3.4 PERMANENT MAGNET MOTOR DRIVE

The permanent-magnet synchronous machine (PMSM) drive is one of best choices for a full range of motion control applications. For example, the PMSM is widely used in robotics, machine tools, actuators, and it is being considered in high-power applications such as industrial drives and vehicular propulsion. It is also used for residential/commercial applications. The PMSM is known for having low torque ripple, superior dynamic performance, high efficiency and high power density. Section 1 deals with the introduction of PMSM and how it is evolved from synchronous motors. Section 2 briefly discusses about the types of PMSM. Section 3 tells about the assumptions in PMSM for modeling of PMSM and it derives the equivalent circuit of PMSM. In Section 4, permanent magnet synchronous motor drive system is briefly discussed with explanation of each blocks in the systems. Section 5 reveals about the control techniques of PMSM like scalar control, vector control and simulation of PMSM driven by field-oriented control using fuzzy logic control with space vector modulation for minimizing torque ripples. PMSM control with and without rotor position sensors along with different control techniques for controlling various parameters of PMSM for different applications.

The electric motors are electromechanical machines, which are used for the conversion of electrical energy into mechanical energy. The foremost categories of AC motors are asynchronous and synchronous motors. The asynchronous motors are called singly excited machines, that is, the stator windings are connected to AC supply whereas the rotor has no connection from the stator or to any other source of supply. The power is transferred from the stator to the rotor only by mutual induction, owing to which the asynchronous motors are called as induction machines.

The synchronous motors require AC supply for the stator windings and DC supply for the rotor windings. The motor speed is determined by the AC supply frequency and the number of poles of the synchronous motor, the rotor rotates at the speed of the stator revolving field at synchronous speed, which is constant. The variations in mechanical load within the machine's rating will not affect the motor's synchronous speed

One of the types of synchronous motor is the PMSM. The PMSM consists of conventional three phase windings in the stator and permanent magnets in the rotor. The purpose of the field windings in the conventional synchronous machine is done by permanent magnets in PMSM. The conventional synchronous machine requires AC and DC supply, whereas the PMSM requires only AC supply for its operation. One of the greatest advantages of PMSM over its counterpart is the removal of dc supply for field excitation as discussed in.

The development of PMSM has happened due to the invention of novel magnetic materials and rare earth materials. PMSM give numerous advantages in scheming recent motion management systems. Energy efficient PMSM are designed due to the availability of permanent magnet materials of high magnetic flux density.

In synchronous motors the rotor rotates at the speed of stator revolving field. The speed of the revolving stator field is called as synchronous speed. The synchronous speed (ωs) can be found by the frequency of the stator input supply (fs), and the number of stator pole pairs (p). The stator of a three phase synchronous motor consists of distributed sine three phase winding, whereas the rotor consists of the same number of p-pole pairs as stator, excited by permanent magnets or a separate DC supply source as given.

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When the synchronous machine is excited with a three phase AC supply, a magnetic field rotates at synchronous speed develops in the stator. The synchronous speed of this rotating magnetic field is shown by the Eq. (1).

N=(120fs)/Prpm

where N, synchronous speed, fs , frequency of AC supply in Hz; P, number of poles; p, pole pairs and it is given by (P/2).

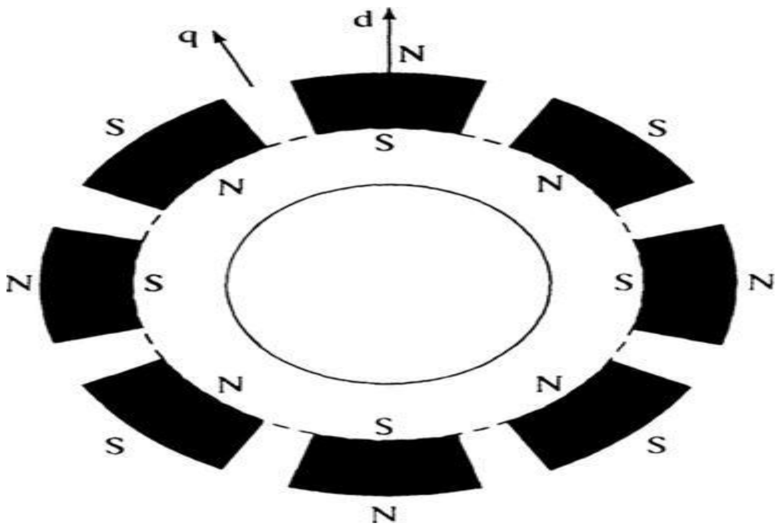
Types of PMSM

The PMSM are classified based on the direction of field flux are as follows,

1. Radial field
2. Axial field

In radial field, the flux direction is along the radius of the machine. The radial field permanent magnet motors are the most commonly used. In axial field, the flux direction is parallel to the rotor shaft. The axial field permanent magnet motors are presently used in a variety of numerous applications because of their higher power density and quick acceleration.

The permanent magnets can be placed in many different ways on the rotor of PMSM as discussed in [3, 4]. Figures 1 and 2 show the permanent magnets mounted on the surface of the outer periphery of rotor laminations. This type of arrangement provides the highest air gap flux density, but it has the drawback of lower structural integrity and mechanical robustness. Machines with this arrangement of magnets are known as Surface mount PMSMs.



One other types of placing the permanent magnets in the rotor, is embedding the permanent magnets inside the rotor laminations. This type of machine construction is generally referred to as Interior PMSM and it is shown in Figures 3 and 4 .

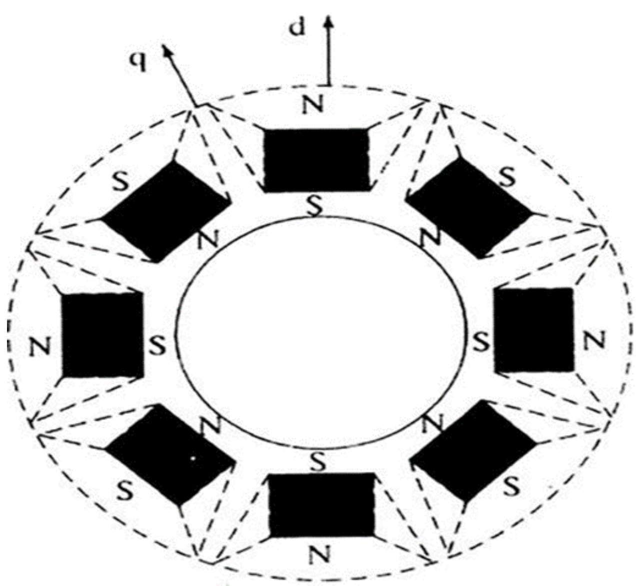


Figure 3.Interior permanent magnet.

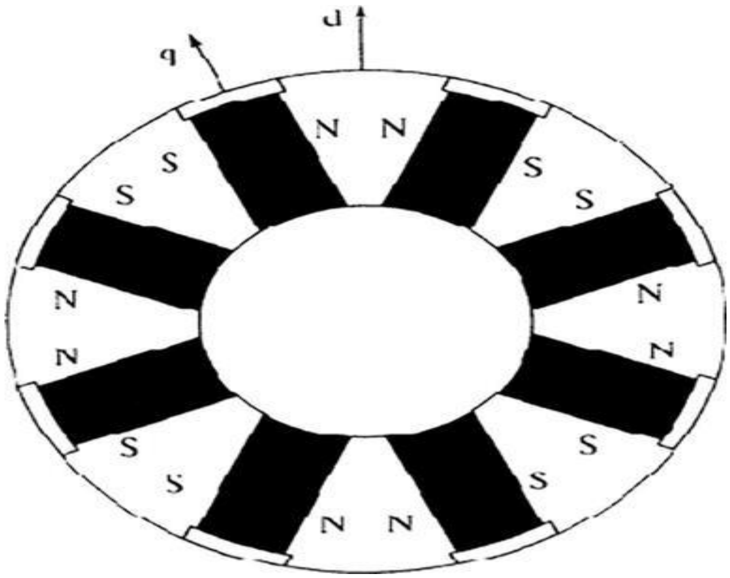


Figure 4.Interior permanent magnet with circumferential orientation.

The development of this arrangement is more difficult than the surface mount or inset magnet permanent magnet rotors. The inset permanent magnet rotor construction has the advantages of both the surface and interior permanent magnet rotor arrangements by easier construction and mechanical robustness, with a high ratio between the quadrature and direct-axis inductances, respectively.

The surface PMSM with radial flux are generally applied for applications which require low speed operations. These machines have the advantage of high power density than the other types of PMSM. The interior PMSM are used for applications which require high speed.

The principle of operation is identical for all the types of PMSM, in spite of the types of mounting the permanent magnets in the rotor.

The important significance of the type of mounting the permanent magnets on the rotor is the variation in direct axes and quadrature axes inductance values, which is explained below. The primary path of the flux through the permanent magnets rotor is the direct axis. The stator inductance when measured in the position of permanent magnets aligned with stator winding is called as direct axis inductance. The quadrature axis inductance is measured by rotating the magnets from the already aligned position (direct axis) by 90°, in this position the iron (inter polar area of the rotor) sees the stator flux. The flux density of the permanent magnet materials is presently high and its permeability is almost equal to that of the air, such that the air gap between the rotor and stator of PMSM can be treated as an extension of permanent magnet thickness. The reluctance of direct axis is always greater than the quadrature axis reluctance, since the effectual air gap of the direct axis is several times that of the real air gap looked by the quadrature axis.

The significance of such an uneven reluctance is that the direct axis inductance is greater than the quadrature axis inductance and it is shown in Eq. (2).

Ld>LqLd>Lq E2

where Ld is the inductance along the direct to the magnet axis and Lq is the inductance along the axis in quadrature to the magnet axis.