Chapter 3
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PMBLDC Motor

3.1 Introduction

This chapter discusses the principle of operation, constructional details, advantages, disadvantages and applications, of the permanent magnet brushless dc motor. Basically, the PMBLDC motor consists of a permanent magnet rotor, three-phase stator windings and position and speed sensors. The motor is fed from a three phase inverter, whose frequency and phase are synchronized with the rotor position, so that locking of the stator magnetic field and rotor flux is ensured at all speeds. Permanent magnet motors are becoming popular with sustained cost reduction and improvements in properties of permanent magnet materials like Samarium-Cobalt and Neodymium-Iron-Boron (Nd-Fe-B). Advances in high-energy permanent magnet materials and power electronic devices and circuits have widely enhanced the application of PMBLDC machines in variable speed drives. Also the robust construction and maintenance free operation of PMBLDC motors increase its acceptability as variable speed drives in industry.
3.2 Constructional Details

A PMBLDC Motor operates like a synchronous machine when driven by a six-step inverter. Unlike a conventional dc motor, a brushless dc motor has a stationary armature and rotating field poles. The field poles consist of permanent magnets mounted on the inside of a steel cylinder, and the armature is wound on a sector shaped laminated iron structure. The brushless dc motor is truly an inside out dc commutator motor with the mechanical commutator replaced by an electronic switching converter. With switched dc in this three phase windings, the stator mmf wave does not rotate at constant speed, and this is an important difference between the brushless dc motor and ac permanent magnet synchronous motor. The brush and commutator arrangement in a dc motor is replaced by magnetic coupling between the stator winding and the permanent magnet rotor, which is the reason for the Hall-motor's smooth noise free operation and long life. A sectional view of the PMBLDC motor [84] is shown in figure 3.1.

![Sectional view of a PMBLDC motor](image)
The permanent magnets used in the motor are constructed of a highly stable material and will not get demagnetized under normal operating conditions. As the motor rotates, the permanent magnets activate the Hall-elements, which control the motor drive currents that flow through the stator windings. The absence of rotor excitation requires that the control of the permanent magnet synchronous motor be done entirely by the stator currents [6], [7].

3.3 Principle of Operation

The three-phase stator windings when energized create a revolving magnetic field, which interacts with the permanent magnet rotor field to produce rotation. For maintaining a unidirectional torque in such a motor, rotor position sensing is required. The principle employed here consists of continual sensing of rotor position using Hall-effect sensors and slave the switching frequency and phase to the instantaneous rotor position. By sequential switching of the stator field coils using the above signals, a unidirectional torque is maintained.

There are three main sources of torque production in PMBLDC motors viz. cogging torque, reluctance torque and mutual torque. Cogging torque is created by the stator slots interacting with the rotor magnetic field and is independent of stator current excitation. Reluctance torque is caused by the variation of the phase inductance with respect to rotor position. Mutual torque is created by the mutual coupling between stator winding currents and the magnetic field.

In general, surface mounted magnets are used in many high performance PMBLDC motors. As the permeability of the magnet material is nearly equal to that
of air, the effective air gap is enlarged by the magnet. This fact ensures minimum armature effect on the rotor field by the stator currents. If the motor is designed with low saliency and either the stator slots or rotor magnets are skewed by one slot, the effects of the first two torque components can be greatly reduced. Therefore, if the waveforms of the phase back emf and phase currents are perfectly matched, torque ripple is minimized and the mutual torque component is maximized. The PMBLDC motor uses Hall-effect principle for rotor position sensing and hence it is called a Hall-effect motor [84], [85].

3.4 Advantages and Disadvantages

Specially designed low inertia PMBLDC motors fed from a PWM inverter provide highly desirable features of drive such as large power/weight ratio, high torque/current ratio, smaller size, better efficiency, fast response and zero steady state error. Some of the attractive features that make it useful in industry and in servo and robotic applications are given below [86], [87].

1. The absence of brushes results in an essentially maintenance free operation and eliminates the undesirable effects of commutation such as spark, brush wear, radio frequency interference, etc.

2. Low inertia of the rotor enhances the quality of the mechanical response of the motor, shortening the acceleration and deceleration times.

3. Utilizing rare earth permanent magnet materials with high coercive force results in substantially higher power/weight ratio as compared to
conventional dc motors. The efficiency is high since there is little hysteresis loss, eddy current loss and rotor copper loss.

4. The armature windings of the PMBLDC motor are located in the stator frame resulting in higher dissipation of heat, which enables operation at higher current density.

5. Because of the absence of commutator segments, the stator construction is simpler.

6. The rotor poles of the PMBLDC motor are made up of permanent magnets and hence no source of power is required for excitation.

7. The efficiency of the motor is high due to minimum armature losses resulting from strong magnetic field and negligible loss in the rotor.

8. Rating of the motor ranges from fractional kW to 200 kW.

The disadvantages of the motor are high initial cost and increased complexity in the electronic controller. Further, no means of control is available on the rotor side.

3.5 Applications

In Industry, PMBLDC motors find applications in [86, [88] textile industries, steel plants, compressors, conveyors, cement kilns, wire drawing machines, sugar mills, machine tools, punch and stamping machines, lifts, printing machines, paper mills, etc. Domestic applications of the motor include fans, pumps, videotapes, capstan drives in VCRs, etc. PMBLDC motors are useful in high tech applications such as computer peripherals, aerospace applications, guided vehicles, etc.
3.6 Conclusion

The constructional details, principle of operation, advantages, disadvantages and applications of the PMBLDC motor in various areas are discussed in this chapter, which reveals the importance of the machine in all areas of our society. Analysis of the drive system including derivation of relationship between the machine parameters and dc link voltage of the inverter using Fourier series analysis and Park’s transformation, torque balance equation, etc are discussed in the next chapter.