Physics II

Synchronous Motors

General Characteristics

Synchronous motors rotate at the same angular velocity as the magnetic field in the gap between the stator and rotor. This velocity is determined by the line frequency (f) and the number of poles (n) according to the equation:

$$v = \frac{f}{n}\left[\frac{7200rpm}{60Hz}\right] \qquad \text{Equation 1}$$

For example, an electric motor with 24 poles at 60Hz has a velocity of

$$v = \frac{60Hz}{24}\left[\frac{7200rpm}{60Hz}\right] = 300rpm$$

In normal operation the motor will only deviate from this velocity for very short times when the load changes. This is different than induction motors that are always slower than the velocity given by equation 1.

Also, different than an induction motor, whose phase is always lagging, synchronous motors can lag or lead in phase. This is controlled by the excitation current in the rotor winding. If the power factor is 1.0, the excitation current is called normal, if it is lower, it is called sub-excited and the power factor will be lagging, if it is higher, it is called over-excited and the power factor will be leading. This last characteristic can make the motor behave as a capacitor for power factor compensation.

The main reason to select a synchronous motor over an induction motor is its high efficiency for applications of high power and low speed, typically more than 100HP and less than 500rpm.

Parts of a Synchronous Motor

Stator: It is like induction motors. Typically, it is made of iron sheets with slots for the poly-phase windings that generate a rotating magnetic field.

Insulation class A is made with fibers such as cotton, paper or linen and its maximum temperature cannot exceed 105°C.

Insulation class B includes mica or asbestos and cannot exceed 130°C. Normally an ambient temperature is estimated at 40°C and a rise of 80°C leaving a tolerance of 10 K.

However it is typical of today's industry to build the stator with insulation class F that can reach 155°C, but it is designed not to exceed the limits of class B, thus adding 25°C of margin.

There is also insulation class H that can reach 180°C.

Rotor: The rotor is generally built with iron sheets that are stamped with the poles' shape and pressed together over a central "spider" to fasten them. The field winding is connected externally through rings and carbon brushes. For starting, the rotor has a set of bars that act as a squirrel cage. They also help to dampen transients.

Field excitation circuit: Traditionally a mechanical DC generator was used which was driven by an induction motor. Presently there are alternatives with diodes, SCRs or other solid state devices.

Starting a Synchronous Motor

Synchronous motors only produce continuous torque when they rotate at the synchronous speed. For that reason the rotor possesses a "squirrel cage" to start as an induction motor. Typically, each pole is terminated in grooves for copper bars that are then connected together with rings at the ends forming the cage.

In the starting procedure, first AC voltage is applied to the stator with the field winding closed through a resistor. This is necessary because otherwise it would behave as an elevator transformer. Once the motor is brought close to the synchronous speed by the squirrel cage, DC voltage is applied to the rotor through slip rings and the motor enters its normal synchronous regime.