Synchronous motor

المرحلة الثالثة

اعداد / أ.باسم محمد حافظ

Electrical machine

synchronous motor is a type of AC (alternating current) motor that operates at a constant speed, determined by the frequency of the supply current and the number of poles in the motor. Unlike induction motors, which rely on electromagnetic induction to generate torque, synchronous motors maintain synchronization between the rotational .speed of the rotor and the frequency of the AC supply

Here is a detailed explanation of how synchronous motors work, their :components, types, advantages, and applications

1-Working Principle

The basic working principle of a synchronous motor is that the rotor revolves in synchrony with the rotating magnetic field (RMF) produced by the stator. This is achieved by using a direct current (DC) excitation to the rotor, creating a stable magnetic field. The stator is supplied with a three-phase AC supply, which generates a rotating magnetic field. For the motor to run synchronously, the rotor locks into the rotating magnetic field and rotates at the same speed as the RMF

:Mathematical Relationship

The speed of the synchronous motor (called synchronous speed) is given :by the equation

$N_s = \frac {120 \times f} {P}$

:Where

,Synchronous speed (RPM) =

,Frequency of the AC supply (Hz) =

.Number of poles =

2-Main Components

Stator: The stationary part of the motor, which is made up of windings connected to the AC power supply. The stator generates a rotating .magnetic field

:Rotor: The rotating part of the motor. The rotor can be either

Salient pole: Poles are projected out from the rotor surface. Common in .low-speed machines

Non-salient pole (cylindrical): Poles are evenly distributed around the .rotor. Used in high-speed applications

Excitation System: This provides a direct current (DC) to the rotor windings to produce a constant magnetic field. The excitation can be provided by slip rings or through brushless excitation systems

3-Types of Synchronous Motors

Synchronous motors can be classified into different types based on :construction and excitation methods

Non-excited Synchronous Motors: These motors use permanent magnets or reluctance effects to produce the necessary magnetic field, eliminating the need for an external excitation system. Examples include .permanent magnet synchronous motors (PMSMs)

Direct Current (DC) Excited Synchronous Motors: These use DC excitation to magnetize the rotor, which requires slip rings or a brushless excitation method

.

4-Starting Methods

Synchronous motors cannot start on their own because the rotor needs to be locked into the rotating magnetic field at synchronous speed. :Some common starting methods include

Using a damper winding: The rotor has an additional winding (like a squirrel cage in an induction motor) to start the motor as an induction motor. Once it reaches near-synchronous speed, DC excitation is applied .to the rotor

Using a separate induction motor: A small induction motor can be used .to bring the synchronous motor up to speed

Frequency variation: In some cases, the frequency of the supply is varied .to slowly accelerate the motor to synchronous speed

Advantages of Synchronous Motors

Constant Speed Operation: Synchronous motors run at a constant speed .regardless of load changes, making them ideal for precision applications

High Efficiency: Synchronous motors are more efficient than induction .motors, especially at higher loads

Power Factor Correction: By adjusting the field excitation, synchronous motors can operate at leading, lagging, or unity power factor, allowing them to compensate for the reactive power in the system and improve .the overall power factor

Large Torque at Low Speeds: These motors are capable of producing high torque at low speeds, which is important for applications like .conveyors, crushers, and compressors

Disadvantages of Synchronous Motors

Complex Starting: Synchronous motors require additional starting mechanisms, which make them more complex and costly compared to .induction motors

Fixed Speed: While a constant speed is an advantage in some applications, it can be a limitation in others where variable speed is needed. Excitation System: The need for an external DC source for rotor .excitation adds complexity and maintenance challenges.

Applications of Synchronous Motors

Power Factor Correction: Large synchronous motors are used in power .plants and industries to correct power factor

High-Precision Applications: In machines where precise and constant .speed is crucial, like in clocks, timers, and conveyor belts

Pumps and Fans: These applications often require motors to run at a .constant speed, and synchronous motors are ideal for this

Electric Traction: In locomotives and electric vehicles, where high torque .and constant speed are beneficial

Robotics: Permanent magnet synchronous motors (PMSMs) are widely used in robotics and automation due to their high precision and efficient

Comparison with Induction Motors

Speed Control: Induction motors have a small slip and thus don't run at a .perfectly constant speed, unlike synchronous motors which have no slip

Efficiency: Synchronous motors generally operate more efficiently at full

Complexity: Induction motors are simpler in design and easier to .maintain due to the absence of excitation systems

Permanent Magnet Synchronous Motors (PMSM) .

A variant of synchronous motors that uses permanent magnets on the rotor instead of electromagnets. PMSMs are highly efficient, have a compact design, and are widely used in electric vehicles, high-efficiency .appliances, and industrial machinery . (Conclusion)

Synchronous motors are widely used in industrial applications where constant speed is required and where power factor correction is beneficial. They offer advantages like high efficiency and precise speed control, but their complex starting methods and the need for an excitation system can be drawbacks. With advancements like permanent magnet motors, synchronous machines are finding more applications in .modern electric vehicles and high-precision systems

Torque low

$$\frac{P}{w} = T$$

Torque T

Power P

$2\pi n \Leftarrow w$

$$T_g = \frac{9.55\, P_m}{N_s}$$

$$\boxed{w = \frac{2\pi N}{60}}$$

Power low

$$P_{in} = \sqrt{3}\, VI \cos\phi$$

V= voltay

I = current

$\cos\phi$ = Power factor

$$P_{mec} = T_e W_m$$

T_e = electro magnetic Torque in Nm

W_m = mechanical angl

$$N = \frac{120\, F}{P}$$

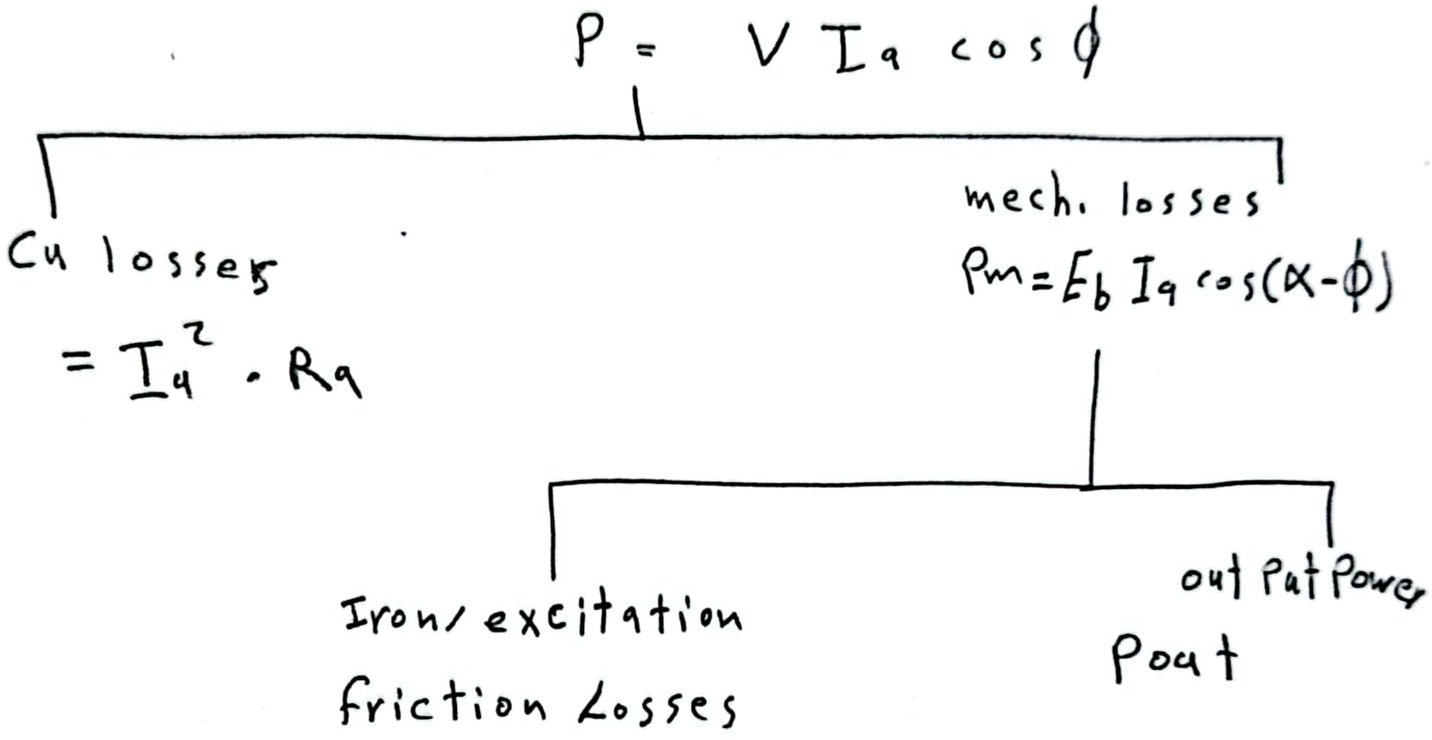
P = no. of Pole , f = freqnncy

N= speed

Losses

① copper losses

$$P_{copper} = 3 I^2 R_s$$



$$P_{Losses} = P_{coper} + P_{iron} + P_{mech.} + P_{stray} + P_{excition}$$

The efficiency (η) of synchronous motor is The ratio of The output mechanical Power to the input Power

$$\eta = \frac{P_{out}}{P_{in}} * 100\%$$

$$\eta = \frac{P_{in} - P_{losses}}{P_{in}} * 100\%$$

Ex 1:

A 3 ϕ Synchronous motor operates at a line Voltag of 400V. drowing current 50A , Power factor 0.8 logging and The motor runs at speed 1500

Calculate :

Pin , Pmech mechanical losses is 5% of Pin

3 - T

Sol: $P_{in} = \sqrt{3}\, V\, I \cos\phi$

$P_{in} = 1.732 * 400 * 50 * 0.8$

$P_{in} = 27.71\ Kw$

$P_{mec} = 0.05 * P_{in} \Rightarrow 0.05 * 27.71$

$= 1.386\ w$

$$w_m = \frac{2\pi * N}{60} = \frac{2 * 3.14 * 1500}{60}$$

$w_m = 157.08\ rad/s$

$$T = \frac{P_{in}}{w_m} \Rightarrow \frac{27.71}{157.08} = 167.6N$$