What's the Difference Between Asynchronous and Synchronous Motors?

Machine Design
(Unpublished) Leland Teschler

Leland E. Teschler

Fri, 2013-01-04 00:33

This 800-hp medium-voltage induction motor is employed in a copper ore plant.

The increasing importance of energy efficiency has brought electric motor makers to promote a variety of schemes that improve motor performance. Unfortunately the terminology associated with motor technologies can be confusing, partly because multiple terms can sometimes be used interchangeably to refer to the same basic motor configuration. Among the classic examples of this phenomenon is that of induction motors and asynchronous motors.

All induction motors are asynchronous motors. The asynchronous nature of induction-motor operation comes from the slip between the rotational speed of the stator field and somewhat slower speed of the rotor. A more-specific explanation of how this slip arises gets into details of the motor internals.

Related

What’s the Difference Between a Pump and a Compressor?

Selecting the Best Electric Drive

A Closer Look at Motors for Motion

Most induction motors today contain a rotational element (the rotor) dubbed a squirrel cage. The cylindrical squirrel cage consists of heavy copper, aluminum, or brass bars set into grooves and connected at both ends by conductive rings that electrically short the bars together. The solid core of the rotor is built with stacks of electrical steel laminations. The rotor contains fewer slots than the stator. The number of rotor slots must also be a nonintegral multiple of stator slots so as to prevent magnetic interlocking of rotor and stator teeth when the motor starts.

It is also possible to find induction motors containing rotors made up of windings rather than a squirrel cage. The point of this wound-rotor configuration is to provide a means of reducing the rotor current as the motor first begins to spin. This is generally accomplished by connecting each rotor winding to a resistor in series. The windings receive current through some kind of slip-ring arrangement. Once the rotor reaches final speed, the rotor poles get switched to a short circuit, thus becoming electrically the same as a squirrel cage rotor.

The stationary part of the motor windings is called the armature or the stator. The stator windings connect to the ac supply. Applying a voltage to the stator causes a current to flow in the stator windings. The current flow induces a magnetic field which affects the rotor, setting up voltage and current flow in the rotor elements.

A north pole in the stator induces a south pole in rotor. But the stator pole rotates as the ac voltage varies in amplitude and polarity. The induced pole attempts to follow the rotating stator pole. However, Faraday's law says that an electromotive force is generated when a loop of wire moves from a region of low magnetic-field strength to one of high magnetic-field strength, and vice versa. If the rotor exactly followed the moving stator pole, there would be no change in magnetic-field strength. Thus, the rotor always lags behind the stator field rotation. The rotor field always lags behind the stator field by some amount so it rotates at a speed that is somewhat slower than that of the stator. The difference between the two is called the slip.

The amount of slip can vary. It depends principally on the load the motor drives, but also is affected by the resistance of the rotor circuit and the strength of the field that the stator flux induces.

A few simple equations make the basic relationships clear.

When ac is initially applied to the stator, the rotor is stationary. The voltage induced in the rotor has the same frequency as that of the stator. As the rotor starts spinning, the frequency of the voltage induced in it, f_r, drops. If f is the stator voltage frequency, then slip, s, relates the two via $f_r = s_f$. Here s is expressed as a decimal.

When the rotor is standing still, the rotor and stator effectively form a transformer. So the voltage E induced in the rotor is given by the transformer equation

$$E = 4.44 f N \phi_m$$

where N = the number of conductors under one stator pole (typically small for a squirrel-cage motor) and ϕ_m = maximum magnetic flux, Webers. Thus, the voltage E_r induced while the rotor spins depends on the slip:

$$E_r = 4.44\ s f N \phi_m = s\ E$$

Explanation of synchronous motors

A synchronous motor has a special rotor construction that lets it rotate at the same speed — that is, in synchronization — with the stator field. One example of a synchronous motor is the stepping motor, widely used in applications that involve position control. However, recent advances in power-control circuitry have given rise to synchronous-motor designs optimized for use in such higher power situations as fans, blowers, and to drive axles in off-road vehicles.

There are basically two types of synchronous motors:

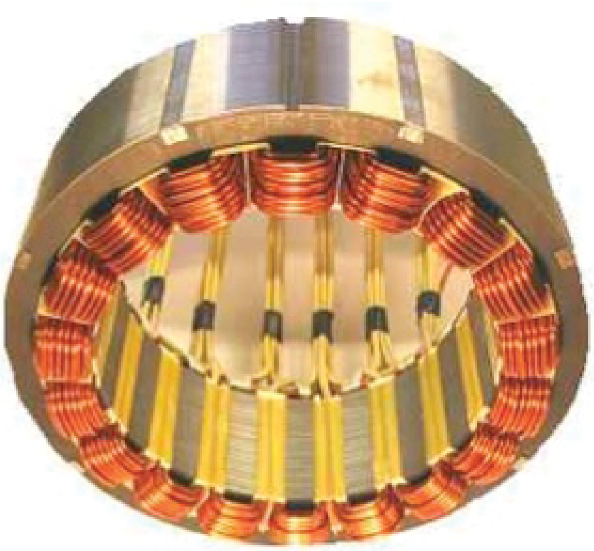
- Self-excited — Using principles similar to those of induction motors, and

- Directly excited — usually with permanent magnets, but not always

The self-excited synchronous motor, also called a switched-reluctance motor, contains a rotor cast of steel that includes notches or teeth, dubbed salient poles. It is the notches that let the rotor lock in and run at the same speed as the rotating magnetic field.

To move the rotor from one position to the next, circuitry must sequentially switch power to consecutive stator windings/phases in a manner analogous to that of a stepping motor. The directly excited synchronous motor may be called by various names. Usual monikers include ECPM (electronically commutated permanent magnet), BLDC (brushless dc), or just a brushless permanent-magnet motor. This design uses a rotor that contains permanent magnets. The magnets may mount on the rotor surface or be inserted within the rotor assembly (in which case the motor is called an interior permanent-magnet motor).

The permanent magnets are the salient poles of this design and prevent slip. A microprocessor controls sequential switching of power on the stator windings at the proper time using solid-state switches, minimizing torque ripple. The principle of operation of all these synchronous-motor types is basically the same. Power is applied to coils wound on stator teeth that cause a substantial amount of magnetic flux to cross the air gap between the rotor and stator. The flux flows perpendicular to the air gap. If a salient pole of the rotor is aligned perfectly with the stator tooth, there is no torque produced. If the rotor tooth is at some angle to the stator tooth, at least some of the flux crosses the gap at an angle that is not perpendicular to the tooth surfaces. The result is a torque on the rotor.Thus, switching power to stator windings at the right time causes a flux pattern that results in either clockwise or counterclockwise motion.



One other type of synchronous motor is called a switched reluctance (SR) motor.

Its rotor consists of stacked steel laminations with a series of teeth. The teeth are magnetically permeable, and the areas surrounding them are weakly permeable by virtue of slots cut into them. Thus the rotor needs no windings, rare-earth materials, or magnets.

Unlike induction motors, there are no rotor bars and consequently no torque-producing current flow in the rotor. The absence of any form of conductor on the SR rotor means that overall rotor losses are considerably lower than in other motors incorporating rotors carrying conductors. Torque produced by the SR motor is controlled by adjusting the magnitude of current in the stator electromagnets. Speed is then controlled by modulating the torque (via winding current). The technique is analogous to the same way speed is controlled via armature current in a traditional brush-dc motor.

An SR motor produces torque proportional to the amount of current put into its windings. Torque production is unaffected by motor speed. This is unlike ac-induction motors where, at high rotational speeds in the field-weakening region, rotor current increasingly lags behind the rotating field as motor rpm rises.

Source URL: http://machinedesign.com/motorsdrives/whats-difference-between-asynchronous-and-

synchronous-motors