Andhra Pradesh State Skill Development Corporation

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Basics of induction Motors

Characteristics and applications of induction motor

An induction motor compared to a dc motor has some major advantages such as - Absence of brushes, commutator segments, rugged construction, being cheap, lesser maintenance requirements and smaller size for the same power output. Due to these advantages' induction machines have become more popular in industrial applications. For any motor load application, it is imperative to know the torque speed characteristic of the motor. Consider a three-phase squirrel cage induction motor whose stator has three windings displaced in space by 120°. When they are excited with currents that are displaced in time by 120°, a rotating magnetic field rotating at a speed called synchronous speed Ns is set up. The synchronous speed, Ns is given by Ns = 120f P.
Where, f is the frequency of the currents and P is the number of poles. If the rotor of the induction motor rotates at a speed, N_r, then the slip, s is defined by s = (Ns – Nr) / Ns.

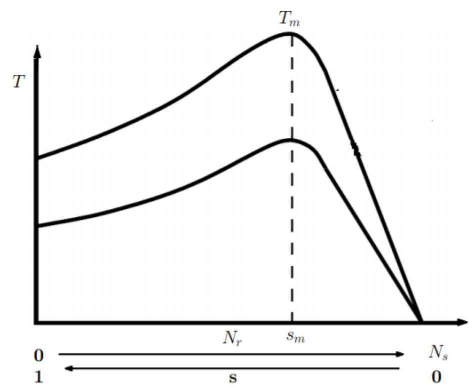
The torque developed by the induction motor is given by $$T = \frac{3}{\omega_s}\frac{I_2{}^2 R_2}{s} = \frac{3}{\omega_s}\frac{V_s{}^2 R_2/s}{(R_1 + R_2/s)^2 + (X_1+X_2)^2}$$

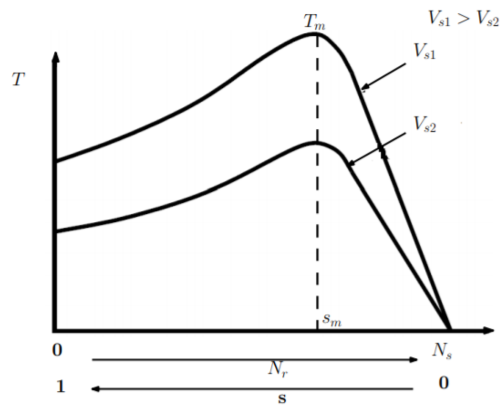
Where ω_s is the synchronous speed in rps, Vs is the voltage applied to the stator, I2, R2, X2 are the rotor current, resistance and reactance referred to stator respectively. R1, X1 are the stator resistance and reactance respectively. The maximum torque developed, Tm and the slip, S_m at which T_m occurs is given by

$$T_m = \frac{3}{2\omega_s}\frac{V_s{}^2}{R_1 \pm \sqrt{R_1{}^2 \pm (X_1+X_2)^2}}$$
$$s_m = \frac{R_2}{\sqrt{R_1{}^2 + (X_1+X_2)^2}}$$

T-Nr characteristics with variable stator voltage:

If voltage applied to the stator of the induction motor is varied, developed torque will vary with a relation T ∝ Vs^2. The maximum torque developed, Tm is also proportional to square of the applied voltage, but S_m is independent of applied voltage. So, if the T-Nr characteristics is plotted for different voltages, we get the characteristics as shown





T-Nr characteristics of a three-phase induction motor   T-Nr characteristics of a three-phase induction motor

with variable voltage control

T-Nr characteristics with V/f control:

If the motor is operated with a variable voltage- variable frequency source, we can implement constant V/f control of the induction motor, where the operating flux ϕ is kept constant.

$$E = 4.44 K_c \phi f N_{st}$$

$$\phi \propto \frac{E}{f}$$

Where Kc is the machine constant, E is the induced voltage in the stator, ϕ is the rated flux in the air-gap, N_{st} is the number of turns in the stator. Assuming Vs = E, if the V/f ratio is kept constant, ϕ will also be constant. If $Vs = K.Vs_{rated}$ and $f = K.f_{rated}$, then the slip will be as follows.

$$s = \frac{K\omega_s - \omega_r}{K\omega_s}$$

$$sK = \frac{K\omega_s - \omega_r}{\omega_s}$$

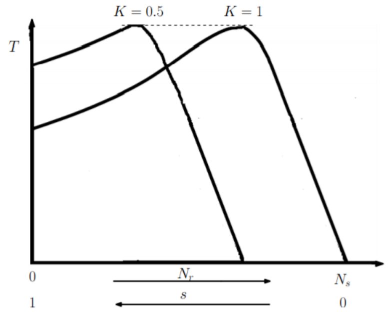
Where the term sK is the slip speed, that is the drop in motor speed from no load speed ($K\omega_s$). The expression for the developed torque with V/f control will be given by

$$T = \frac{3}{K\omega_s}\frac{{I_2}^2 R_2}{s} = \frac{3}{\omega_s}\frac{{V_s}^2 R_2/sK}{(R_2/Ks)^2 + {X_2}^2}$$

The maximum torque developed, Tm and the slip at which Tm occurs, S_m are given by

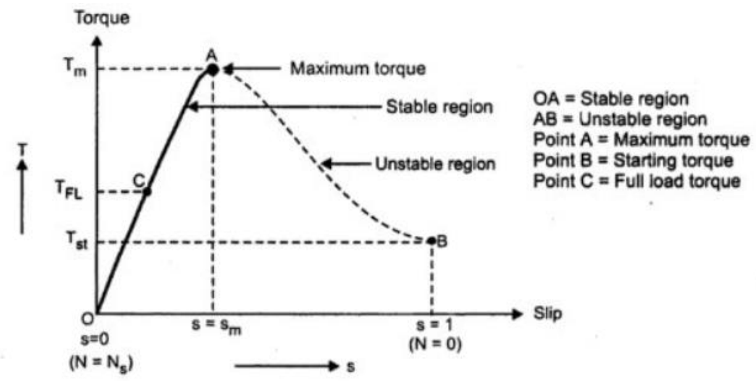
$$T_m = \frac{3}{2\omega_s}\frac{{V_s}^2}{X_2}$$

$$s_m = \frac{R_2}{KX_2}$$



T-Nr characteristics of a three-phase induction motor with V/f control

The stable and unstable region are shown below:



In high slip region as Slip increases ⇒ Torque decreases, due to extra loading effect ⇒ Speed further decreases ⇒ and slip further increases ⇒ again Torque decreases hence same load acts as an extra load due to reduction in torque produced. Hence speed further drops. Eventually motor comes to standstill condition. The motor cannot continue to rotate at any point in this high slip region. Hence this slip region is called unstable region of operation.

So, torque – Slip characteristics has two parts:

Straight line called stable region of operation.
Rectangular hyperbola called unstable region of operation.

Which value of slip, torque – slip characteristic represents stable region of operation?

In low slip region, as load increases ⇒ Slip increases and torque also increases linearly. Every motor has its own limit to produce a torque. The maximum torque, the motor can produce as load increases is Tm which occurs at s = sm. So stable region of operation is up to $S = S_m$. Maximum torque which motor can produce is also called breakdown torque or pull out torque.

Three phase induction motors are most widely used in many applications because of their rugged construction and they are almost maintenance free. The following are the major applications of an induction motor.

1. Conveyors
2. Blowers
3. Fans
4. Compressors
5. Crushers
6. Mixers
7. Agitators
8. Mills
9. Cranes
10. Hoists
11. Electric Locos
12. VFDs
13. Centrifuges
14. Evaporators
15. Winders
16. Lathes
17. Elevators
18. Hydraulic Pumping
19. Pressing Machines
20. Grinding Machine