

Development of Brushless DC Motor Drive

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ABSTRACT: *BLDC Motors have advantages over brushed DC Motors and IM. They have better speed verses torque characteristics, high dynamic response, high efficiency, long operating life, noiseless operation, higher speed ranges, and rugged construction. Also, torque delivered to motor size is higher, making it useful in application where space and weight are critical factors. With these advantages BLDC motors find wide spread application in automotive appliance, aerospace medical, and instrumentation and automation industries. In this paper, drive for speed control of BLDC motor using microcontroller PIC18F4520 was developed. For speed control sinusoidal PWM technology was implemented. Simulation was carried out using MATLAB/SIMULINK software for speed control of BLDC drive. Based on mathematical model of BLDC drive, simulation results were demonstrated. It presents the simulated waveforms fit theoretical analysis well.*

Keywords: *BLDC, MATLAB/SIMULINK, PIC 18F4520, VSI,*

I. INTRODUCTION

Brushless motor technology makes it possible to achieve high reliability with high efficiency, and for a lower cost in comparison with brush motors. Although the brushless characteristic can be apply to several kinds of motors – AC synchronous motors, stepper motors, switched reluctance motors, AC induction motors - the BLDC motor is conventionally defined as a permanent magnet synchronous motor with a trapezoidal Back EMF waveform shape. Permanent magnet synchronous machines with trapezoidal Back-EMF and (120 electrical degrees wide) rectangular stator currents are widely used as they offer the following advantages first, assuming the motor has pure trapezoidal Back EMF and that the stator phases commutation process is accurate, the mechanical torque developed by the motor is constant; secondly, the Brushless DC drives show a very high mechanical power density.

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and instrumentation.[1][2] As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. Better speed versus torque characteristics, High dynamic response, High efficiency, Long operating life, Noiseless operation, Higher speed ranges. In addition, the ratio of torque delivered to the size of the motor is higher, making it useful in applications where space and weight are critical factors. BLDC Motors are available in many different power ratings, from very small motors as used in hard disk drives to larger motors used in electric vehicles.

The purpose of this paper is to build a simple, accurate and fast running model of three phase star-connected BLDC Motor drive. Results are verified using MATLAB/SIMULINK

II. WORKING OF BLDC MOTOR

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator (fix part). Permanent magnets create the rotor flux and the energized stator windings create electromagnet poles. The rotor (equivalent to a bar magnet) is attracted by the energized stator phase. By using the appropriate sequence to supply the stator phases, a rotating field on the stator is created and maintained. This action of the rotor - chasing after the electromagnet poles on the stator - is the fundamental action used in synchronous permanent magnet motors.[2] The lead between the rotor and the rotating field must be controlled to produce torque and this synchronization implies knowledge of the rotor position.

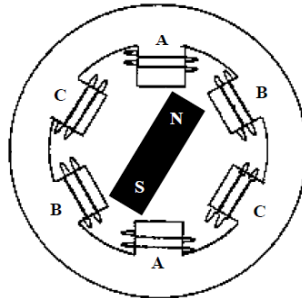


Fig.2.1 A three-phase synchronous motor with a one permanent magnet pair pole rotor

On the stator side, stator is three phase similar to induction motor These offer a good compromise between precise control and the number of power electronic devices required to control the stator currents. For the rotor, a greater number of poles usually create a greater torque for the same level of current. On the other hand, by adding more magnets, a point is reached where, because of the space needed between magnets, the torque no longer increases. The manufacturing cost also increases with the number of poles. As a consequence, the number of poles is a compromise between cost, torque and volume. [3]

Permanent magnet synchronous motors can be classified in many ways, one of these that is of particular interest to us is that depending on back-emf profiles: Brushless Direct Current Motor (BLDC) and Permanent Magnet Synchronous Motor (PMSM). This terminology defines the shape of the back-emf of the synchronous motor. Both BLDC and PMSM motors have permanent magnets on the rotor but differ in the flux distributions and back-emf profiles. To get the best performance out of the synchronous motor, it is important to identify the type of motor in order to apply the most appropriate type of control is described.

We have seen that the principle of the BLDC motor is, at all times, to energize the phase pair which can produce the highest torque. To optimize this effect the Back EMF shape is trapezoidal. The combination of a DC current with a trapezoidal Back EMF makes it theoretically possible to produce a constant torque. In practice, the current cannot be established instantaneously in a motor phase; as a consequence the torque ripple is present at each 60 degree phase commutation. [4] [5]

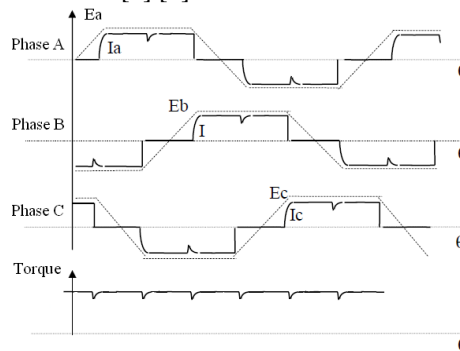


Fig 2.2 Electrical Waveforms in the Two Phase ON Operation and Torque Ripple

III. HARDWARE DESCRIPTION

3.1 Three phase inverters

BLDC Motor is controlled from three phase VSI.
 The standard three-phase VSI topology is shown in Fig. 3.1

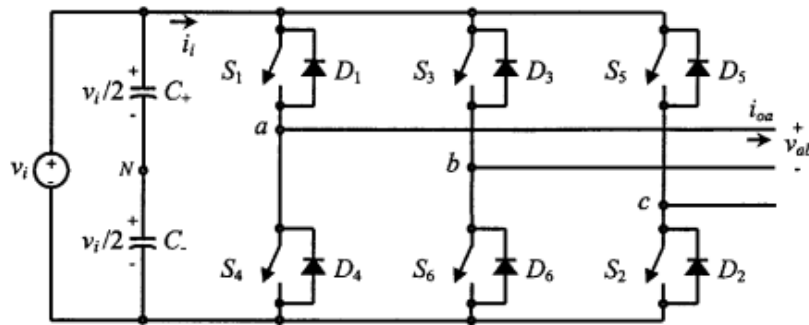


Fig 3.1 Three Phase VSI Topology

3.2 Protection Circuit:

In this, over voltage and over current detection is done by using op-amp LM311. Main transformer of 0-9VDC/30mA from which 5VDC is generated. In LM311, in built hysteresis is present. CT used are of rating 30A/30mA. When supply is given to 230V/3V PT, pin 3 is connected to LM311.Vcc of 5 VDC is present. Pull ups resistor for 3 CT and 3 PT are connected to pin no.7 of LM311.Reference voltage is set at pin 2 of LM311. This reference voltage is set for PT. So that, above set reference voltage level changed. Same way for CT and PT diodes are OR ing and given to relay.

3.3 Driver Circuit:

The SKYPER 32 PRO UL core constitutes an interface between IGBT modules and the controller. The driver is developed according to the requirements of UL standard. This core is a half bridge driver. Functions for driving, potential separation and protection are integrated in the driver. Thus it can be used to build up a driver solution for IGBT modules.

3.4 Driver performance

The driver is designed for application with half bridges or single modules and a maximum gate charge per pulse < 6.3 μC. The charge necessary to switch the IGBT is mainly depending on the IGBT’s chip size, the DC-link voltage and the gate voltage. This correlation is shown in module datasheets. It should, however, be considered that the driver is turned on at +15V and turned off at -7V. Therefore, the gate voltage will change by 22V during each switching procedure.

Unfortunately, many datasheets do not show negative gate voltages. In order to determine the required charge, the upper leg of the charge curve may be prolonged to +22V for determination of approximate charge per switch.

The medium output current of the driver is determined by the switching frequency and the gate charge. The maximum switching frequency may be calculated with the shown equations and is limited by the average current of the driver power supply and the power dissipation of driver components.

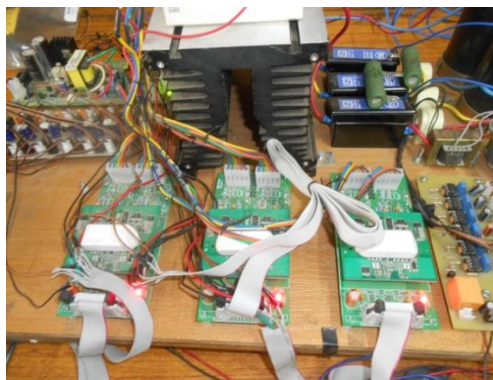
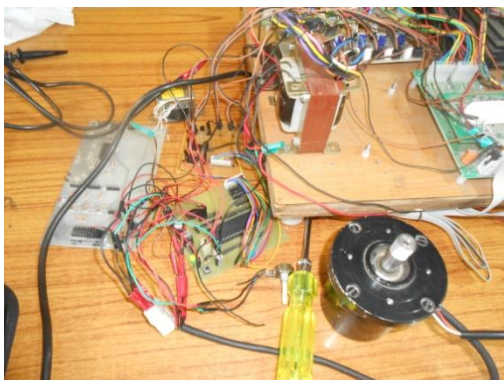


Fig.3.2 Actual Hardware Photo.

3.5 Mathematical Modeling

The BLDC motor has three stator windings and a permanent magnet on the rotor. Rotor induced currents can be neglected due to high resistivity of both magnets and stainless steel. No damper winding are modeled the circuit equation of three windings in phase variables are obtained.[6]

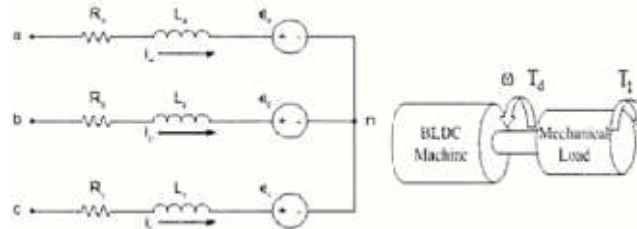


Fig 3. 3Phase BLDC machine equivalent circuit.

The voltage equation of three phases is given by,

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} L_s & 0 & 0 \\ 0 & L_s & 0 \\ 0 & 0 & L_s \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

IV. SIMULATION AND RESULTS

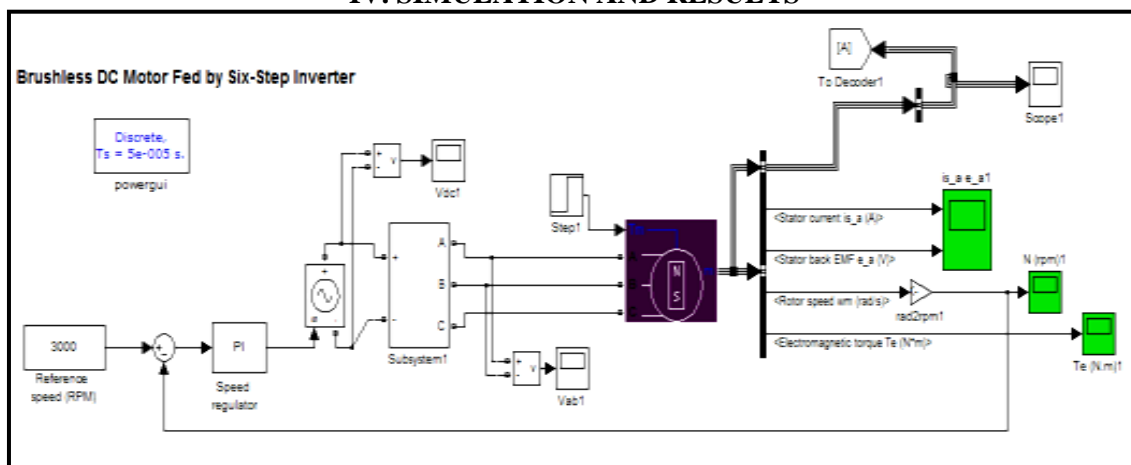


Fig 4.1 Simulation diagram

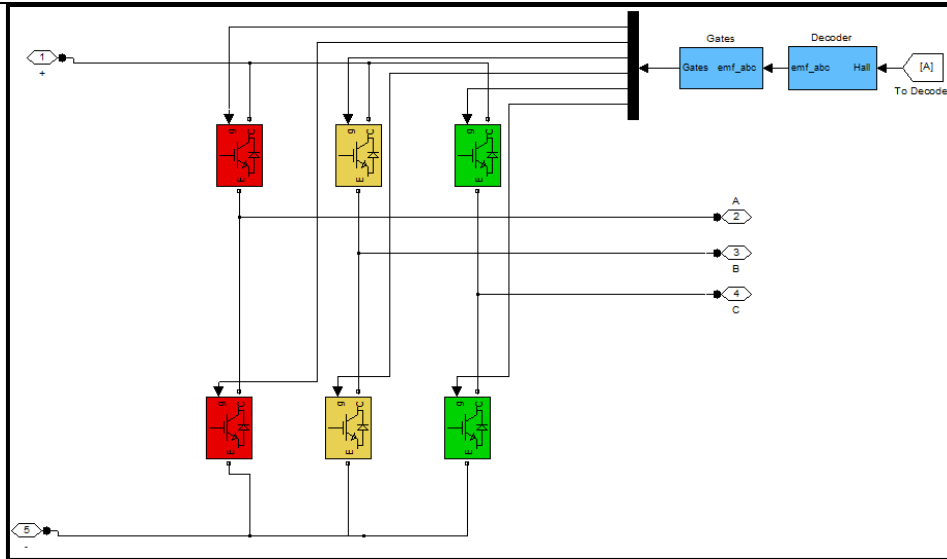


Fig 4.2 Subsystem1 block diagram

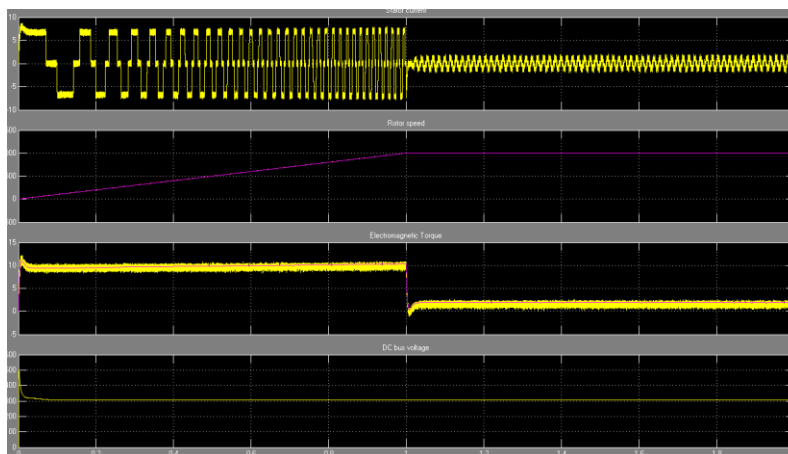


Fig.4.3 Results for stator current and electromotive force for speed 1000rpm

V. CONCLUSION

5.1 Experimental Results:

Readings took by varying voltage fed to BLDC motor and took the readings for speed.

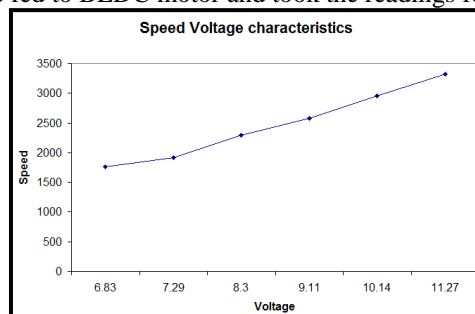


Fig 5.1 Speed-Voltage Characteristics.

From graph, it shows that as voltage increases speed also increases. The starting current of BLDC motor is high about 7-8A.

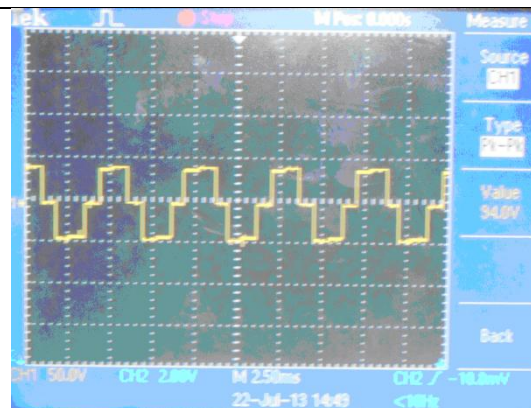


Fig.5.2 Hall A Waveform

Fig. shows output pulses from Hall sensor A when winding is excited as per the energizing sequence. When the next winding is energized in the same direction this causes shifting of magnetic field in the stator produces torque because of the development of repulsion and attraction forces which moves the rotor in clockwise direction.

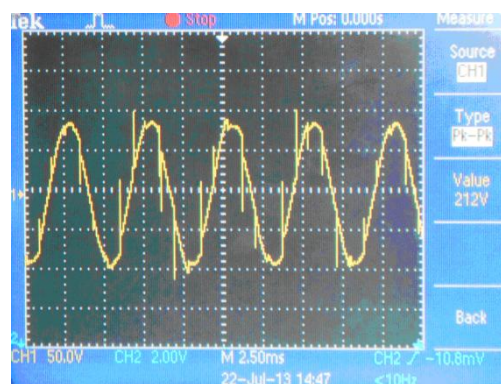


Fig 5.3 Line to line VRY waveform

In this paper, MATLAB/SIMULINK model and hardware of inverter for three phase Bldc motor was developed. The main part of the work was involved in the development of six-step inverter and its interaction with the motor. The aim was to make a model that would be simple, accurate, easy to modify. It is believed that these goals have been reached. SPWM control method for speed variation is used. The SPWM control worked very well and would in most cases be a better alternative than hysteresis band control and variable DC-link voltage control. There was, however, some steady state speed control error but the cause of it was not investigated due to time limitations. The position controller performed very well with practically zero error.

Switching frequency was used which is quite high. Such a high frequency was chosen because the motor can operate at very high speed. Such a high frequency may cause excessive switching losses but the magnitude of the losses was not investigated. Finally, only on-state losses were considered and simulation showed that even though currents and on-resistance are small, its effects are clearly noticeable. The side effects of a commutation delay showed that the delay should be kept as short as possible because the delay increases the infamous torque ripples of the BLDC Motor.

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