SPEED CONTROL OF SENSORLESS BLDC MOTOR

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Abstract : This paper is designed to control the speed of a Sensorless BLDC motor using PIC micro controller. Through sensorless technology The reliability &performance of BLDC motor drivers have been improved as the conventional control and sensing techniques have been improved. BLDC motor has widely application used in industries like in drilling, lathes, spinning, electric bikes etc. it is very essential to control the speed of BLDC motor. This paper provides a very accurate and effective speed control system. The person can enter the desired speed and the motor will run at that exact speed.

IndexTerms - **Brushless DC (BLDC) Motor; Electro Motive Force (EMF); Permanent Magnet (PM); Permanent Magnet, Synchronous Motors (PMSM), PIC Microcontroller).**

I. INRODUCTION

For energy saving applications such as air conditioners and refrigerators [1], several Asian countries such as Japan have been under pressure from high energy prices, have implemented variable speed PM motor drives. On another side for energy saving applications ,cheap induction motor drives are used by U.S.A. which have around 11% lower efficiency than adjustable PM motor drives for energy saving applications.Therefore recently, the increase in energy prices spurs higher demands of variable speed PM motor drives. Also there is a serious demand of high efficient PM motor drives in automobile industry

Another name for BLDC motor, is Permanent Magnet DC Synchronous motor,is one of the motor types that have more rapidly increased popularity, mainly because of their better performance and characteristics [2]. These motors are used in a large amount of industrial sectors because their architecture is suitable for any safety critical applications.

The BLDC motor is a synchronous electric motor that, looks exactly like a DC motor, having a linear relationship between current and torque, voltage and rpm. It is an electronically controlled commutation system, instead of having a mechanical commutation, which is typical of brushed motors. Additionally, the electromagnets do not move, the permanent magnets rotate and the armature remains static. Which leads to the problem of how to transfer current to a moving armature. In order to do accommodate this, the brush-system/commutator assembly is replaced by an intelligent electronic controller, which accomplish the same power distribution as a brushed DC motor [3]. Compare to brushed DC motors and induction motors, BLDC motors have many advantages. They are 1. better speed *versus* torque characteristics. ,2. high dynamic response, 3. high efficiency and reliability,4. long operating life (no brush erosion), 5. noiseless operation, 6. higher speed ranges, and reduction of electromagnetic interference (EMI)

In this paper the of BLDC motor speed control can be done automatically based on the variation of the potential meter. pulse width of PWM is varied based on the Voltage Source Inverter input. The proposed system controls the speed the motor in an efficient manner.

The control of BLDC motors can be done in two ways they are sensor or sensorless mode, but to minimize overall cost of actuating devices, sensorless control techniques are normally used. The benfit of sensorless BLDC motor control is that the sensing part can be omitted, and thus overall costs can be considerably minimized. The drawback of sensorless control are higher requirements for control algorithms and more complicated electronics [3]. the electrical motors that do not require an electrical connection (made with brushes) between stationary and rotating parts can be considered as brushless permanent magnet (PM) machines [4], which can be classified based on the PMs mounting and the back-EMF shape.The PMs can be *mounted on the surface of the rotor* (SMPM) or installed *inside of the rotor* (IPM) [5], and the back-EMF shape can either be trapezoidal or sinusoidal . Based on the back-EMF shape, *PM AC synchronous motors* (PMAC or PMSM) have sinusoidal back-EMF and *Brushless DC motors* (BLDC or BPM) have trapezoidal back-EMF. A PMAC motor is excited by a three-phase sinusoidal current, and a BLDC motor is usually powered by a set of currents having a quasi-square waveform [6,7].

2.1. BRUSHLESS DC MOTOR:

DC motors, rather surprisingly, is a kind of permanent magnate synchronous motor. Permanent magnet synchronous motors are ,mainly classified on the basis of the wave shape of their induce emf, i.e, the first one is sinusoidal and second trapezoidal. The former is known as permanent magnet synchronous motor; the trapezoidal type as PM Brushless dc (BLDC) machine. Permanent magnet (PM) DC brushed and brushless motors consists of combination of PM and electromagnetic fields to produce torque (or force) resulting in motion. This is done in the DC motor by a PM stator and a wound armature or rotor. To create continuous motion Commutator and brushes switches automatically current in the DC Motor to different windings

In a brushless motor, the rotor consists the magnets, and the stator contains the windings. brushes are absent and hence commutation is implemented electronically with a drive amplifier that uses semiconductor switches to change current in the windings based on rotor position feedback. In this respect, the BLDC motor is equivalent to a reversed DC commutator motor, in which conductors remain stationary and the magnet will rotates. Therefore, BLDC motors often consists of either internal or external position sensors to sense the actual rotor.

2.2 PRINCIPAL OF THE BLDC

BLDC motor consists of the permanent magnet rotor and wound stator. The brushes motors are controlled using a three phase inverter. To start the motor rotor position sensor is required and for providing commutation sequence to turn on the power device in the inverter that can be achieved by hall sensor. Based on the rotor position, the power devices are commuted sequentially. The problem associated with the commutator and the brushes are eliminated, such as sparking wear and tear of commutator. thereby, making a BLDC motor and rotor magnet arrangement.Commutation is nothing but the act of changing the motor phase current at the appropriate it times to produce rotational torque. . In a DC motor, the motor assembly contains a physical commutator which is moved by means of actual brushes in order to move the rotor. In a

BLDC motor, permanent magnet is powered by electrical current, that causes the motor to move, so no physical commutator is required. since it does not have any brushes to wear out , BLDC motor is highly reliable.

2.3 CONSTRUCTION

BLDC motors come in single-phase, 2-phase and3-phase configurations. Corresponding to its type, the Stator has the same number of windings. Among these,3-phase motors are the most widely used. There are two basic BLDC motor designs: outer rotor and inner rotor design. In the former the windings are located in the core of the motor. The rotor magnets surround the stator windings as shown Fig 1. The rate of heat dissipation from the motor is reduced as The rotor magnets act as an insulator. Due to the presence of the stator windings, outer rotor designs typically operate at lower duty cycles or at a lower rated current. The main advantage of an outer rotor BLDC motor is relatively low cogging torque. In an inner rotor design, the stator windings surround the rotor and are affixed to the motor's housing as shown Fig.2. The another advantage of an inner rotor construction is its ability to dissipate heat. A motor's ability to dissipate heat directly impacts its ability to produce torque. For this reason, the majority of BLDC motors use an inner rotor design. Also an inner rotor design has lower rotor inertia.

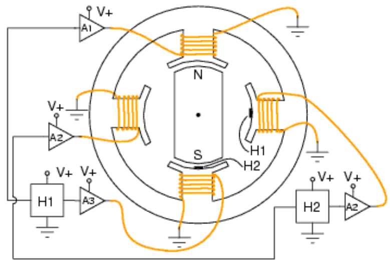
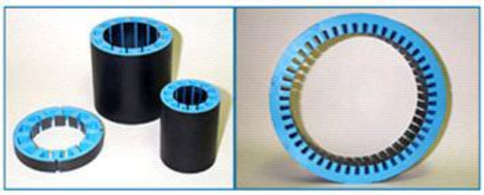


Fig.1. Brushless DC motor

2.3.1 Stator

The BLDC motor stator is laminated steel stacked up to carry the windings. Windings in a stator can be arranged in two ways; i.e. a star (Y) or delta (Δ). The main difference between the two is that the Y connection gives high torque at low RPM and the Δ connection gives low torque at low RPM. This is because in the Δ connection, half of the voltage is applied across the winding that is not driven, thus increasing losses and, in turn, efficiency and torque. Steel laminations in the stator can be slotted or slot less as shown in figure. A slot less core has lower inductance, thus it can run at very high speeds. cogging torque is reduced due to the absence of teeth in the lamination stack, thus making them an ideal fit for low speeds too (when permanent magnets on rotor and tooth on the stator align with each other then, because of the interaction between the two, an undesirable cogging torque develops and causes ripples in speed).



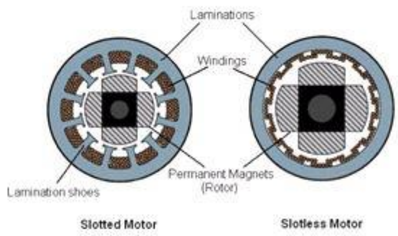


Fig : 2. Stator Fig : 3 motor with and without slots

The main disadvantage of a slot less core is higher cost because it requires more winding to compensate for the larger air gap.
The main disadvantages of the slotted motor are higher cost because it requires more to compensate for the large air gap.

2.3.2 Rotor

The rotor is made up of permanent magnet and the number of poles is varying from 2 to 8 poles. The material used for the rotor can be selected based on the required field density in the rotor. Generally ferrite magnets are used for the rotor. As the technology advances the rare earth alloy magnets are gaining popularity. Due to the disadvantage of low flux density for a given vaolume ,The ferrite magnets are less expensive. While the alloy earth material has high magnetic density per volume and make the rotor to compress further for the same torque.

2.3.3 Hall Sensor

The commutation of the BLDC motor is controlled electronically. Winding should be energized in a sequence, to rotate the BLDC motor,for this the rotor position is important in order to find out which winding should be energized according to the sequence. The rotor position is sensed which is mounted into the stator the rotor of the motor has alternate N and S permanent magnets. The hall sensor are mounted on the stationary part of the motor which is very complicated process because any the stator misalignment will generate an error in determination of the position of the rotor. To simplify the process of mounting the Hall sensors onto the stator, some motors may have the Hall sensor magnets on the rotor, in addition to the main rotor magnets

2.4. BLDC Motor Speed Controller

For precise speed control of BLDC motor, closed-loop control is normally used. The basic block diagram of the BLDC motor speed control is shown in Figure 2. The rotor position, which is sensed by the HALL sensor is given to the microcontroller, it is used to sense the each 60degree rotation.
Fig. 2 Basic block diagram for DC Motor speed control

2.6. APPLICATION

The Applications of the BLDC motors are Automotive, appliance, industrial controls, automation, aviation and so on, have applications for BLDC motors. Out of these, we can categorize the type of BLDC motor control into two
Major types:
• Constant load
• Varying loads

3. REVIEW OF BLDC MOTOR CONTROL SCHEMES

The control schemes of BLDC motor are mainly categorized in following two methods • Sensor based control • Sensor less control In sensor based control, a Hall sensor is used which detects the position of the rotor magnet and gives a signal which is used to give appropriate excitation to the stator winding. Hall sensor works on Hall effect which states that when a current carrying conductor is placed in magnetic field, it exerts a transverse force on the conductor. The sensor based control scheme is shown in Fig.2. Sensor based control Micro controller based control using Hall sensors gives effective control on BLDC motors. The sensor less drive principle is depends on the detection of the rotor position using various techniques one of which is the EMF detection. There are various methods for position and velocity estimation based on the induced Back EMF detection. Various micro controllers and DSP controllers are available for sensor less control.

4. MICROCONTROLLER BASED CONTROL

The proposed control for BLDC motor control using PIC microcontrollers of MICROCHIP with device name PIC16F877A is shown in the Fig.4

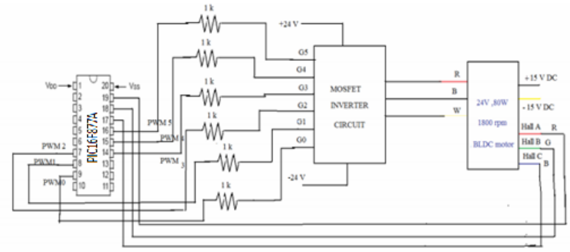


Fig.4 Micro Controller based Control

The base drive to the MOSFETS in the Inverter circuit is given by the PIC16F877A micro-controller. The Hall signals from the motor are fed as inputs to the PIC16Fseries device and based on the Hall position and the direction of rotation of the motor is specified by the corresponding gate drive and is made active by the microcontroller and fed to the stator of the BLDC motor.

4.1. PIC16Fseries Micro controller

PIC16Fseires microcontroller used in this project is a 40-pin device, 8 bit CMOS Microcontroller which belongs to the MICROCHIP family of microcontrollers. It has 10-bit Analog to Digital converter (ADC) and for our control we have used only 8 bits so that the speed can be controlled in 255 steps ranging from 6 to 1500 rpm. The various features of this device make this device to be selected for the proposed control. Timer1 is operated in external oscillator mode with an external crystal oscillator of 20 MHz connected to the micro controller device. An external Potentiometer is connected to the ADC pin which provides the required speed range.

4.2. Algorithm for Assembly language code

Coding for generation of switching pulses is written usually in assembly language. However writing the same in assembly language takes a long time and it is a difficult task . Hence the code is written in C language in the MPLAB IDE(Micro Processor Laboratory Integrated Development Environment).

using MPLAB IDE v7.52tool . It is similar to MATLAB .Here the pulses can be verified by simulating the written code in C using the MPLAB IDE..The written code is then compiled by HITECH PIC C compiler which converts the code in C language into Hex code. This Hex code is written into the PIC micro controller chip using a burner kit.

Algorithm

• Set PORTE as digital input.

• Set PORTC as Outputs to transistors.

• Generate interrupt on timer1 over flow and also on completion of ADC conversion by setting the appropriate registers.

• Enable Global interrupt.

•Irrespective of the Hall signal according to the direction of rotation of the motor (clock wise or counter clock wise), gives excitation to the motor windings.

• Start TIMER1 is operated with external crystal oscillator at 20 MHz frequency

• Generate LOOK-UP Table for clock wise rotation of the motor irrespective of the Hall signal.

• At the timer overflow interrupt service routing (ISR), generate LOOK-UP Table Journal of Engineering Research and Studies E-ISSN0976-7916 JERS/Vol. II/ Issue IV/October-December, 2011/ for clock wise rotation of the motor based on Hall signal.

• motor speed is set by using external potentiometer connected to the ADC pin.

• To convert the analog voltage into digital enable ADC

• this digital value is compared with the counter value equivalent to the motor speed (rated).

• If rated speed is lower than the motor speed then turn off all the transistors for short duration in ADC conversion complete ISR and return back from the ISR.

• Then continue the excitation process based on Hall signal.

• This program drives the BLDC motor at constant speed and the motor speed can be changed by varying the external potentiometer and make the motor run at that constant speed. To write a program in MPLAB IDE algorithm is used and is dumped on to the PIC16F690 device and tested on the 24 V, 80 W, and 1500 rpm BLDC motor shown in the figure (4).

Fig 5. 24 V, 80 W, 1500 rpm BLDC motor

5. PROPOSED HARDWARE FOR BLDC MOTOR

The important circuits of proposed hardware are

5.1. Main Block Diagram

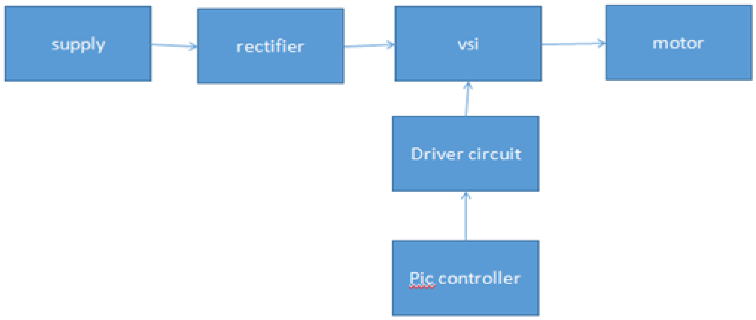


Fig : 6. Block diagram unit

5.2. Microcontroller circuit

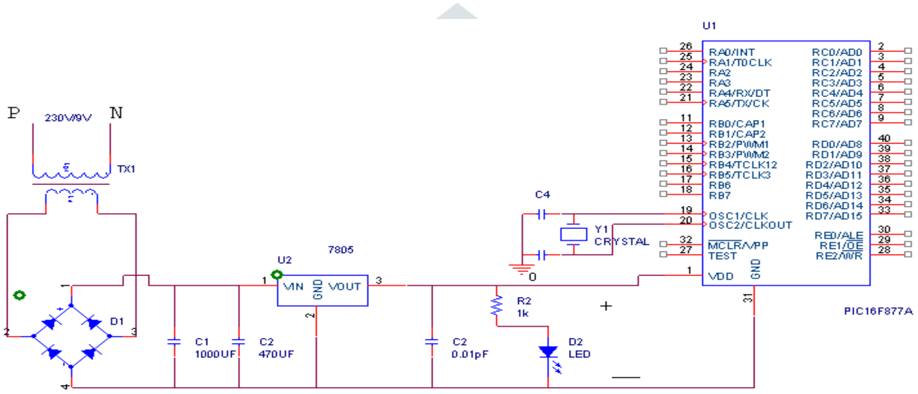


Fig. 7. pulse generation Triggering circuit.for

5.3.MOS FET driver circuit:

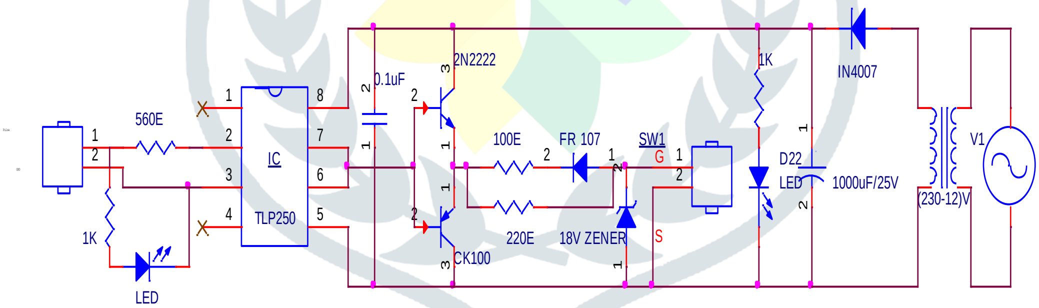


Fig.9. MOSFET Driver circuit

To trigger the MOSFET switches o f the inverter it requires 9 to 20 volts . Driver amplifies the voltage from microcontroller which is 5volts. Also it consists of an opto coupler for isolating purpose. So amage to MOSFET is prevented. The complete hardware set up for the motor control is shown in below Fig .10

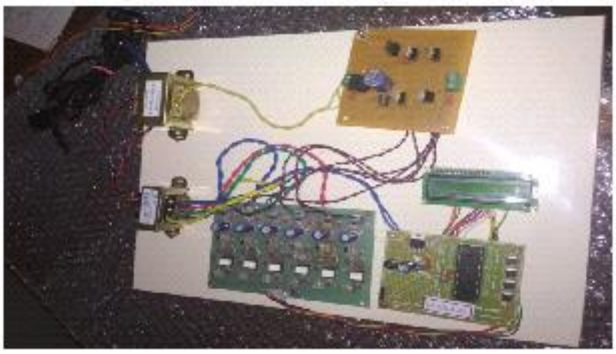


Fig.10. The complete hardware set up for the motor control

6. CONCLUSION

In this project a review of speed control methods for BLDC motors has been presented. A classification of existing methods and newer methods were presented with their merits and drawbacks to provide insight in control techniques and their benefits. To further reduce cost and increase reliability ,shaft encoders, resolvers or Hall-effect probes sensors are eliminated.

Furthermore, sensor less control is the only choice for some applications where those sensors cannot function reliably due to harsh environmental conditions and a higher performance is required.

The proposed algorithm has been programmed in MPLABIDE v 7.52. and it generates the firing pulses required to drive the MOSFETs of three phase fully controlled bridge converter. The program has been dumped on to the PIC16Fseries device and fed to the MOSFETs of three phase fully controlled bridge converter driven by IR2101 driver circuit. The output from the converter is fed to the three phase stator winding of 24V, 80 W, 1500 rpm BLDC motor and the motor is found to run at constant speed set by the external potentiometer connected to the microcontroller circuit.

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