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 $\delta := 90 \cdot deg$

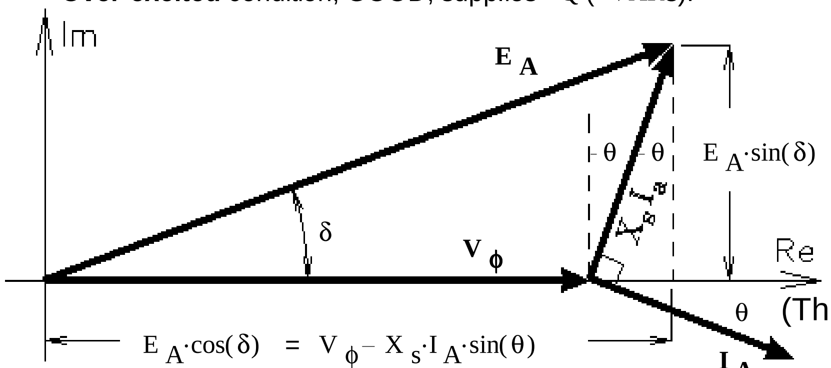
$$P_{po} = \frac{E_A \cdot V_\phi}{X_s} \cdot \sin(90 \cdot deg) = \frac{E_A \cdot V_\phi}{X_s}$$

Generators

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

Note: Voltages and currents are magnitudes, not complex numbers

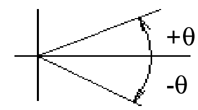
The **signs** of the angles are **important!**



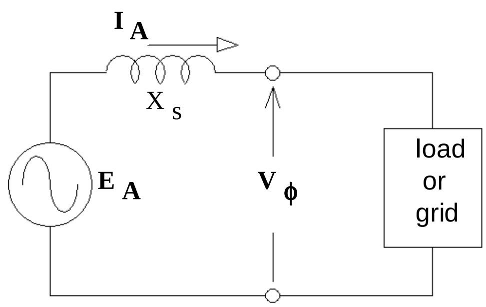
$E_A \cdot \sin(\delta) = X_s \cdot I_A \cdot \cos(\theta)$

$E_A \cdot \cos(\delta) = V_\phi - X_s \cdot I_A \cdot \sin(\theta)$ (θ is negative)

(This θ is **neg**ative)



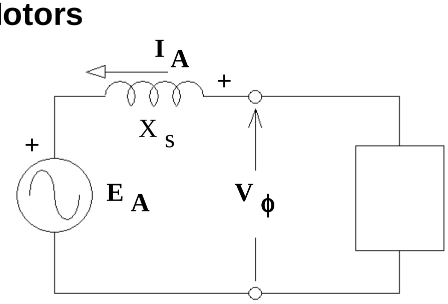
$E_A \cdot \sin(\delta) = X_s \cdot I_A \cdot \cos(\theta)$

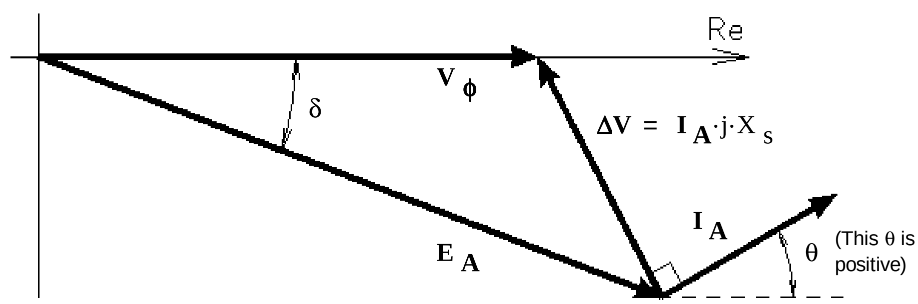


$$P_{1\phi} = \frac{V_\phi \cdot E_A \cdot \sin(\delta)}{X_s} \qquad \delta = \operatorname{asin}\left(\frac{P_{1\phi} \cdot X_s}{V_\phi \cdot E_A}\right)$$

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

Motors

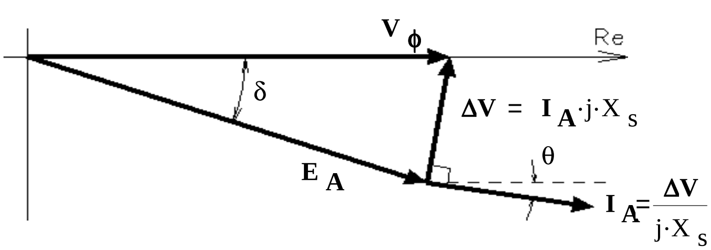




Over-excited condition, GOOD, supplies +Q (+VARs).

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

$Q = V_\phi \cdot I_A \cdot \sin(-\theta)$



Under-excited condition, BAD, absorbs +Q (+VARs).

<u>Important relations</u>

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

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

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

(Bigger E_A makes Q negative (good))

Induction Motors

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

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

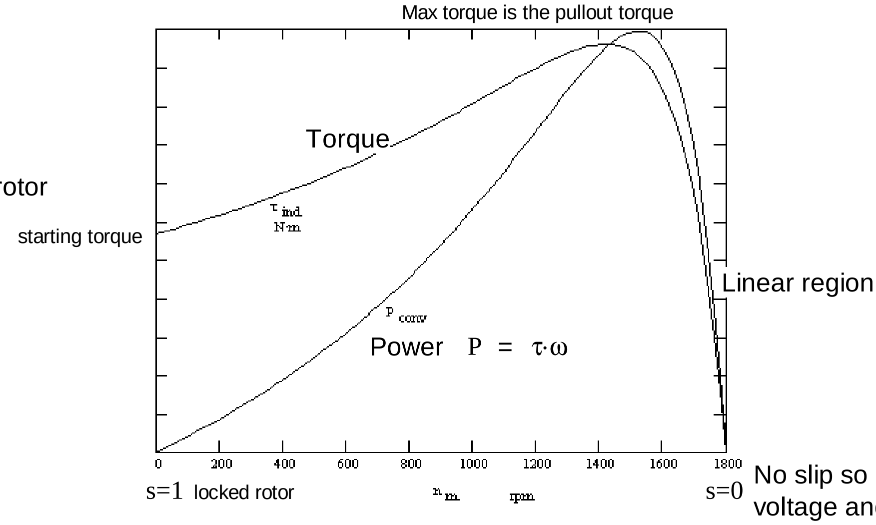
n_m = the mechanical speed of the rotor

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

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

$\dfrac{rad}{sec}$ rpm

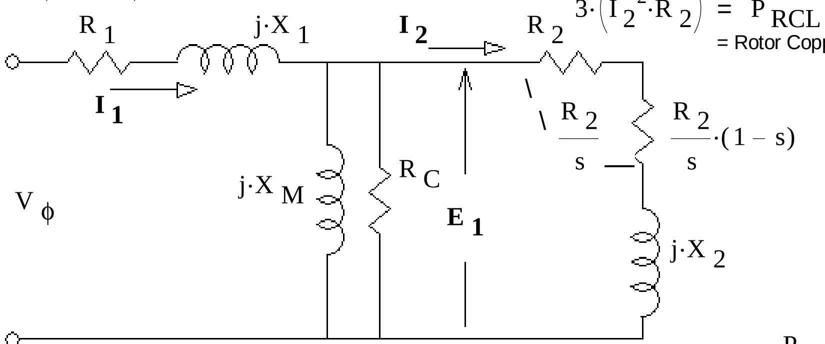
Typical torque-speed and power-speed curves for a 4-pole Induction motor



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



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

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

= power converted to mechanical

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

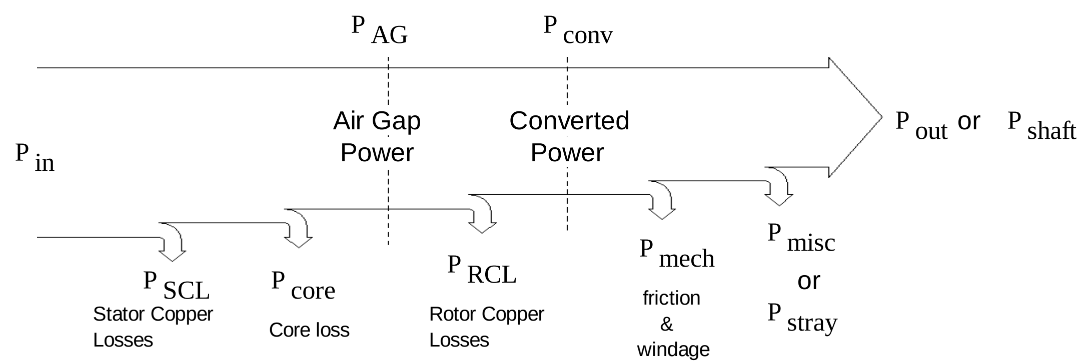
$P_{out} = P_{conv} - P_{mech} - P_{misc}$

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



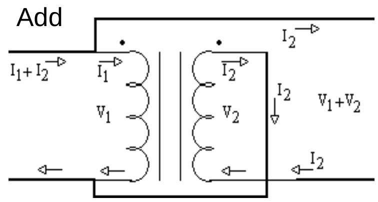
Special Sensing Transformers PT or VT, **P**otential or **V**oltage **T**ransformer, to monitor voltage.

CT, **C**urrent **T**ransformer, to monitor current. The secondary must always be shorted or nearly shorted.

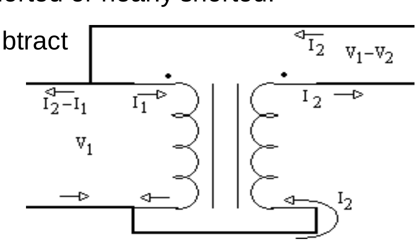
Autotransformers

Single winding, High-current (low voltage) side carries more current than any part of the winding.

Add



Subtract



Three-Phase transformers

May be 2 individual transformers wired as open Δ or T. May be 3 individual transformers. May share a single core.

Lower-voltage side is often connected Δ, so that 3rd harmonic currents can flow arround the Δ side without affecting external current waveforms. These connections cause a 30° phase shift.

Δ - Y is usually step-up

Y - Δ is usually step-down

Phase-Shifting Transformers are used to control the direction of power flow on the network.