SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE NAME : 19EE401 SYNCHRONOUS AND INDUCTION MACHINES

II YEAR /IV SEMESTER

Unit 3: INDUCTION MOTOR

Topic 3 : Torque Equation of Three Phase Induction Motor

Torque Equation of Three Phase Induction Motor

The torque produced by three phase induction motor depends upon the following three factors:

- Flux Φ which interacts with the rotor
- Magnitude of the rotor current I_2
- Power Factor of the rotor circuit

$$T \propto \phi I_2 \cos\theta_2$$

Stator flux is proportional to standstill rotor emf per phase E_2.

Rotor Current

$$I_2 = \frac{E_r}{Z_2}$$

Where E_r is the rotor emf per phase at running condition & Z_2 is the impedance of the rotor circuit.

Torque Equation of Three Phase Induction Motor

Torque

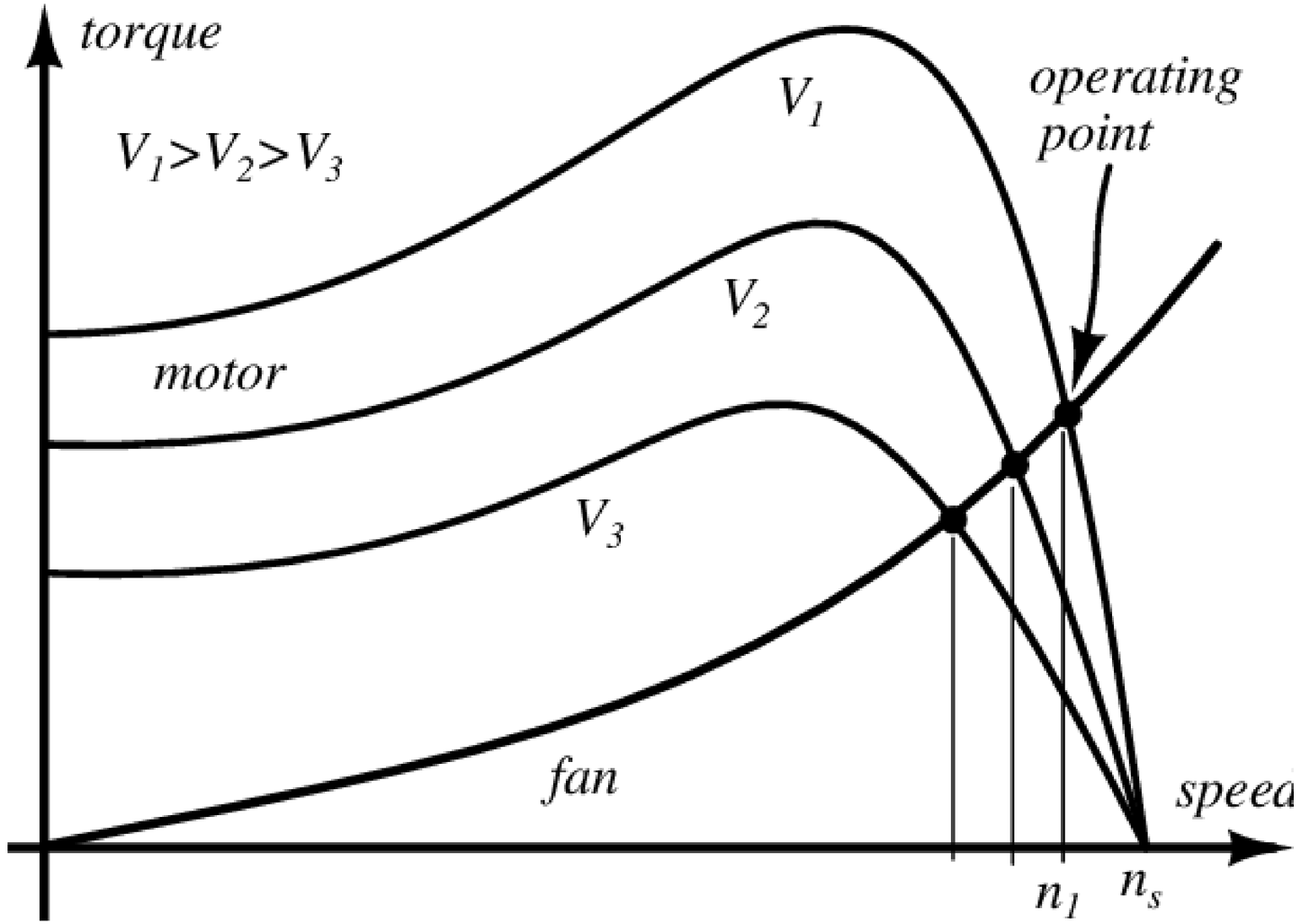
$$T \propto E_2 \frac{E_r}{\sqrt{(R_2)^2+(sZ_2)^2}} \frac{R_2}{\sqrt{(R_2)^2+(sZ_2)^2}}$$

$$T \propto E_2 \frac{sE_2}{\sqrt{(R_2)^2+(sZ_2)^2}} \frac{R_2}{\sqrt{(R_2)^2+(sZ_2)^2}}$$

$$T \propto \frac{s(E_2)^2 R_2}{(R_2)^2+(sZ_2)^2}$$

$$T = \left(\frac{3*60}{2\pi N_s}\right) \frac{s(E_2)^2 R_2}{(R_2)^2+(sZ_2)^2}$$

Torque Slip Characteristics of Three Phase Induction Motor



Maximum Torque of Three Phase Induction Motor

For torque to be maximum, Now differentiate the above equation by using division rule of differentiation. On differentiating and after putting the terms equal to zero we get $\frac{dT}{ds} = 0$

$$T = K s E_2^2 \frac{R_2{}'}{R_2^2 + (sX_2)^2}$$

The torque will be maximum when slip $S_m = R_2 / X_2$

$$T_m = \frac{3*60}{2\pi N_s} \frac{(E_2)^2}{2X_2}$$

Maximum Torque of Three Phase Induction Motor

- The maximum torque is directly proportional to square of rotor induced emf at the standstill.
- The maximum torque is inversely proportional to rotor reactance.
- The maximum torque is independent of rotor resistance.
- The slip at which maximum torque occur depends upon rotor resistance, R_2. So, by varying the rotor resistance, maximum torque can be obtained at any required slip.

Maximum Starting Torque of Three Phase Induction Motor

At starting, the value of slip S =1

The condition for starting torque to be maximum is $R_2 = X_2$

$$T_{st} = \frac{3*60}{2\pi N_s} \frac{(E_2)^2}{2}$$

Hence, the starting torque is directly proportional to the square of the supply voltage. Therefore, the starting torque is very sensitive to changes in the value of the supply voltage.

Maximum Starting Torque of Three Phase Induction Motor

- Starting Torque of Squirrel Cage Motors – For the squirrel cage motors, the starting torque is very low about 1.5 to 2 times of the full-load value.
- Starting Torque of Wound Rotor Motors – In case of slip ring induction motors, the resistance of the rotor circuit can be increased by inserting external resistance. By adding the proper value of the external resistance (i.e., $R_2 = X_2$), maximum starting torque can be obtained.

Full load and Maximum Torque of Three Phase Induction Motor

At starting, the value of slip S =1

The condition for starting torque to be maximum is $R_2 = X_2$

$$T_{st} = \frac{3*60}{2\pi N_s} \frac{(E_2)^2}{2}$$

Hence, the starting torque is directly proportional to the square of the supply voltage. Therefore, the starting torque is very sensitive to changes in the value of the supply voltage.

Torque Ratios of Three Phase Induction Motor

$$\frac{T_f}{T_m} = \frac{2S_f R_2}{R_2^2 + S_f X_2^2}$$

$$\frac{T_f}{T_m} = \frac{2aS_f}{a^2 + S_f^2}, \left(\because a = \frac{R_2}{X_2}\right)$$

$$\frac{T_{st}}{T_m} = \frac{2a}{a^2 + 1^2}, \left(\because a = \frac{R_2}{X_2}\right)$$

References

1.Kothari, D.P., Nagrath, I.J., “Electric Machines”, McGraw Hill Publishing Company Ltd, 5th Edition, 2017.

2. Murugesh Kumar, K., “Induction and Synchronous machines”, Vikas Publishing House Private Ltd, 2016.

Thank You