SPEED CONTROL OF BRUSHLESS DC (BLDC) MOTOR USING PULSE WIDTH MODULATION (PWM) TECHNIQUE

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Abstract—This paper describes a simple way to control the speed of BLDC motor using pwm control method. A brushless DC (BLDC) motor drive is characterized by high efficiency, and higher cost, lower maintenance. So, it is necessary to have a low cost but powerful BLDC motor controller. PWM has been mostly used in power converter control. The speed is regulated by PID controller. The method proposed suppresses torque oscillations. This drive has high precision, robust operation from near zero to high speed. This paper deals with controlling method to reduce speed oscillations. Pulse width modulation control is the most powerful technique that offer simple method for controlling of analog system with processors digital output.

Keywords— Brushless DC (BLDC) motor, converters, inverter, pulse width modulation (PWM), Speed control

I. INTRODUCTION

Brushless DC motors are very popular in variety of applications. Compared with a DC Motor, the BLDC motor usage an electronic commutator. As the name indicate, BLDC motors do not use brushes for commutation instead they are electronically commutated. BLDC motors are basically synchronous motor. BLDC motors do not experience slip factor BLDC motors are comes in different configurations like single phase, 2-phase and 3-phase. Out of these, 3-phase motors are popular and widely used. Brushless DC (BLDC) motors have the advantage of higher power density than other motors such as induction motors because of having no losses of copper on the rotor side and they do not need mechanical commutation as compared with DC motors, which result in tiny and durable structures. With these features, BLDC motors have become more popular in the applications where efficiency is a critical issue, or where spikes caused by mechanical commutations are not allowed. A BLDC motor requires an rotor position sensor and inverter to perform commutation process because a permanent magnet synchronous motor do not have brushes and commutator in DC motors.

Recent development in the field of semiconductor have faster and smaller dspic controller available at low cost. The speed control of BLDC motor can be done by using PWM pulses by the dspic controller according to the programming done. PWM is a common technique for controlling electrical power for electrical device. The average value of current and voltage fed to a load is controlled by turning on and off the switch between supply and load at a fast pace. In a proportionate fashion the percentage of duty cycle from keypad is received by the dspic controller and it gives wanted output to switch the motor driver so as to vary the BLDC motor speed.

II. TYPES OF CONTROL TECHNIQUES OF BLDC MOTOR

Basically there are two techniques are available to control BLDC motor. They are sensor control and sensor less control. To control the motor using sensors, the current position of the rotor is need to determine the next commutation interval. In BLDC motors the commutation is done by electronic switches which need the rotor position. The proper stator windings have to be energized when rotor poles align with the stator winding. The BLDC motor also drive with predefined commutation interval. But to achieve appropriate speed control and maximum generated torque, BLDC commutation should be done with the knowledge of rotor position. In control methods using
sensors, mechanical position sensors, such as a hall sensor, shaft encoder or resolver have been used in order to provide rotor position information. In sensor less control BLDC motors can be commutated by monitoring the back EMF signals instead of the Hall sensors. Back EMF is proportional to the speed of rotation, at a very low speed, the back EMF would be at a very low amplitude to detect zero-crossing. The motor has to be started in open loop, from standstill and when sufficient back EMF is built to detect the zero cross point, the control should be shifted to the back EMF sensing. The minimum speed at which back EMF can be sensed is calculated from the back EMF constant of the motor. With this method of commutation, the Hall sensors can be eliminated and in some motors, the magnets for Hall sensors also can be eliminated. This simplifies the motor construction and reduces the cost as well.

III. OPERATING PRINCIPLE

BLDC motors are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotates at the same frequency. BLDC motors do not experience the “slip” that is normally seen in induction motors. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know that the rotor position in order to understand which winding will be energized. The rotor is made up of permanent magnets and it varies from two to eight poles with alternate North (N) and South (S) poles. Based on required magnetic field density in the rotor, proper magnetic materials are chosen to make the rotor. Rotor position is sensed by using the Hall effect sensors which are embedded into the stator on the non-driving end of the motor. When the rotor magnetic poles pass near the Hall effect sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. On the basis of combination of these three hall sensor signals, the exact sequence of commutation can be determined.

Back EMF

There are two types of stator windings variants: trapezoidal and sinusoidal motors.

**Fig. 1.** Back EMF for trapezoidal motor

**Fig. 2.** Back EMF for sinusoidal motor

**Transverse section of BLDC motor**

**Fig. 3.** Three hall sensors
In the figure 3 the three hall sensors can be shown in the non-driving end of the stator of motor. The stator winding are inside out which are normally opposite in case of brushed DC motor, this exceptional construction helps the motor to keep it cool for a long time, and if at all external setup is required to cool the motor it can be easily installed, flowing of cold water is one of them.

III. THEORY OF OPERATION

A three-phase BLDC motor requires three Hall sensors to detect the rotor’s position. Based on the physical position of the Hall sensors, there are two types of output: a 60° phase shift and a 120° phase shift. Combining these three Hall sensor signals can determine the exact commutation sequence. Three Hall sensors—“a,” “b,” and “c”—are mounted on the stator at 120° intervals, while the three phase windings are in a star formation. For every 60° rotation, one of the Hall sensors changes its state; it takes six steps to complete a whole electrical cycle. In synchronous mode, the phase current switching updates every 60°. For each step, there is one motor terminal driven high, another motor terminal driven low, with the third one left floating. Individual drive controls for the high and low drivers permit high drive, low drive, and floating drive at each motor terminal. However, one signal cycle may not correspond to a complete mechanical revolution. The number of signal cycles to complete a mechanical rotation is determined by the number of rotor pole pairs. Every rotor pole pair requires one signal cycle in one mechanical rotation. So, the number of signal cycles is equal to the rotor pole pairs.

Fig. 4. Winding energizing sequence

Fig. 5. Circuit diagram of the BLDC motor with inverter and the DSPIC Controller
TABLE I CW FROM BACK END

| Hall Sensor | Switches | Phase Current |
|-------------|----------|---------------|
|             | A B C    | On            |
| A B C       | A B C    | A B C         |
| 0 0 1       | Q1 Q6    | + OFF         |
| 0 0 0       | Q1 Q5    | + - OFF       |
| 1 0 0       | Q3 Q5    | OFF - +       |
| 1 1 0       | Q3 Q4    | - OFF +       |
| 1 1 1       | Q2 Q4    | - + OFF       |
| 0 1 1       | Q2 Q6    | OFF + -       |

TABLE III CCW FROM BACK END

| Hall Sensor | Switches | Phase Current |
|-------------|----------|---------------|
|             | A B C    | On            |
| A B C       | A B C    | A B C         |
| 0 1 1       | Q3 Q5    | OFF - +       |
| 1 1 1       | Q1 Q5    | + - OFF       |
| 1 1 0       | Q1 Q6    | + OFF -       |
| 1 0 0       | Q2 Q6    | OFF + -       |
| 0 0 0       | Q2 Q4    | - + OFF       |
| 0 0 1       | Q3 Q4    | - OFF +       |

IV. CONCLUSIONS

In conclusion, BLDC motors has advantages over brushed DC motor and induction motors. They have better speed versus torque characteristics, high dynamic response, high efficiency, long operating life, noiseless operation, higher speed ranges, rugged construction and so on. Also the torque delivered to the motor size is higher, making it useful in applications where space and weight are critical factors.

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