ECE 3600 Exam 2 Information

You may write more on this sheet. You may also use Exam 1 Information

Synchronous Machines

for 60Hz systems $n_{sync} = \frac{7200 \cdot rpm}{poles}$ $\omega_{sync} = \frac{4 \cdot \pi \cdot f}{N_{poles}}$

When spinning, the induced armature voltages ($\mathbf{E_A}$ for our phase) depends on the field current, I_f.
I_f cause the field flux (call **excitation**).

Pullout power is the maximum power a generator can produce for a given excitation, at δ=90º

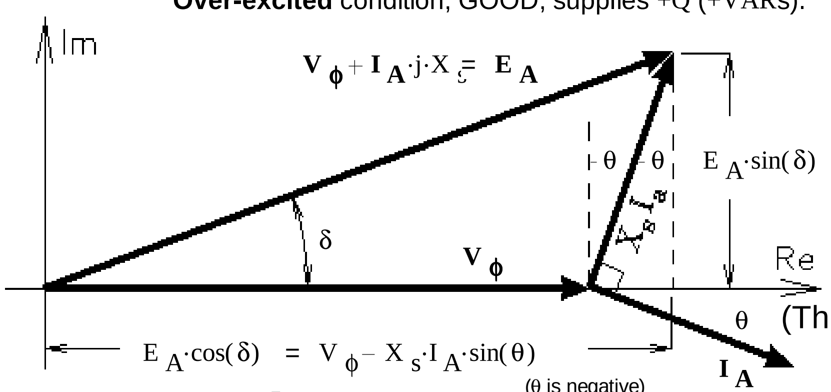
$$P_{po} = \frac{E_A \cdot V_\phi}{X_s} \cdot \sin(90 \cdot deg) = \frac{E_A \cdot V_\phi}{X_s}$$

Generators

Over-excited condition, GOOD, supplies +Q (+VARs).

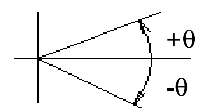
Note: Voltages and currents are magnitudes, not complex numbers

The **signs** of the angles are **important!**



$E_A \cdot \sin(\delta) = X_s \cdot I_A \cdot \cos(\theta)$

(This θ is **neg**ative)



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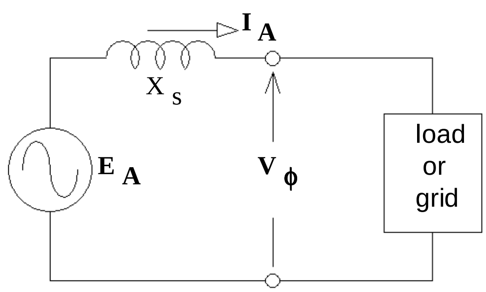


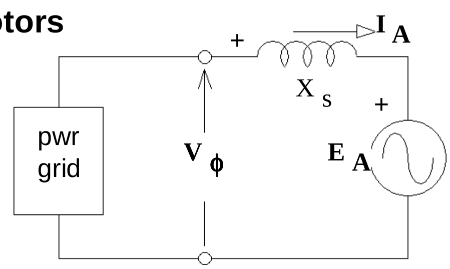
$$P_{1\phi} = \frac{V_\phi \cdot E_A \cdot \sin(\delta)}{X_s} = V_\phi \cdot I_A \cdot \cos(\theta) \qquad \delta = asin\left(\frac{P_{1\phi} \cdot X_s}{V_\phi \cdot E_A}\right)$$

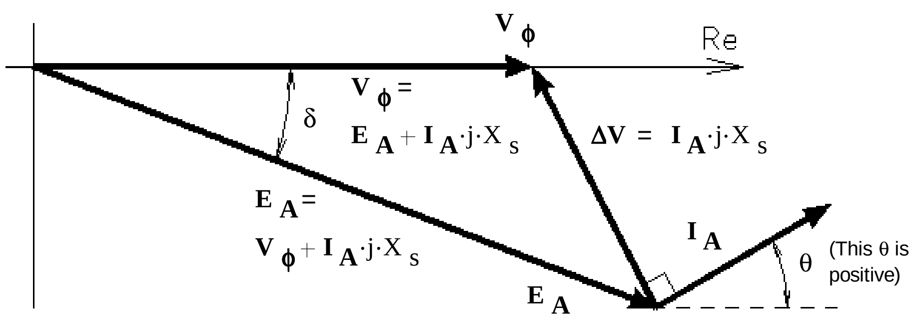
$$Q_{1\phi} = \frac{V_\phi \cdot E_A \cdot \cos(\delta) - V_\phi^2}{X_s} = V_\phi \cdot I_A \cdot \sin(-\theta)$$

(produced)

$\mathbf{E_A} = \mathbf{V_\phi} + \mathbf{I_A} \cdot j \cdot X_s$

Motors

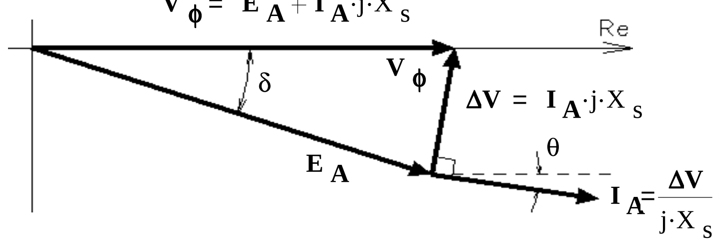




(θ is measure in opposite direction to a regular load)

Over-excited condition, GOOD, supplies +Q (+VARs).
uses -Q

$\mathbf{V_\phi} = \mathbf{E_A} + \mathbf{I_A} \cdot j \cdot X_s$



Under-excited condition, BAD, absorbs (uses) +Q (+VARs).
like an inductor

<u>Important relations</u>

$$E_A \cdot \sin(|\delta|) = X_s \cdot I_A \cdot \cos(\theta)$$

$$P_{1\phi} = \frac{E_A \cdot V_\phi}{X_s} \cdot \sin(|\delta|) = V_\phi \cdot I_A \cdot \cos(\theta)$$

$$Q_{1\phi} = \frac{V_\phi^2 - E_A \cdot V_\phi \cdot \cos(\delta)}{X_s} = V_\phi \cdot I_A \cdot \sin(-\theta)$$

(used)

(Bigger E_A makes Q negative (good))

$\mathbf{E_A} = \mathbf{V_\phi} - \mathbf{I_A} \cdot j \cdot X_s$

Induction Motors

$n_{slip} = n_{sync} - n_m = s \cdot n_{sync}$

slip $s = \dfrac{n_{slip}}{n_{sync}} = \dfrac{n_{sync} - n_m}{n_{sync}}$

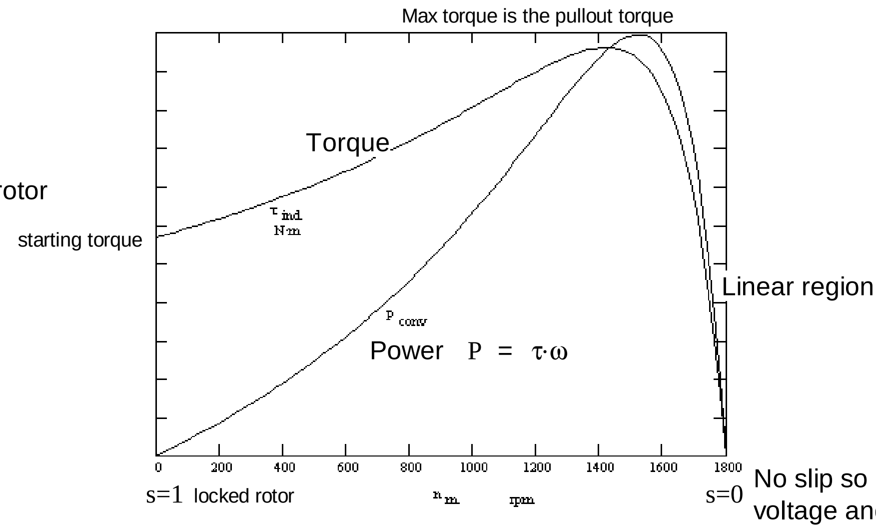
n_m = the mechanical speed of the rotor

$= (1 - s) \cdot n_{sync}$

$$\omega = n \cdot \left(2 \cdot \pi \cdot \frac{rad}{rev}\right) \cdot \left(\frac{min}{60 \cdot sec}\right)$$

$\dfrac{rad}{sec}$ rpm

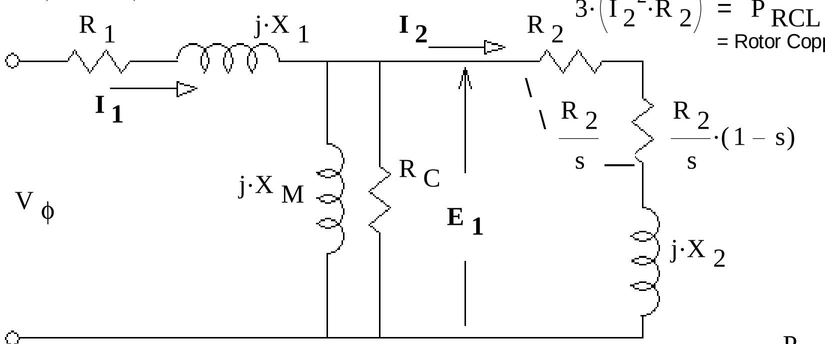
Typical torque-speed and power-speed curves for a 4-pole Induction motor



No slip so no induced voltage and current in the rotor and thus no torque

$3 \cdot \left(I_1^{\,2} \cdot R_1\right) = P_{SCL}$ = Stator Copper Losses

$3 \cdot \left(I_2^{\,2} \cdot R_2\right) = P_{RCL}$ = Rotor Copper Losses



$$3 \cdot \left[I_2^{\,2} \cdot \frac{R_2}{s} \cdot (1 - s)\right] = P_{conv}$$

$= (1 - s) \cdot P_{AG}$

= power converted to mechanical

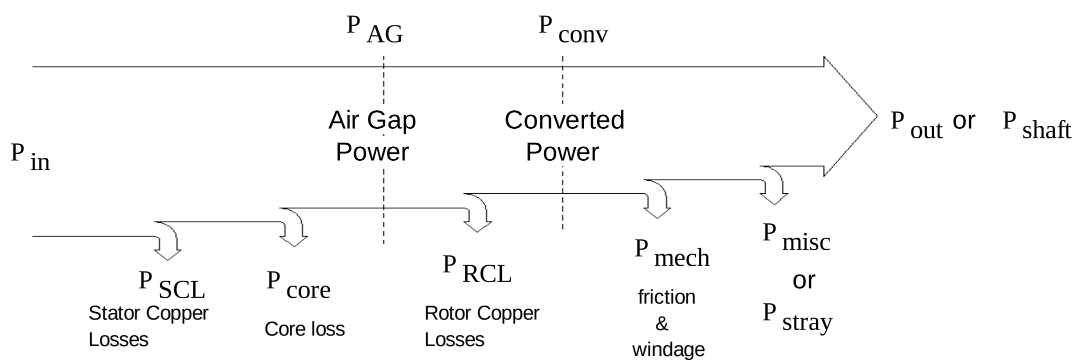
$3\,E_1^{\,2}/R_C = P_{core}$ = core loss

$P_{out} = P_{conv} - P_{mech} - P_{misc}$ (mechanical losses)

induced torque = $\tau_{ind} = \dfrac{P_{conv}}{\omega_m}$ OR: $\tau_{ind} = \dfrac{P_{AG}}{\omega_{sync}}$ $(N \cdot m)$

load torque = $\tau_{load} = \dfrac{P_{out}}{\omega_m}$

Power Flow



Per Unit

S_{base} is the same across the entire system.

V_{base} = The nominal V_L (V_{LL}) in each region of the power system, where regions are regions are separated by transformers.

$$I_{base} = \frac{S_{base}}{\sqrt{3} \cdot V_{base}} \qquad Z_{base} = \frac{V_{base}^{\,2}}{S_{base}}$$

Base changes $Z_{pu} = Z_{pu\_device} \cdot \dfrac{S_{base} \cdot \left(V_{rated}\right)^2}{S_{rated} \cdot \left(V_{base}\right)^2}$

Often the device: $V_{rated} = V_{base}$