DESIGN DETAILS OFCONTROL CIRCUIT OF PMBLDC MOTOR USING DSP

Sreedevi S Nair

Electrical Engineering Department, FCRIT, Vashi, (India)

ABSTRACT

This paper presents the design and hardware implementation of a 50W Permanent Magnet Brushless Direct Current (PMBLDC) motor for driving a fan. The design of the entire system consists of DC supply, Boost Converter, inverter, and controllers are dealt in detail. The hardware implementation consists of a three phase inverter, 50W BLDC motor and DSP TMS32028069 for controlling the commutation sequence and thereby the operation of the motor. Experimental results are also presented.

Keywords: Boost Converter, PMBLDC

I.INTRODUCTION

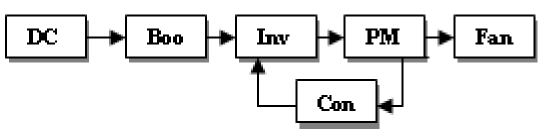
Brushless motors offer several advantages over brushed DC motors such as reduced noise, longer life (no commutator and brush assembly), more torque per watt (increased efficiency), and overall reduction of electromagnetic interference (EMI). When converting electricity into mechanical power, brushless motors are more efficient than brushed motors. Brushless motors are commonly used as pump, fan and spindle drives in adjustable or variable speed applications.

The "Bureau of Energy Efficiency"(BEE)" directs us to reduce the power consumption of consumer loads. So it is necessary to analyze energy consumption by each household loads and analyze how energy can be saved in running such equipment. One important load coming under this category is fan. Currently fans build up with an AC induction motor which is 60-70W power rated. These are heavier and less efficient, not more than 50% overall efficiency.

If a PMBLDC motor is used instead of an AC induction motor, there is a huge power saving. A 40-50% lesser power rated PMBLDC motor can provide the same amount of air flow output as given by the induction motor. A 30W PMBLDC based fan system will replace existing 60-70W power consumption with the AC induction motor.

PMBLDC motors find application in diverse fields such as domestic applications, automobiles, transportation, aerospace equipment, power tools, toys, and healthcare equipment ranging from microwatt to megawatts. Advanced control algorithm and ultrafast processor have made PMBLDC motors suitable for position control in machine tools, robotics, and high precision servos, speed control and torque control in various industrial drives and process control application [1].

The block diagram of a PMBLDC motor driving a fan is shown in Fig.1. This system consists of a DC power supply, Boost Converter, inverter, and a PMBLDC motor coupled to a fan. A DC/DC converter is used to boost the DC voltage which is required for the inverter. Fig.2[2] shows the BLDC motor and its drive considered for implementation. Three inbuilt Hall Effect sensors were used to sense the rotor position.This paper presents the design details of the entire system and the hardware implementation of the inverter and its control circuit of the PMBLDC motor. The control circuit senses the hall sensor outputs and generates the PWM pulses to activate the appropriate switches of the inverter. The control circuit includes the DSP processor TMS320F28069.



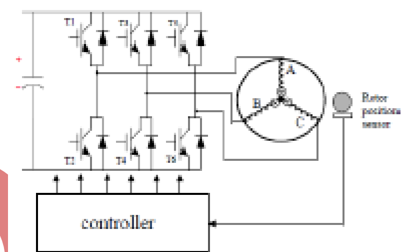


Figure1.Block Diagram of the System. **Figure 2.BLDC motor and its drive**

II.BOOST CONVERTER

The Boost Converter ratings are chosen based on the ratings of the input DC voltage and the inverter voltage. Boost Converter configuration shown in Fig.3 steps up the input voltage to the voltage required by the inverter. 10% of the input current is considered as ripple in inductor current (ΔI) and 1% of the output voltage V_o is taken as ripple in the output voltage (ΔV_o) for the boost converter . A switching frequency of 20kHz is chosen for the design and a MOSFET of suitable rating is selected as the switch (S) [3].

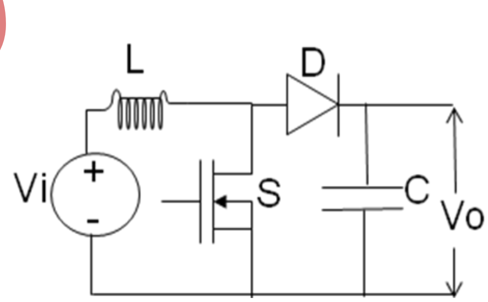


Figure 3.Boost Converter

$L \geq V_i * D * T_s / (2 * \Delta I)$ (1)

$C = D * I_o * T_S / \Delta V_o$ (2)

Here T_s and D are the switching time period and duty cycle of the switch S used in the converter. V_i is the DC input voltage which is 6V and V_o is the inverter input voltage of 12V. A value of 150µH of inductor and 300µF capacitor was designed for this work based on (1) and (2).

III. THREE PHASE INVERTER

MOSFET is selected as the power switch for the inverter because MOSFETs are more suitable for low voltage and high speed switching applications. Switching frequency is selected to be 5 KHz.

IV. PMBLDC MOTOR

The PMBLDC motors are considered as one of the best motors which exhibit the highest efficiency among all conventional motors. The popularity of PMBLDC motors are increasing day by day due to the availability of high energy density and cost effective rare earth PM materials like Samarium Cobalt (Sm-Co) and the Neodymium-Iron-Boron (Nd-Fe-B) which enhances the performance of PMBLDC drives and reduces the size and losses in these motors.

Permanent magnet brushless motors can be considered a kind of three phase synchronous motor, having permanent magnets on the rotor, replacing the mechanical commutator and the brush gear as shown in Fig.4. Commutation is accomplished by electronic switches, which supply current to the motor windings in synchronization with the rotor position. Rotor position sensing is an important part of the BLDC machine to produce torque or required power.

In a conventional DC motor, current polarity is altered by commutator and brushes. In the brushless DC motor, polarity reversal is accomplished by power transistor switching in synchronization with the rotor position. To accomplish this, the input of PMBLDC motor is connected to inverter.Inverter is designed in such a way that, its output frequency is a function of instantaneous rotor speed and its phase control will correspond to actual rotor position [4]. Typically a BLDC motor is driven by 3 phase inverter with six step commutation as shown in Fig.4. Here the conducting interval of each phase is 120º electrical angle. In order to produce maximum torque, inverter is commutated every 60º, such that current is in phase with back emf. Commutation timing is determined by the rotor position and the sequence of commutation is retained in the proper order so that the inverter performs the function of brush and commutator in the conventional DC motor to generate a rotational stator flux. At one time instant, only 2 out of 3 phases are conducting current, and one winding is floating. Since input is dc, BLDC motor is a good choice for solar powered applications. PMBLDC motor's main disadvantage is higher cost, which arises from the fact that it requires electronic controllers to run [1].

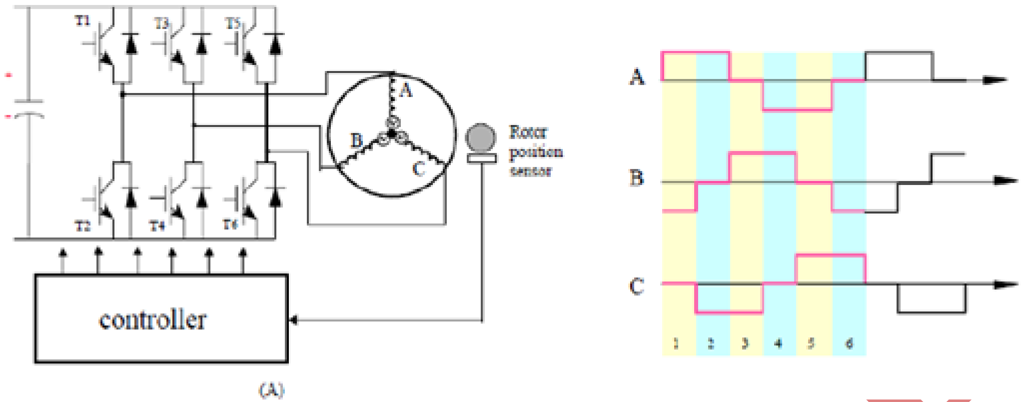


Figure 4.BLDC Motor With Its Drive And Its Three Phase Current Conducting Intervals

V. DESIGN DETAILS OF HARDWARE IMPLEMENTATION

The component selection of the entire system considered for hardware implementation is discussed below.

5.1 PMBLDC Motor

The manufacturer's specification of the 50W, 3000 rpm, 12V PMBLDC motor which is selected for our work is shown in TABLE1. The voltage constant is 3Vkrpm which is sometimes called the "Back EMF constant" (V/krpm). When the motor is operating it will generate a voltage proportional to speed which opposes the applied voltage. As the back emf approaches the supplied voltage, the motor will not have the ability to increase its rpm past that point.

Table 1. Specification of PMBLDC motor

Sr.No.	Parameters	Values
1	Motor type	3 phase 12V delta connected PMBLDC motor
2	Rated speed	3000 rpm
3	Number of poles	16
4	Stator resistance	84mΩ
5	Stator inductance	277µH
6	Voltage constant	3 V/Krpm

5.2Three Phase MOSFET Bridge

A three phase full bridge arrangement using MOSFETS is chosen for the power interface between the motor and the DSP controller. IRF260n is chosen for driving the 12V BLDC motor and the specifications of which is given below. TABLE 2 shows the specifications of IRF 260n [5].

5.3 Gate Drive

The gate drive circuit forms the interface between the DSP and the power MOSFETs.The gate drive has two purposes. First it buffers the gate signal generated by the DSP. The peak charging current required to turn on the

MOSFETs may be as high as 2amp. This is due to the high switching frequency used along with the inherent gate capacitance of the MOSFET. To turn on an N-channel MOSFET, the gate source voltage must be greater than the inherent threshold voltage i.e. Vgs>Vth. HCPL 3120 is selected as the driver IC to drive the MOSFET. For each MOSFET one driver IC is used.

Table 2. Specifications of IRF260n

IRF260n Specifications	**N Channel**
	Vdss= 200 V
	Id= 50 A
	Rds(on)=0.04Ω

5.3Digital Signal Processor (DSP)

The DSP processor used here is TMS320F28069. This DSP processor has speed up to 100 MHz. It has enhanced peripherals such as high resolution PWM module and 12 bit A/D converter with conversion speed up to 160 ns. It also has 32x32 bit multiplier, 32 bit timers and real time code debugging capability which gives all the benefits of the digital control and also allows implementation of high bandwidth.

5.4PCB Layout

The PCB layout of the six MOSFETs, six driver HCPL ICs along with buffer IC 74HC244N is made using PCB WIZARD software which is shown in Fig.5

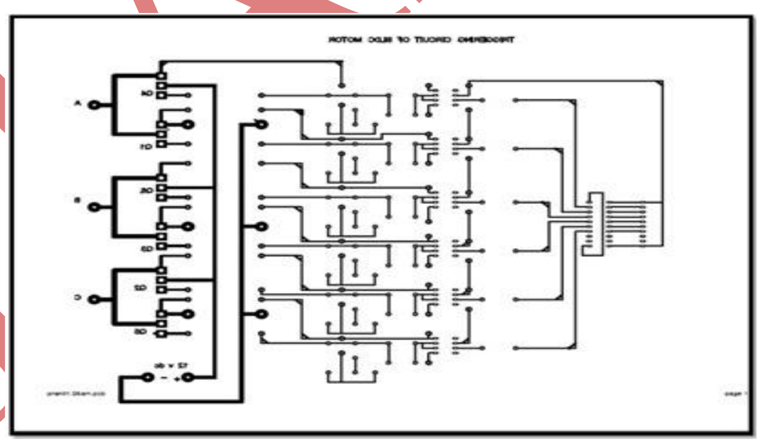


Figure 5. PCB Layout of the Control Circuit.

VI. EXPERIMENTAL RESULTS

The results of the hardware implementation of the PMBLDC motor is discussed here. The output of the inbuilt hall effect sensors were given to the DSP processor. The controller produces six PWM signals which were given to the

MOSFETs of three phase inverter. The hall effect sensors which were there in the motor was tested by using pull up resistors of 1.2kohms. Fig.6 shows the hall sensor outputs.The three phase inverter is tested with a three phase star connected resistive load of 50W, 50ohms and Fig.7 shows the three phase output voltage signals V_a,V_b, and V_c shifted in phase by 120º.

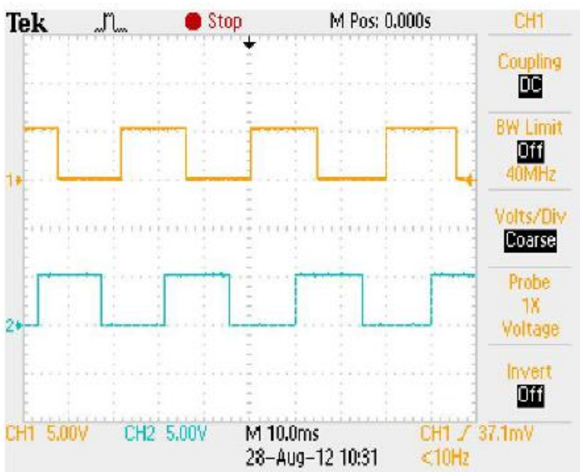


Figure 6. Hall Sensor outputs

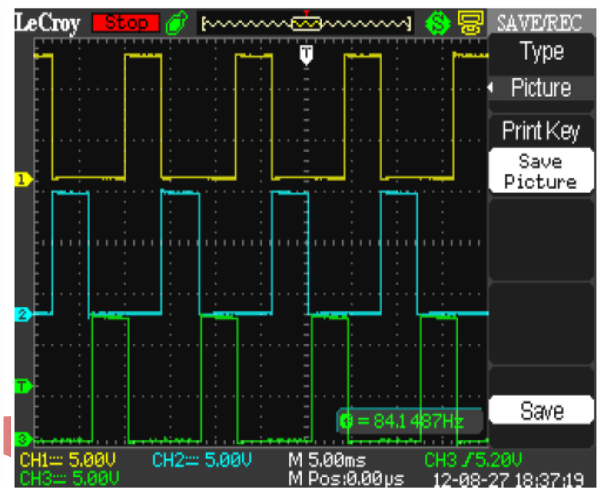


Figure 7.V_a,V_b, and V_c signals

VII. CONCLUSION

This paper presents the hardware setup of the control circuit of the 50W PMBLDC motor using DSP. Nowadays PMBLDC motors are the latest choice of researchers due to their high efficiency, maintenance free operation and compact size. Advancements in power electronics and digital signal processors have added more features to these motor drives to make them more prevalent in industrial installations.

References

[1]S.L Putta Swamy, Bhim Singh, B.P Singh and S.Murthy, *"Experimental Investigations on a PMBLDC motor fed by PV Array for Water Pumping," Journal of Solar Energy Materials and Solar Cells*, Vol 36,1995, pp:187-200

[2]Dr,A.Moussi and T.Amal.*"An Improved Efficiency PMBLDC motor for PV Pumping systems,"LARHYSS Journal*, Nov.2001

[3] Sreedevi S Nair, Mini Rajeev, "*Design and Simulation of PV Powered PMBLDC motor for water pumping," NCNTE 2012*

[4] Sreedevi S Nair "*A Survey of PV Powered BLDC motor for Water Pumping," Zenith 2010*

[5]*www.irf.com/product-info/datasheets/data/irfp260n.pdf*