# Permanent Magnet Synchronous Motor & Control Schemes

# Glossary for PMSM

| | |
|---|---|
| B | friction and windage constant |
| $i_{r1}, i_{r2}, i_{r3}$ | instantaneous values of the currents in the rotor phase coils |
| $i_{s1}, i_{s2}, i_{s3}$ | instantaneous values of the currents in the stator phase coils |
| $\underline{i}^r_r$ | space phasor of rotor currents in rotor co-ordinates |
| $\underline{i}^s_s$ | space phasor of stator currents in stator co-ordinates |
| $\underline{i}^r_s$ | space phasor of stator currents in rotor co-ordinates |
| $\underline{i}^s_r$ | space phasor of rotor currents in stator co-ordinates |
| $i_{sa}, i_{sb}$ | components of the stator current space phasor in stator frame reference |
| $i_{ds}, i_{qs}$ | d and q axis components of the stator current |
| $i_{smax}$ | maximum permissible amplitude of stator current space-phasor |
| $I_F$ | equivalent current source representing MMF of the rotor magnet |
| $K_E$ | back EMF constant of PMSM |
| $K_T$ | torque constant of PMSM |
| $L_o$ | magnetising inductance of the airgap |
| $L_s$ | self inductance of the stator winding |
| P | Number of poles |
| $R_s$ | stator resistance per phase |
| $u_{sa}, u_{sb}$ | components of the stator voltage space-phasor in stationary co-ordinates |
| $u_{ds}, u_{qs}$ | d and q axis components of stator voltage |
| $\omega_r$ | angular speed in mechanical radians/sec |
| $\omega_s$ | ngular speed in electrical radians/sec |
| $\omega_{rmax}$ | maximum speed |
| $\in$ | instantaneous position of the rotor with respect to the stator reference axis (electrical radians) |
| $\lambda_f$ | stator flux linkage due to the rotor magnet |

# 1 Overview

## 1.1. Variable Speed AC Drives

Many industrial applications need variable speed electric drives. These applications have traditionally been served by DC motors because of their better controllability. Since DC motors, inherently, provide an independent torque and speed control, they were considered to be more easily tractable than AC motors. However, DC motors have certain disadvantages due to presence of commutator and brushes. They require periodic maintenance; they cannot be used in explosive or corrosive environments and they have limited commutator capability under high-speed, high-voltage operational conditions.

These problems are absent in alternating current - AC motors. AC motors have simple and rugged structure, high maintainability and economy; they are also robust and immune to heavy overloading. The small dimension of AC motors compared with that of DC motors allows AC motors to be designed for substantially higher output ratings. The high cost of the efficient, fast switching frequency inverters restricted the use of AC motors to applications where DC motors were not suitable because of working environment or commutator limits.

However, developments in the areas of power semiconductor devices and microelectronics, and the advances in control techniques have made efficient variable speed AC motors a viable alternative.

## 1.2. Vector Control Of AC Motors

The torque control in AC motors is achieved by controlling the motor currents. Unlike in DC motors, both the modulus and the phase angle of the current have to be controlled in AC motors *i.e.,* . the current vector has to be controlled. With vector control of AC motors, the torque- and flux- producing current components are decoupled and the transient response characteristics are similar to those of a separately excited DC motor. The system will adapt to any load disturbances and/or reference value variations as fast as a DC motor.

The AC motors available for variable speed applications are:

1. Induction Motors
2. Permanent Magnet Synchronous Motors (PMSM)

**INDUCTION MOTORS VS PMSM**

Induction motors have many advantages over the DC motors with regard to robustness, inertia, speed range, power ratings, maintenance, and cost. However they draw magnetizing current from the power supply resulting in a low power factor. This results in some rotor losses too.

In the case of PMSMs the excitation is derived from the permanent magnets in the rotor. Hence there is no magnetizing current.

**ADVANTAGES OF PMSM**

The advantages of the PMSMs over the induction motors are therefore,

1. Higher Efficiency
2. Higher Torque to Inertia Ratio
3. Higher Power Density; Compact Size

PMSMs are preferred for certain high performance applications such as industrial robots, aerospace actuators, machine tool drives, etc., where fast dynamic response is required.

## 1.3. DSP Control Of Motors

With the advent of fast digital signal processors like ADSP-2101, the traditional analog controller is being replaced by digital controllers. The major factor contributing towards this trend is the availability and lower costs of digital signal processors.

The analog implementation of controller with the complexity of a vector controller is an arduous task. The number of controller parameters involved is so high that tuning becomes a formidable exercise in analog controllers.

In a DSP based controller, the controller is implemented by executing a software (a set of difference equations written in assembly language). The consequent advantages of doing so are as follows.

1. A control strategy can be changed easily without changing hardware.
2. Undesirable mechanical behavior can be cancelled or compensated by appropriate software.
3. The undesirable performance of a sensor and a controller can be cancelled or compensated.
4. It is easy to construct a large-scale control system ( a distributed control system ), since a servo system has its own computer and this can communicate with either a host or another computer.
5. A system so constructed has reduced size and weight, and is cheap.
6. The system achieves greater reliability, maintainability, and testability.
7. The system gains increased noise immunity.
8. Sophisticated control algorithms can be realized for higher control performance.

## 1.4. Summary

AC motors are fast replacing the DC motors in variable speed drive applications. The vector control scheme has made possible the control of AC motors to achieve the same dynamic performance as a DC motor drive. Of the AC motors available, PMSMs have certain advantages over the others. It is better to have a DSP based controller rather than an analog controller for this kind of application.