Motor Types and Their Control

Summary of key motor types and control

Overview

Freescale provides comprehensive motor control solutions for almost all electric motor topologies.

Motor Control Application Requirements

- Minimize energy losses
- Prevent environment pollution
- Decrease acoustic noise and power harmonics
- Increase system performance-versus-cost ratio
- Increase productivity, flexibility and robustness
- Increase safety and reliability
- Reduce system size and weight
- Growth of digital control and reducing usage of analog components and total system cost

Motor types that most effectively meet these requirements include AC induction motors (ACIM), permanent magnet synchronous motors (PMSM), brushless DC motors (BLDC) and switched reluctance motors (SR). The following pages will cover their main characteristics, types of control, advantages and typical applications.

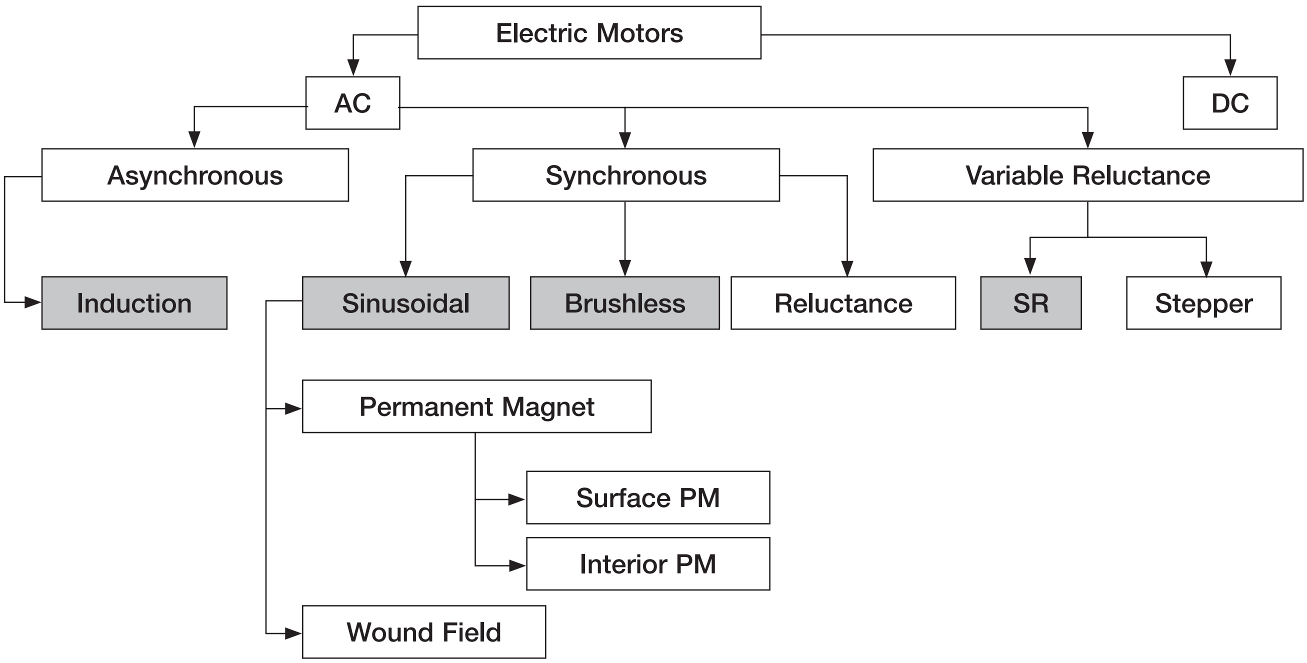
Digital Motor Control

Digital control allows more efficient motor control with variable speed and sensorless control. The term sensorless control means that there is no position/velocity sensor on the motor shaft, so the rotor position/velocity is calculated from measured current and voltage. The sensorless control provides a cost-effective and reliable solution that eliminates the position/velocity sensor, sensor wiring, sensor power supply and increases reliability. Still, there are applications where higher cost of sensors is not as important as higher position resolution. The most common speed/position sensors are:

- Tachogenerators
- Hall sensors
- Encoders
- Resolvers

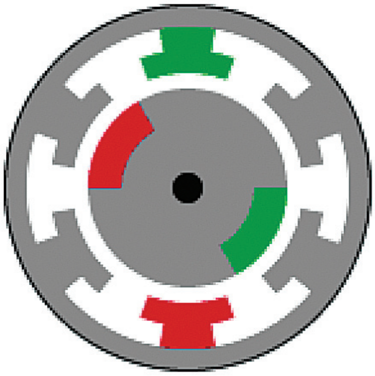
Applications requiring the motor to operate with a required speed (pumps, fans, compressors, etc.) are speed controlled. In variable frequency drives, motor speed is typically proportional to frequency. The actual motor speed is maintained by a speed controller to reference speed command. Speed control offers low dynamic performance. For high dynamic and

Figure 1: Electric Motor Type Classification



stability performance, speed control with inner current loop (cascade control) is required. The majority of variable speed drives are controlled by cascade control. Most complex drives (servos, industrial robots, linear motors) require additional position control. Applications requiring the motor to operate with a specified torque regardless of speed (hand tools, electric power steering, traction, vehicles, etc.) employ torque control.

Brushless DC Motor



BLDC motors have a three-phase stator winding and a rotor with surface-mounted permanent magnets. A BLDC motor does not have a commutator and is more reliable than a DC motor. The digital control and power electronics replace the function of the commutator and energize the proper winding. They are used in home appliances (such as refrigerators, washing machines and dishwashers), pumps, fans and other devices that require high reliability and efficiency.

In the BLDC motor, the rotor position must be known to energize the phase pair and control the phase voltage.

If sensors are used to detect rotor position, then sensed information must be transferred to a control unit. This requires additional connections to the motor, which may not be acceptable in some applications. Also, the additional cost of the position sensors and the wiring may be unacceptable. The physical connection problem could be solved by incorporating the driver in the motor body, however, a significant number of applications do require a sensorless solution due to their low-cost nature.

Most BLDC sensorless techniques are based upon extracting position information from the back EMF voltage of the stator windings while the motor is spinning. Those techniques could be used from 5 percent of nominal speed, when back EMF is measurable. BLDC back EMF sensorless techniques can be used without complex control algorithms, due to back EMF voltage sensing in unexcited motor phase.

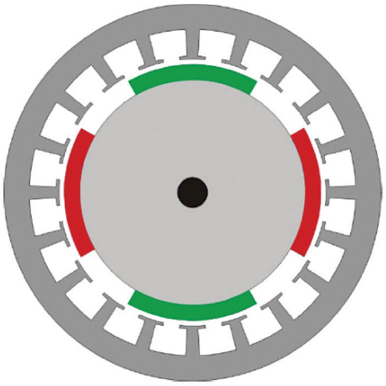
Advantages

- Heat generated in stator is easy to remove
- High torque per frame size
- Reliability due to absence of brushes and commutator
- Highest efficiency
- Good high-speed performance
- Precise speed monitoring and regulation possible

Drawbacks

- Rotor position sensing required for commutation
- Torque ripple
- Position sensor or sensorless technique is required for motor operation
- Difficult to startup the motor for variable load using sensorless technique

Permanent Magnet Synchronous Motor



Similar to BLDC motors, PMSMs have a three-phase stator and a rotor with surface/interior-mounted permanent magnets.

A PMSM provides rotation at a fixed speed in synchronization with the frequency of the power source. PMSMs are therefore ideal for high-accuracy fixed-speed drives. Boasting very high-power density, very high efficiency and high response, the motor is suitable for most sophisticated applications in the industrial segment. It also has a high overload capability. A PMSM is largely maintenance free, which ensures the most efficient operation.

Synchronous motors operate at an improved power factor, thereby improving the overall system power factor and eliminating or reducing utility power factor penalties. An improved power factor also reduces the system's voltage drop and the voltage drop at the motor terminals.

Advantages

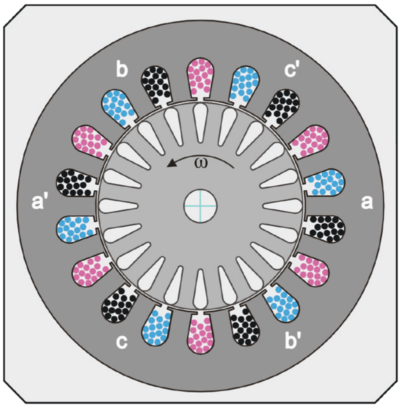
- Heat generated in stator is easy to remove
- High torque per frame size
- Reliability due to absence of brushes and commutator
- Highest efficiency
- Synchronous operation makes field orientation easy

- Good high-speed performance
- Precise speed monitoring and regulation possible
- Smooth torque

Drawbacks

- Rotor position sensing required
- Position sensor or sensorless technique is required for motor operation
- Difficult to startup the motor using sensorless technique

AC Induction Motor



ACIM is the most popular motor for industrial and consumer applications. This is due to many factors such as the lack of commutator/brushes (high reliability), high efficiency at high loads and the ability to connect directly to the AC line. ACIMs have a classic three-phase stator and commonly have a "squirrel cage" rotor in which the conductors are shorted together at both ends. The operation principle of ACIM is very similar to a transformer. A rotor current is induced in the rotor circuit from the stator windings. This current produces rotor flux, which interacts with the stator electromagnets to produce torque.

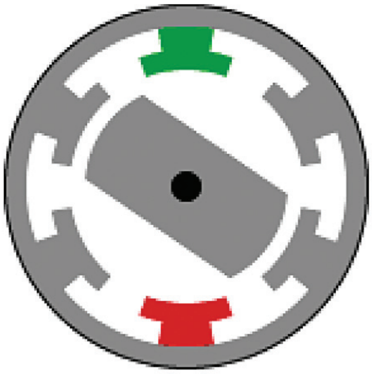
Advantages

- Low cost per horsepower (no permanent magnets)
- Inherent AC operation (direct connection to AC line)
- Very low maintenance (no brushes) and rugged construction
- Available in wide range of power ratings
- Low-cost speed control with tachogenerator
- Simple control (volt per hertz + PFC can handle 8-bit MCU)

Drawbacks

- Inefficient at light loads
- Rotor temperature change complicates sensorless control
- Speed control requires varying stator frequency
- Position control difficult (field orientation required)

Switched Reluctance Motor



SR motors do not contain magnets and are constructed such that both the stator and rotor have salient poles. The motor is driven by a sequence of current pulses applied at each phase, which requires control electronics for operation. The SR motor works on the principle that the magnetic circuit tries to minimize the reluctance (air gap distance) of the magnetic circuit. The magnetic field creates a force on the rotor so that its poles line up with the poles of stator phase.

Advantages

- Low cost resulting from simple construction
- High reliability
- High fault tolerance
- Heat generated in stator is easy to remove
- High-speed operation possible

Drawbacks

- Acoustically noisy
- High vibration
- Magnetic non-linearities make smooth torque control difficult
- Dependent on electronic control for operation

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Document Number: BBMTRCNTRLART REV 0