Torque of three phase induction motor

Torque of three phase induction motor : T ά Er Ir cos Ø2 , Er ά Ø

T ά Ø Ir cos Ø2

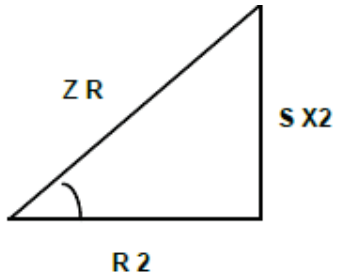
Where

E_r = rotor e.m.f / phase

I_r = rotor current / phase

$$E_r = S E_2$$

$$I_r = \frac{E_r}{Z_r} = \frac{S E_2}{\sqrt{\{R^2_2 + (S X_2)^2\}}}$$



From figure above

$$\text{Cos } Ø_2 = \frac{R_2}{\sqrt{\{R^2_2 + (SX_2)^2}}$$

$$T \text{ ά } = \frac{S Ø E_2 R_2}{R^2_2 + (SX_2)^2} = \frac{K Ø S E_2 R_2}{R^2_2 + (SX_2)^2}$$

But E_2 ά Ø

$$T = \frac{K S E^2_2 R_2}{R^2_2 + (SX_2)^2}$$

At standstill when S = 1 , obviously

$$T = \frac{K E^2_2 R_2}{R^2_2 + X^2_2}$$

Condition for maximum torque :

The torque of a rotor under running condition is

$$T = \frac{K Ø S E_2 R_2}{R^2_2 + (SX_2)^2}$$

The condition for maximum torque may be obtained by differentiating the above equation with respect to slip (S) and then putting it equal to zero.

Hence , torque under running conditions is maximum at that value of the slip (S) which makes rotor reactance per phase equal to rotor resistance per phase .

$$T_{max} = \frac{K \Phi S E_2}{2R_2}$$

Relation between torque and slip :

A family of torque/slip curves is shown in figure below, for a range of S = 0 – 1 We have seen above that

$$T = \frac{K \Phi S E_2 R_2}{R^2_2 + (SX_2)^2}$$

It is clear that when S = 0 , T = 0 . Hence the curve starts from point 0. At normal speeds , close to synchronism the term (S X2) is small and hence negligible w.r.t R2 .

$$T \propto \frac{S}{R_2}$$

If R2 is constant , then T ά S

Hence , for low values of slips , the torque /slip curve is approximately a straight line .

As slip increase (for increasing load on the motor) the torque also increases and

become maximum when S = R2/X2 .

As the slip further increases (i.e. motor speed falls) with further increase in motor load , R2 becomes negligible as compared to (S X2) ,therefore

$$T \propto \frac{S}{(S X_2)^2} \propto \frac{1}{S}$$

Hence , the torque/slip curve is a rectangular hyperbola . So ,we see that beyond the point of maximum torque , any further increase in motor load results in decrease of torque developed by the motor . The result is that the motor slows down and eventually stops . The circuit – breaker will be tripped and open the circuit . In fact , the stable operation of motor lies between the values of S = 0 and that corresponding to maximum torque The operating range is shown shaded in the next figure.