Lecture 11

Monday, 14 September 2009
10:27 AM

Definition of slip (Im)

$$\text{Slip } s \triangleq \frac{\left(\text{difference in speed btw rotor \& stator}\right)}{\text{rotor synchronous speed}}$$

$$= \frac{\omega_{ms} - \omega_m}{\omega_{ms}}$$

$$= \frac{\frac{2}{p}\omega_s - \omega_m}{\frac{2}{p}\omega_s}$$

$$s = \frac{\omega_s - \frac{p}{2}\omega_m}{\omega_s}$$

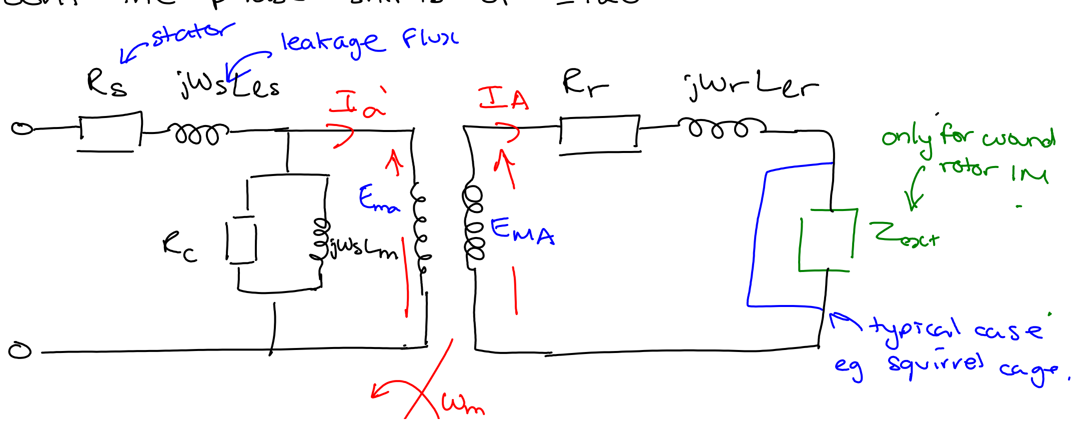
$$= \frac{\omega_r}{\omega_s}$$

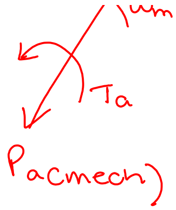
$$= \frac{\text{rotor current frequency}}{\text{stator current frequency}}$$

$$\boxed{s = \frac{f_r}{f_s}}$$

Single phase equivalent cct

We assume that we are dealing with a balanced 3ϕ Im. Hence it is possible to analyze one phase of the machine and then the results will apply to the other phases by taking into account the phase shifts of $\pm 120°$





one of three balanced phases

Single phase Equivalent Circuit

Note that the stator frequency $\neq$ the rotor frequency except for $\omega_m = 0$.

Note that $Z_{ex} = 0$ for rotors with shorted rings eg squirrel cage rotors.

The amplitude of the induced EMF in the rotor is proportional to the speed difference between the flux and the rotor conductors. Clearly, if the speed difference is zero, ($s = 0$) then the induced EMF is zero.

If the rotor is "locked" in a fixed position, then the EMF is determined only from the turns ratio ($s = 1$).

$$\therefore \frac{E_{MA}}{E_{ma}} = \frac{\frac{2}{p}\omega_s - \omega_m}{\frac{2}{p}\omega_s} \cdot \frac{N_{re}}{N_{se}}$$

N_{re} = effective rotor turns

N_{se} = effective stator turns.

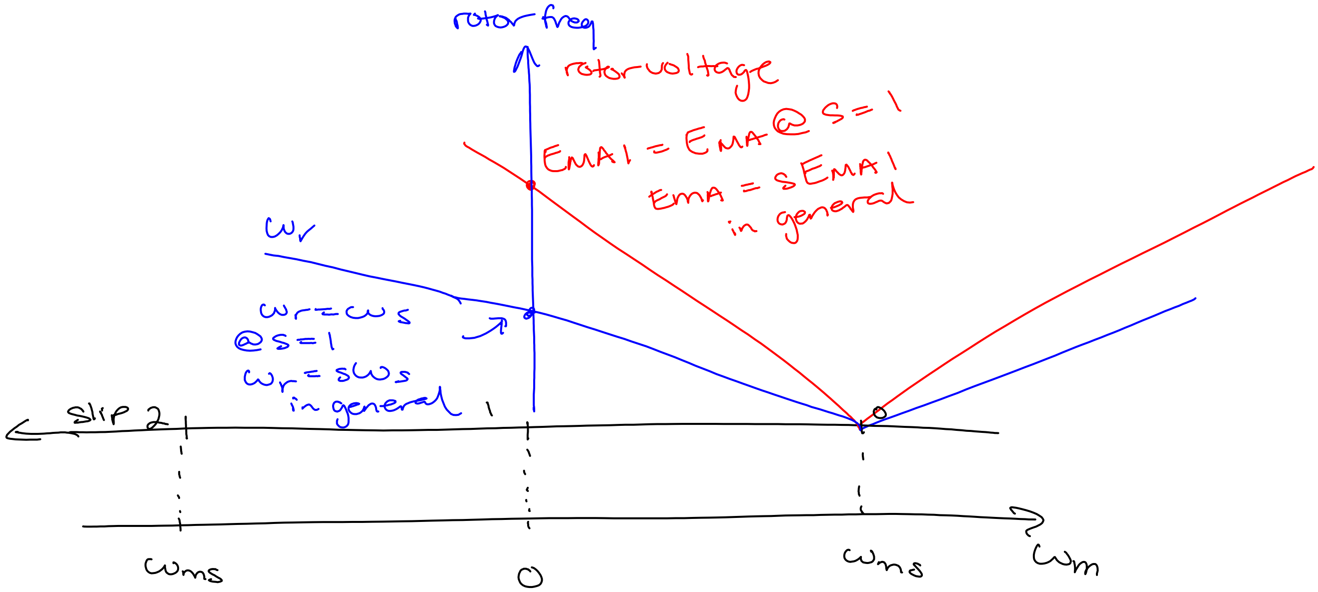
$$\frac{|E_{MA}|}{|E_{ma}|} = \frac{\omega_s - \frac{p}{2}\omega_m}{\omega_s} \frac{N_{re}}{N_{se}}$$

$$= \frac{\omega_r}{\omega_s} \frac{N_{re}}{N_{se}} = s \frac{N_{re}}{N_{se}}$$

Consider currents:

mmfs must balance:

$$\therefore \frac{|I_A|}{|I_a'|} = \frac{N_{se}}{N_{re}}$$



Examine rotor cct

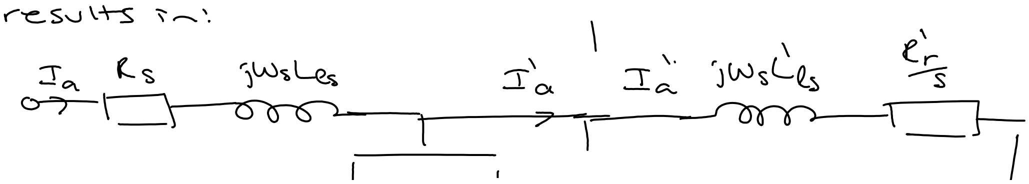
$$I_A = \frac{E_{MA}}{R_r + j\omega_r L_{er}} \qquad (Z_{ex} = 0)$$

$$= \frac{sE_{MA1}}{R_r + js\omega_r L_{er}}$$

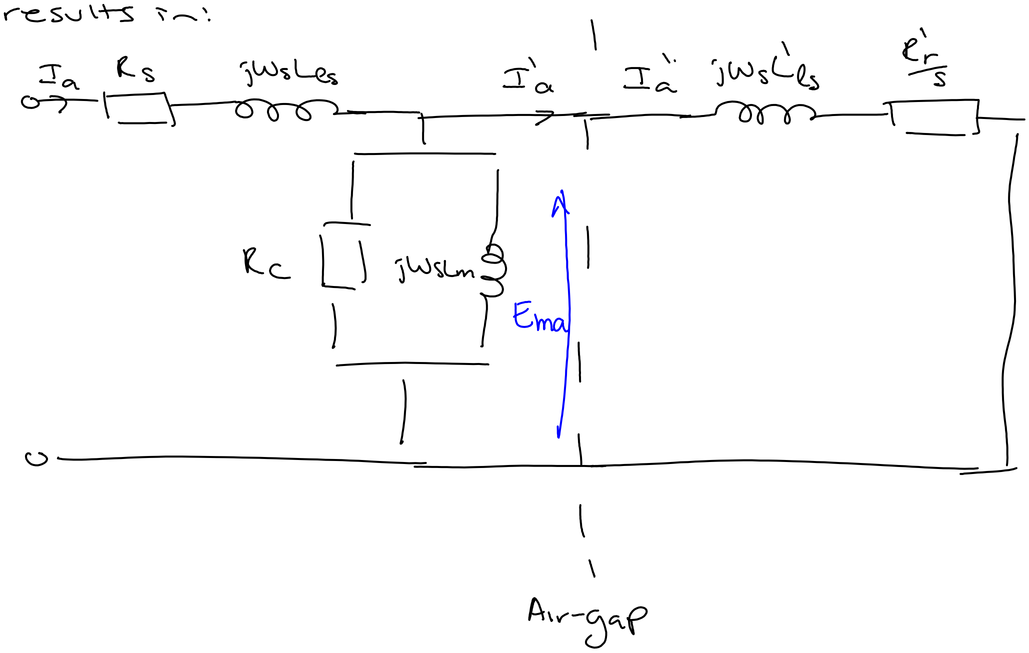
$$= \frac{E_{MA1}}{\frac{R_r}{s} + j\omega_s L_{er}}$$

This observation allows a changed equivalent cct to be used:

Now, like the transformer we can refer the rotor quantities to the stator and this results in:



results in:



The power transferred across the air-gap is

$$P_{ma} = 3\,(I_a')^2\,\frac{R_r'}{s}$$

$$= 3\,(I_A)^2\,\frac{R_r}{s}$$

The rotor winding loss is

$$3\,(I_a')^2 R_r' = s\,P_{ma}$$

and the difference between these must be the mechanical output power.

$$P_{amech} = P_{ma} - 3(I_a')^2 R_r'$$

$$= P_{ma} - s\,P_{ma}$$

$$= P_{ma}\,(1-s)$$

$$\boxed{\text{Rotor winding loss} = s\,P_{ma}}$$

$$\boxed{\text{Gross mech O/P power} = (1-s)P_{ma}}$$

$$P_{a\,mech} = T\omega_n$$

$$\therefore T\omega_n = (1-s)P_{ma}$$

$$\boxed{\therefore \tau = \frac{P_{ma}}{\omega_n}}$$

It is often useful to segregate rotor losses from mechanical O/P power and so the quantity R_r'/s is seperated into

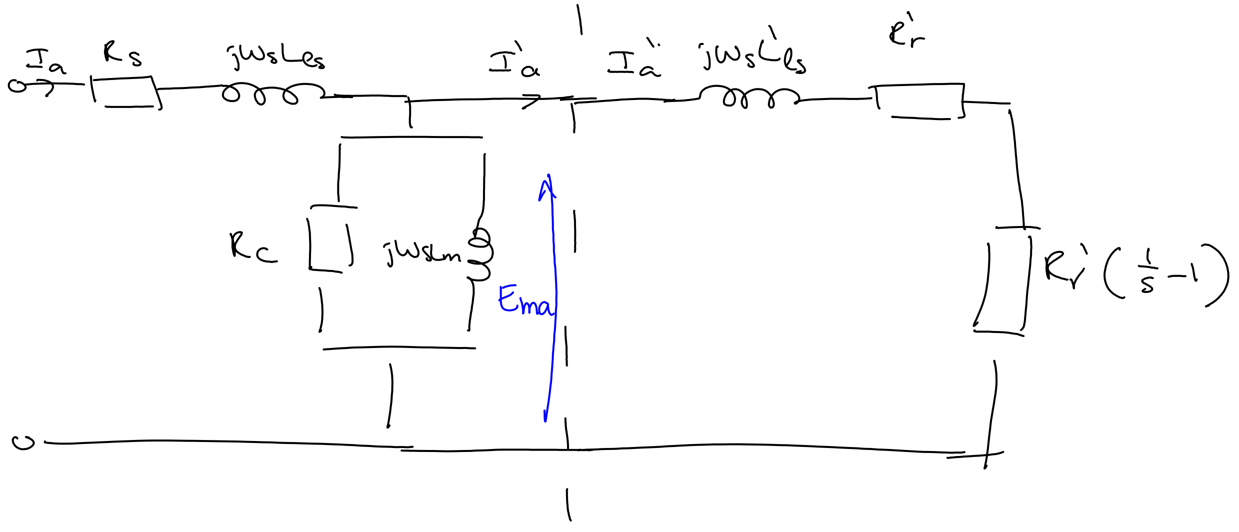
$$\frac{R_r'}{s} = R_r' - R_r' + \frac{R_r'}{s}$$

$$= R_r' + R_r'\left(\frac{1}{s} - 1\right)$$

$$= R_r' + R_r'\left(\frac{1-s}{s}\right)$$

$$\therefore \text{mech O/P power} = P_{ma} - \text{rotor loss}$$

$$= 3\left(\underline{I}'_a\right)^2 R_r'\left(\frac{1-s}{s}\right)$$



To simplify the problem solution we may replace that portion of the equivalent cct to the left of the air-gap with a Thevenin equivalent.