator using sensing part.

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