# SNS COLLEGE OF TECHNOLOGY

**(An Autonomous Institution)**

**COIMBATORE-35**

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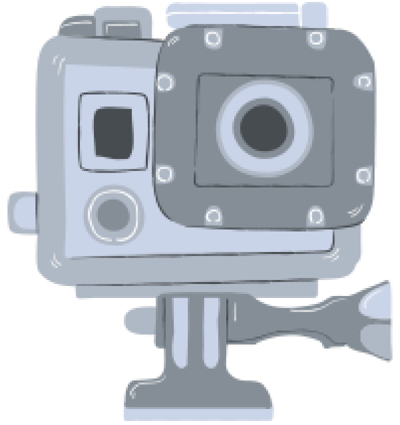
## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## COURSE NAME: 19EET207/ SYNCHRONOUS AND INDUCTION MACHINES

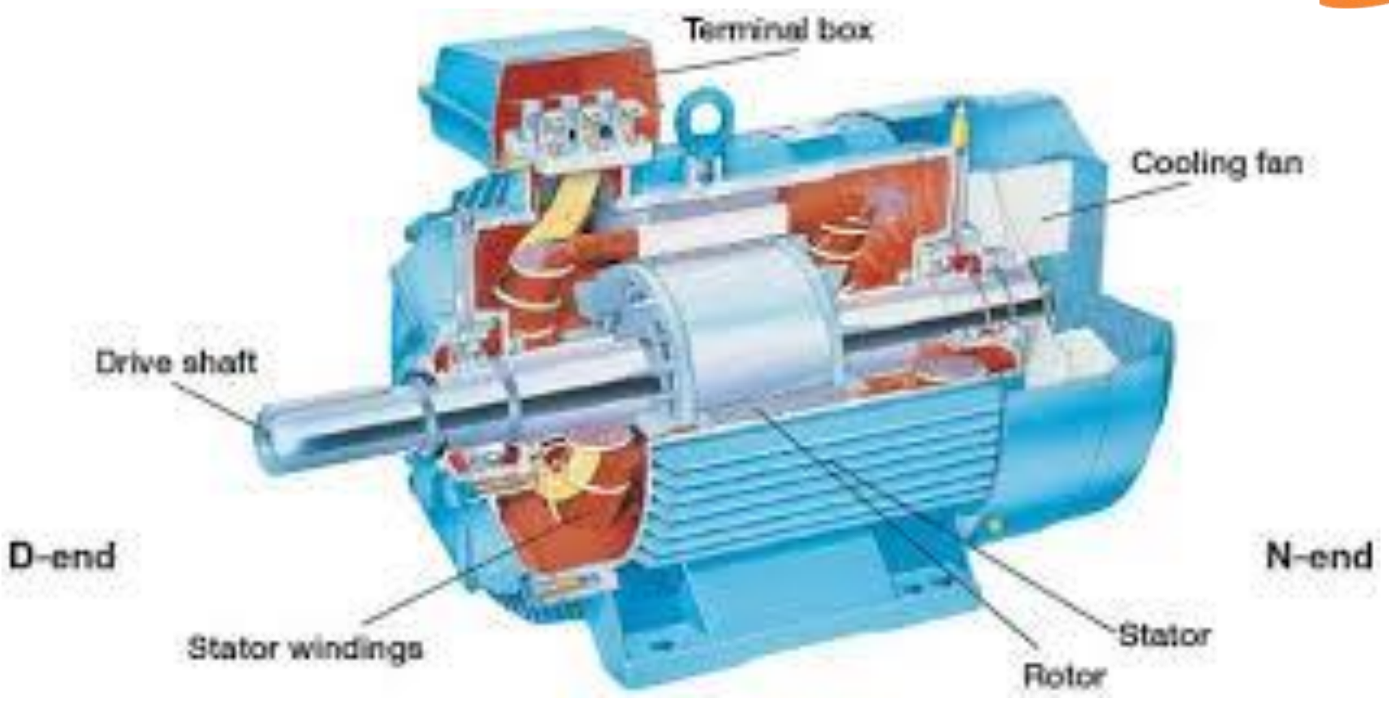
II YEAR / IV SEMESTER

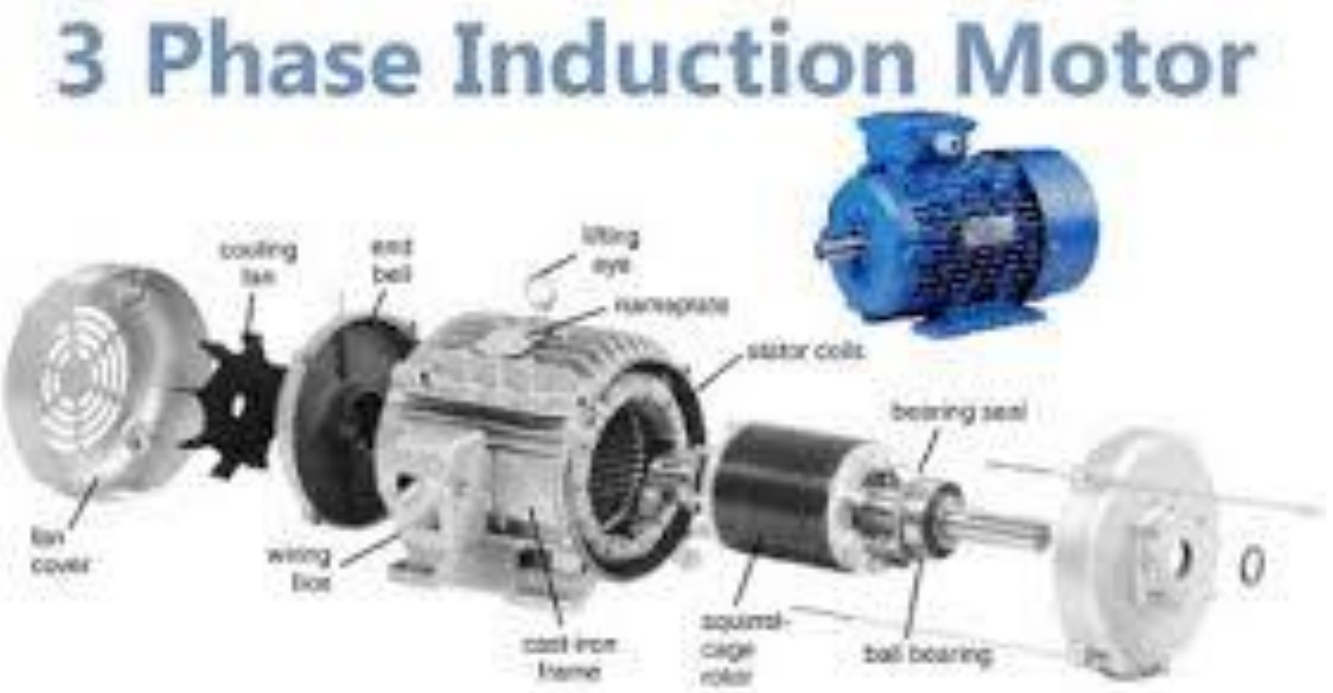
Unit 3 – THREE PHASE INDUCTION MOTOR



Topic 4: Slip –cogging and crawling

# GUESS THE TOPIC NAME…



# Induction motor speed

- At what speed will the IM run?

– Can the IM run at the synchronous speed, why?

– If rotor runs at the synchronous speed, which is the same speed of the rotating magnetic field, then the rotor will appear stationary to the rotating magnetic field and the rotating magnetic field will not cut the rotor. So, no induced current will flow in the rotor and no rotor magnetic flux will be produced so no torque is generated and the rotor speed will fall below the synchronous speed

– When the speed falls, the rotating magnetic field will cut the rotor windings and a torque is produced

# Induction motor speed

- So, the IM will always run at a speed lower than the synchronous speed
- The difference between the motor speed and the synchronous speed is called the Slip

$$n_{slip} = n_{sync} - n_m$$

Where

$n_{slip}$= slip speed

$n_{sync}$= speed of the magnetic field

$n_m$ = mechanical shaft speed of the motor

# The Slip

$$s = \frac{n_{sync} - n_m}{n_{sync}}$$

Where s is the slip

Notice that : if the rotor runs at synchronous speed

s = 0

if the rotor is stationary

s = 1

Slip may be expressed as a percentage by multiplying the above

eq. by 100, notice that the slip is a ratio and doesn't have units

# Frequency

- The frequency of the voltage induced in the rotor is given by

$$f_r = \frac{P \times n}{120}$$

Where fr = the rotor frequency (Hz)
P = number of stator poles
n = slip speed (rpm)

$$f_r = \frac{P \times (n_s - n_m)}{120}$$

$$= \frac{P \times sn_s}{120} = sf_e$$

- When the rotor is blocked (s=1) , the frequency of the induced voltage is equal to the supply frequency
- On the other hand, if the rotor runs at synchronous speed (s = 0), the frequency will be zero

# Torque

- While the input to the induction motor is electrical power, its output is mechanical power and for that we should know some terms and quantities related to mechanical power

- Any mechanical load applied to the motor shaft will introduce a Torque on the motor shaft. This torque is related to the motor output power and the rotor speed

$$\tau_{load} = \frac{P_{out}}{\omega_m} \quad N.m$$

$$\omega_m = \frac{2\pi n_m}{60} \quad rad/s$$

# Horse power

- Another unit used to measure mechanical power is the horse power
- It is used to refer to the mechanical output power of the motor
- Since we, as an electrical engineers, deal with watts as a unit to measure electrical power, there is a relation between horse power and watts

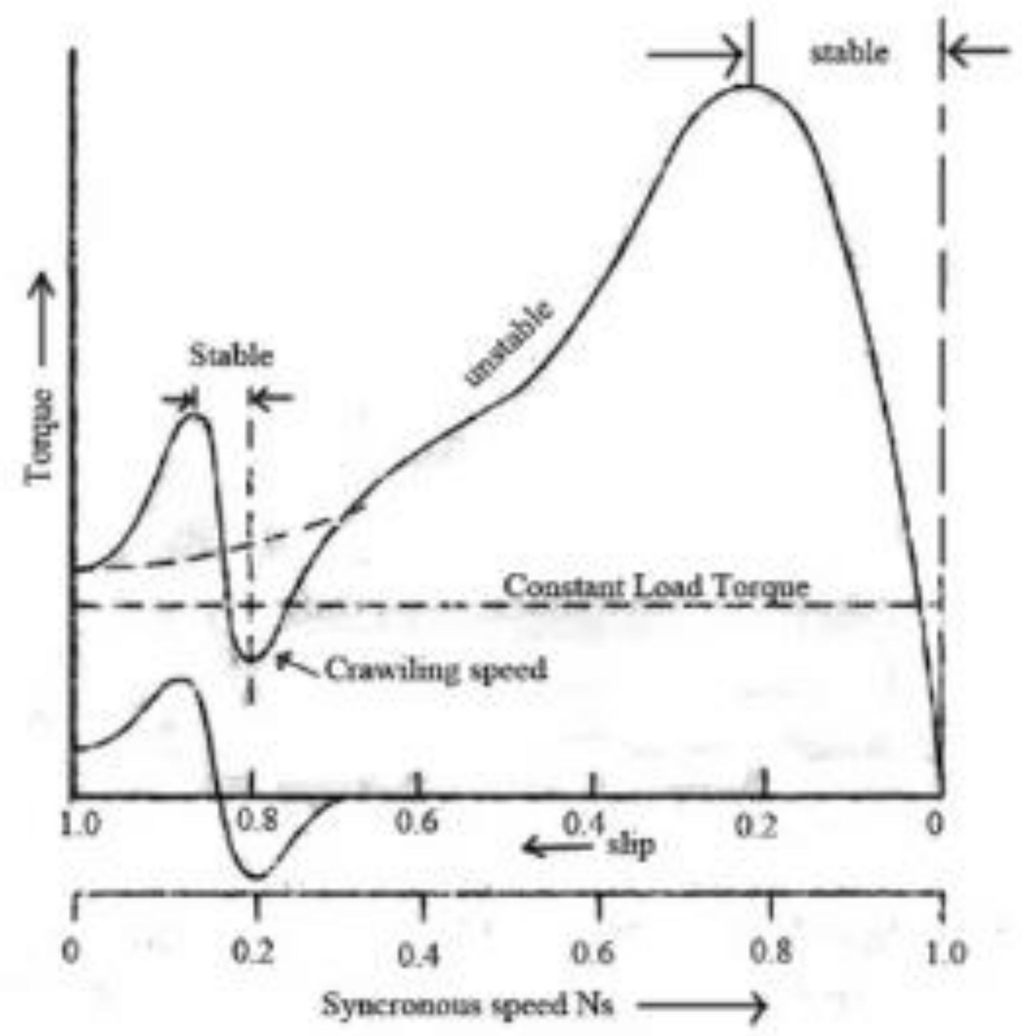
$$hp = 746\ watts$$

# Crawling of Induction Motor

It has been observed that squirrel cage type induction motor has a tendency to run at very low speed compared to its synchronous speed, this phenomenon is known as crawling.

The resultant speed is nearly 1/7th of its synchronous speed. Now the question arises why this happens? This action is due to the fact that harmonics fluxes produced in the gap of the stator winding of odd harmonics like 3rd, 5th, 7th etc.

These harmonics create additional torque fields in addition to the synchronous torque.



# Crawling of Induction Motor

The torque produced by these harmonics rotates in the forward or backward direction at Ns/3, Ns/5, Ns/7 speed respectively. Here we consider only 5th and 7th harmonics and rest are neglected. The torque produced by the 5th harmonic rotates in the backward direction. This torque produced by fifth harmonic which works as a braking action is small in quantity, so it can be neglected. Now the seventh harmonic produces a forward rotating torque at synchronous speed Ns/7. Hence, the net forward torque is equal to the sum of the torque produced by 7th harmonic and fundamental torque. The torque produced by 7th harmonic reaches its maximum positive value just below 1/7 of Ns and at this point slip is high. At this stage motor does not reach up to its normal speed and continue to rotate at a speed which is much lower than its normal speed. This causes crawling of the motor at just below 1/7 synchronous speed and creates the racket. The other speed at which motor crawls is 1/13 of synchronous speed.

# Cogging of Induction Motor

This characteristic of induction motor comes into picture when motor refuses to start at all. Sometimes it happens because of low supply voltage. But the main reason for starting problem in the motor is because of cogging in which the slots of the stator get locked up with the rotor slots.

As we know that there is series of slots in the stator and rotor of the induction motor. When the slots of the rotor are equal in number with slots in the stator, they align themselves in such way that both face to each other and at this stage the reluctance of the magnetic path is minimum and motor refuse to start.

This characteristic of the induction motor is called cogging. Apart from this, there is one more reason for cogging. If the harmonic frequencies coincide with the slot frequency due to the harmonics present in the supply voltage then it causes torque modulation. As a result, of it cogging occurs. This characteristic is also known as magnetic teeth locking of the induction motor.

# Cogging of Induction Motor

## Methods to overcome Cogging

This problem can be easily solved by adopting several measures. These solutions are as follows:

The number of slots in rotor should not be equal to the number of slots in the stator.

Skewing of the rotor slots, that means the stack of the rotor is arranged in such a way that it angled with the axis of the rotation.

# SUMMARY

Construction, Types of Rotors of Induction Motors

KEEP LEARNING..

# Thank u

SEE YOU IN NEXT CLASS