3-4 Maximum Torque: -

Taking the derivative of Tem by S (dTem/ds) and equating this to zero (dt/ds =0)then the slip at max. torque(critical slip) can be obtained:-

$$sm = \pm \frac{R2e}{\sqrt{R1^2 + (X1 + X2)^2}}$$

If neglecting the stator risis.(R_1=0)then

$$sm = \pm \frac{R2e}{\sqrt{(X1 + X2)^2}} = \pm \frac{R2e}{\mathrm{xsc}}$$

Substituting S_m in the torque equation in (Tem)then

$$Tm = \pm \frac{3V1^2}{\omega 1} \times \frac{1}{2(\mathrm{R1} \pm \sqrt{\mathrm{R1}^2 + (\mathrm{X1} + \mathrm{X2})^2}}$$

Neglecting the R_1=0 then the maximum torque is

$$Tm = 1.5\,\frac{V^2}{\omega 1\; XSC} = 0.2388P\,\frac{V^2}{f1\; XSC}$$

The max. torque value is inversely proportional to the short circuit reactance(Tα 1/XSC)and it is independent of (R_{2e}):that mane it's no effect of R_{2e} on T_m value.

To have max. torque at starting: $T_s=T_m$

Then $S_m=1=R_{2e}/X_{SC}$ Or $R_{2e}=X_{sc}=X_1+X_{sc}$

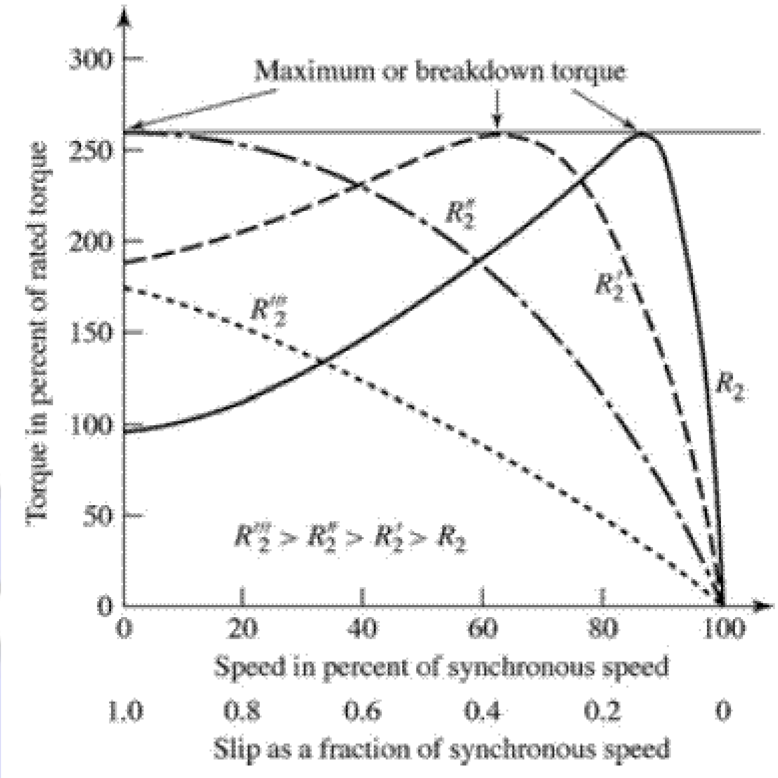
This means that $\varphi_2=45^\circ$ and cosφ2=0.707

3-5 Starting Torque:-

At starting S=1, substituting this slip value is torque equation then.

$$Ts = \frac{3V1^2}{\omega 1} \cdot \frac{R2e}{(R1 + R2e)^2 + (x1 + x2e)^2}$$

Usually if is required that Ts=Tm then Sm=1 or R2e=X2e if should be rotated that R2e/s= constant always or $\frac{R2}{S} = \frac{R2'}{S'} = \frac{R2'''}{S'''} = \frac{R2''''}{S''''}$


Maximum or breakdown torque
Torque in percent of rated torque
300
250
200
150
100
50
0
R_2'''
R_2''
R_2'
R_2
$R_2''' > R_2'' > R_2' > R_2$
0
20
40
60
80
100
Speed in percent of synchronous speed
1.0
0.8
0.6
0.4
0.2
0
Slip as a fraction of synchronous speed

3- 6 Effect of Applied Voltage:-

From approximate equivalent cct and assuming Z1=0 then

$$Tm = \frac{3}{\omega 1} \cdot \frac{V1^2 R2e}{(R2e)^2 + (SX2e)^2} \quad since\ \ T1 = T2 = T$$

Then

$$\frac{V1^2\ \ S1\ R2e}{(R2e)^2 + (S1X2e)^2} = \frac{V2^2\ S2\ R2e}{(R2e)^2 + (S2X2e)^2}$$

$$OR\ \left(\frac{V1}{V2}\right)^2 = \frac{S2}{S1}\left(\frac{R2e^2 + (S1\ X2e)^2}{R2e^2 + (S2\ X2e)^2}\right.$$

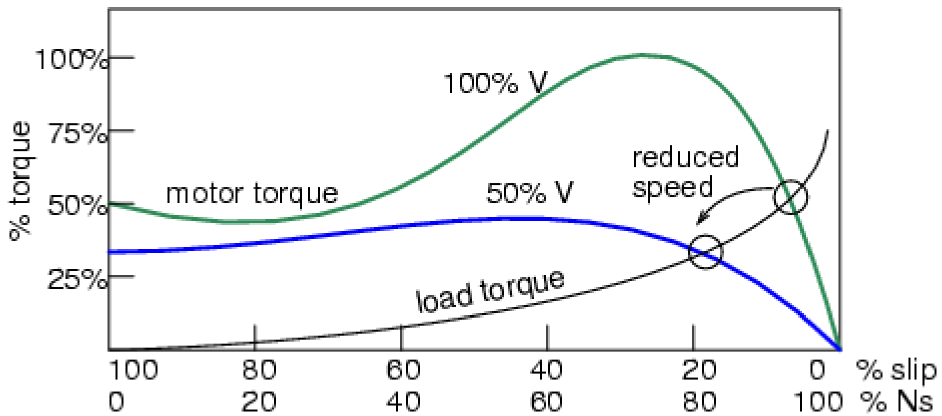
Since slip variation will not effect the value in the rotor coil of machine then.

$$\frac{T1}{T2} = \left(\frac{V1}{V2}\right)^2 = \frac{S2}{S1} \quad Since\ S1\ X2e = S2\ X2e$$

If V_2=0.75V_1 then T2=0.44 T1

That mane the voltage variation ΔV must be in rang of (10-(-5))%

ΔV=+10% , -5%



3-7 Ratio of Max To Rated Torque:-

$$Tr = \frac{3V^2}{\omega 1} \cdot \frac{R2e/sr}{(R1 + R2e/sr)^2 + (x1 + x2)^2}$$

$$Tm = \frac{3V^2}{\omega 1} \cdot \frac{\frac{R2e}{sm}}{\left(R1 + \frac{R2e}{sm}\right)^2 + (x1 + x2)^2}$$

Kmr or $\mu m = \frac{Tm}{Tr}$

$$\mu m = \frac{\left(R1 + \frac{R2e}{sr}\right)^2 + (X1 + X2e)^2}{\left(R1 + \frac{R2e}{sm}\right)^2 + (X1 + X2e)^2} \cdot \frac{sr}{sm}$$

$$Sm = \frac{R2}{\sqrt{R1^2 + (X1 + X2)^2}} \rightarrow R1^2 + (X1 + X2)^2 = \left(\frac{R2}{Sm}\right)^2$$

$$(X1 + X2)^2 = \left(\frac{R2}{Sm}\right)^2 - R1^2$$

$$\mu m = \frac{R1^2 + 2R1\frac{R2}{Sr} + \left(\frac{R2}{Sr}\right)^2 + \left(\frac{R2}{Sm}\right)^2 - R1^2}{R1^2 + 2R1\frac{R2}{Sr} + \left(\frac{R2}{Sr}\right)^2 + \left(\frac{R2}{Sm}\right)^2 - R1^2} \cdot \frac{sr}{sm}$$

$$= \frac{2R1R2 + \frac{R2^2}{Sr} + sr\left(\frac{R2}{Sm}\right)^2}{2R1R2 + \frac{R2^2}{Sm} + \frac{R2^2}{Sm}} \times \frac{R2^2}{R2^2} divided$$

$$= \frac{\frac{2R1}{R2} + \frac{1}{Sr} + \frac{Sr}{Sm^2}}{\frac{2R1}{R2} + \frac{1}{Sm} + \frac{1}{Sm}} \times \frac{sm}{sm}$$

$$\mu m = \frac{\frac{sm}{sr} + \frac{sr}{sm} + 2sm\frac{R1}{R2}}{2 + 2Sm\frac{R1}{R2}}$$

$$\mu m = \frac{\frac{sm}{sr} + \frac{sr}{sm} + Q}{2 + Q} \qquad Q = 2Sm\frac{R1}{R2}$$

$$Z1 = 0, \quad Q = 0$$

$$\frac{Tm}{Tr} = \frac{\frac{sm}{sr} + \frac{sr}{sm}}{2} = 2\frac{Tm}{Tr} = \frac{Sm^2 + Sr^2}{Sm\,Sr}$$

$$\frac{Tm}{Tr} = \frac{Sm^2 + Sr^2}{2Sm\,Sr}$$

μm= 1.7 …….3