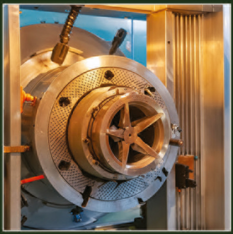
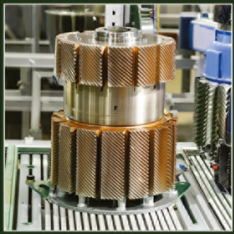
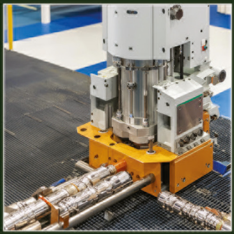
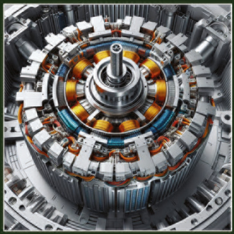

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Martin Scrivener (martin@scrivenerpublishing.com)
Phillip Carmical (pcarmical@scrivenerpublishing.com)

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Preface

In the developing landscape of electrical engineering and motor technology, the demand for specialized machinery custom-made to exact application requirements has never been more dominant. This book is an endeavour to link the knowledge gap often found in the traditional discourse on motor technologies, focusing instead on a spectrum of specialized machines that are progressively pivotal in a variety of applications. From Switched Reluctance Motors to PMSM Motors and beyond, this text delves into the operational principles, applications, and control mechanisms of machines that, while critical, have received less attention in mainstream engineering literature.

The majority of texts available to students, professionals, and enthusiasts alike tend to concentrate on conventional motors and their controls, such as Induction Motors, Synchronous Motors, and Transformers, to name a few. These resources, while invaluable, often overlook the nuanced and innovative approaches being applied to specialized motors designed to meet specific operational criteria.

The book intention is not merely to introduce these machines but to offer a deep dive into their operating principles, highlighting how these principles are applied across a range of applications and how they can be harnessed through sophisticated control strategies. This approach ensures that readers are not just encountering another catalog of motor types but are being equipped with the understanding necessary to innovate, design, and optimize these machines for their unique requirements.

The subsequent chapters are meticulously organized to ensure both a seamless understanding and comprehensive coverage of the material. The journey begins in Chapter 1 with an exploration of the Brushless Direct Current (BLDC) Motor, a technology that has found widespread application in both the electric vehicle (EV) and machinery industries due to its efficiency and reliability. Following this, Chapter 2 delves deeply into the workings of the Permanent Magnet Synchronous Machine (PMSM), offering detailed insights into a technology that plays a critical role in modern electrical engineering.

In Chapter 3, attention shifts to the Hysteresis Motor, providing a thorough examination of its principles and applications. This sets the stage for Chapter 4, where the spotlight is on the Switched Reluctance Motor (SRM), identified as one of the most promising technologies in the field for its robustness and versatility.

Moving forward, Chapter 5 focuses on the Stepper Motor, highlighting its significance in the renewable energy sector, particularly in solar and wind applications, due to its precise control and reliability. Chapter 6 addresses the Universal Motor, exploring its unique ability to operate on both AC and DC power supplies, making it indispensable in a wide range of household and industrial devices.

Finally, Chapter 7 culminates the discussion by analysing torque pulsation, a critical aspect for optimizing the performance and efficiency of electric motors. This analysis not only ties together the concepts discussed in the preceding chapters but also underscores the importance of addressing this challenge in the design and application of electric motors.

This book is the zenith of extensive research, practical insights, and a deep passion for the field of motor technology.

Jigneshkumar P. Desai

1

Brushless Direct Current Motor

Jitendra G. Jamnani

Department of Electrical Engineering School of Energy Technology, Pandit Deendayal Energy University, Raisan, Gandhinagar, Gujarat, India

Abstract

The development of permanent magnet materials with high magnetic energy product lead to the development of dc machines with Permanent magnet field excitation. A BLDC motor is a motor having stator similar to a synchronous motor and permanent magnets in the rotor, operates in self-controlled mode by the use of position sensors to detect rotor poles and an inverter for controlling the phase currents of stator winding.

In conventional dc motor, the commutator and brushes are needed, which are subjected to wear and require maintenance. In BLDC motor, the function of commutator and brushes are implemented by using semiconductor power switches and digital controllers and hence maintenance free motor can be released. This motor is called BLDC motor. The rotor position sensors and the semiconductor power switches in the inverter performs the role of the commutator and brushes of the conventional dc motor. A conventional dc motor has stationary field system which consists of field magnets. It produces magnetic field in the machine. The armature is rotating part and it is the rotor. The armature is free to rotate between the field poles and it is mounted on the shaft. The construction of BLDC motor is similar to the AC motor called Permanent Magnet Synchronous Motor (PMSM).

The brushless dc motors offer many advantages as compared to conventional dc motors. BLDC motors have small size rotor, high power density, low inertia, higher efficiency and requires lower maintenance. High speed and torque capability because of absence of commutator and brushes.

Presently BLDC motors are the significant contributors for the modern drive technology. They are used for a wide variety of applications in the fields of Electric vehicles, hybrid vehicles, robotics, computer disk drives, servo drives, DVD players, fans, washing machines, pumps, blowers, compressors, Industrial robots and CNC machine tools etc.

Email: jg.jamnani@sot.pdpu.ac.in

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***Keywords*:** Brushless DC motors, position sensors, permanent magnet, permanent magnet synchronous motor (PMSM), BLDC drive

1.1 Brushless DC (BLDC) Motors

A BLDC motor is a motor having stator similar to a synchronous motor and permanent magnets in the rotor, operating in self-controlled mode by the use of position sensors to detect rotor poles and an inverter for controlling the phase currents of stator winding.

In conventional dc motor, the commutator and brushes are needed, which are subjected to wear and require maintenance. In BLDC motor, the function of commutator and brushes are implemented by using semiconductor power switches and digital controllers and hence maintenance free motor can be released. This motor is called BLDC motor. The rotor position sensors and the semiconductor power switches in the inverter performs the role of the commutator and brushes of the conventional dc motor [1].

1.2 Construction of Brushless DC (BLDC) Motors

The construction of BLDC Motor is shown in Figure 1.1. A BLDC Motor has two main parts: A stator- stationary part and a rotor – a rotating part. The stator consists of stator core and 3-phase AC distributed winding. The windings are similar to those in synchronous motor.

The construction of modern BLDC motor is similar to the AC motor called PMSM. The construction of PMSM is the same as conventional

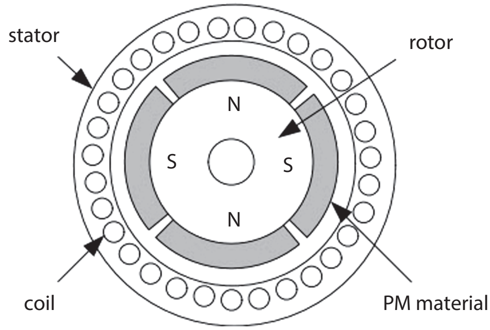

Figure 1.1 Construction of BLDC motor.

synchronous motor, but the only difference is with the rotor. The rotor consists of permanent magnets to create field poles instead of wound field winding.

Instead of wound field for the rotor, permanent magnets are mounted for creating rotating magnetic field. Since no dc supply is needed for exciting the rotor poles, these motors are very simple, robust, reliable and low cost.

The PMSM are very reliable, brushless, robust and gives very fast response when compared to the conventional motors. It produces ripple free torque, lower noise and suitable for high-speed applications.

1.3 Brushless DC Motor Drive System

The main parts of a BLDC drive system are shown in the schematic block diagram of Figure 1.2. The drive motor has three elements: stator, a rotor carrying a permanent magnet excitation system and a non-contacting means of sensing rotor position (rotor position sensors).

For a 3 phase motor supplied from a six-step power conditioner, the operation of the system is as follows:

The control circuit receives information on the position of rotor from the position sensors. This is then translated into one of six current states as shown in Figure 1.4. Each current pulse produces an EMF in the stator which remain fixed in space for 60^0 electrical until the next current state. Once the rotor completes 60° electrical rotation, the phase currents are ideally switched instantaneously into the next state. This results in a step of armature emf of 60° in the direction of rotation. This process will be repeated six times per electrical revolution resulting in a discretely emf and continuous rotation.

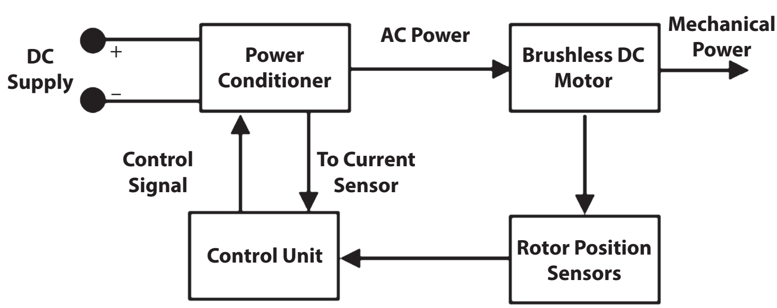

Figure 1.2 Schematic block diagram of brushless DC drive system.

The BLDC motor operates in the same way as self-controlled synchronous motor. The semiconductor power switches in the inverter controls the motor current are commutated by the back emf of the motor.

Nowadays, the inverter which consists of semiconductor power switches such as IGBTs or MOSFETs are used. The ON and OFF states of power switches are controlled by the gate signals, that can be obtained from rotor position sensors.

Figure 1.3 shows an inverter configuration which is fed from dc source and used for a BLDC drive system. The turn-on and off instants for the power swithes are controlled by rotor position sensors such that the angle between the rotor and stator field is regulated at 90°. The waveforms of the stator phasecurrents are shown in Figure 1.4.

On every 60^0 electrical the inverter switches will be turned on, the power switches are given numbers in the sequence in which they are turned ON. If the inverter is suppled from a DC voltage (VSI), the PWM of the individual switches can provide the control of the motor phase current [2].

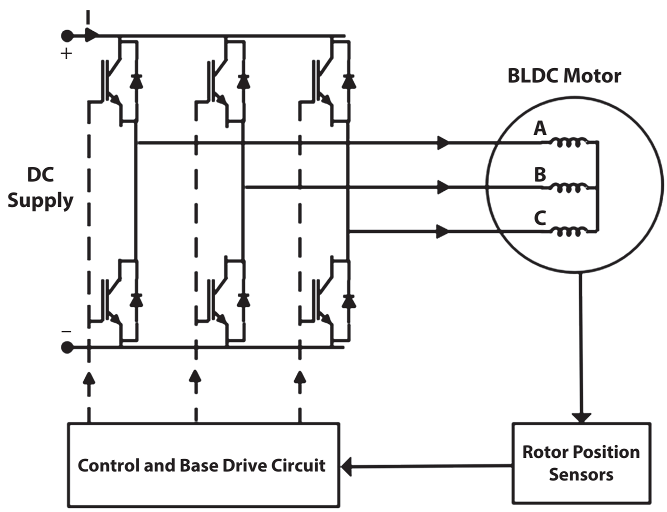

Figure 1.3 Brushless dc motor drive system.