ECE330: Power Circuits & Electromechanics

Lecture 22. Induction machine

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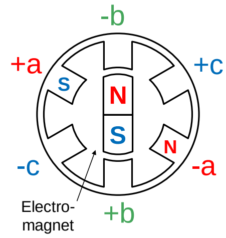
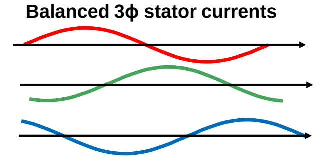
Last time: Synchronous machine



Balanced 3ϕ stator currents



Stator field at synchronous speed

Rotor spins at same speed

Rotor construction?

- Magnetic material → Reluctance machine
- Permanent magnet → Brushless DC
- Electromagnet → Synchronous machine

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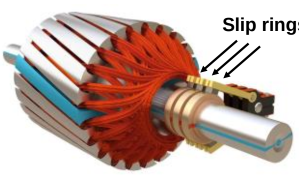
Image: Youtube.com/LearnEngineering



Wound rotor

- Slip rings wear out
- High centrifugal forces
- Many breakable parts
- Maintainence expensive and time consuming

Rotor is the weakest link

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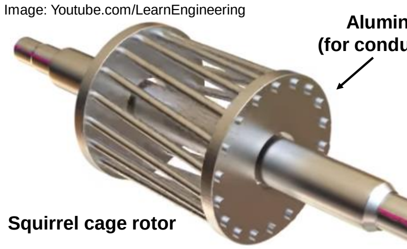
Image: Youtube.com/LearnEngineering



Squirrel cage rotor

Use induced current to excite rotor
Cheap, rugged, zero-maintence

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Works with any conductive rotor!

https://youtu.be/z-oue39E5PA

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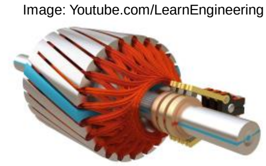
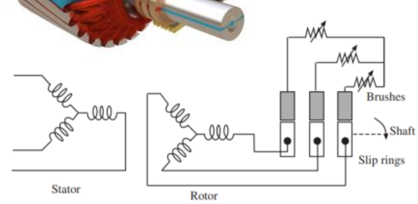
Wound rotor induction machine – Why??

Image: Youtube.com/LearnEngineering





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Today

- Electrical model
- Mechanical model

Next lecture: Torque-speed characteristic

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Preliminary: Definition of Slip

Synchronous **speed**
= 60 π [rad/s]
= 1800 rpm

Synchronous machine

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

Synchronous **frequency**
= 120 π [rad/s]
= 60 [Hz]

Induction machine

$$\omega_m = \frac{2}{p}(1-s)\omega_s$$

slip
[dimensionless]

Rotor frequency $\omega_r = s\omega_s$

Efficiency $\eta \approx 1 - s$

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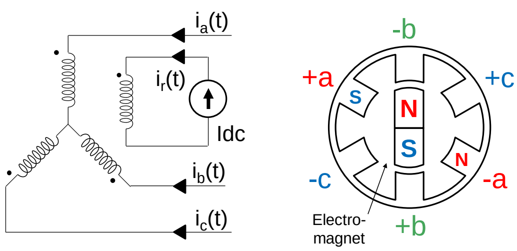
Recall: Synch mach



$$v_a(t) = L_a\frac{di_a}{dt} + M_{ar}(\theta)\frac{di_r}{dt} + M'_{ar}(\theta)i_r(t)\frac{d\theta}{dt}$$

0 M cos(ωt) Idc ω

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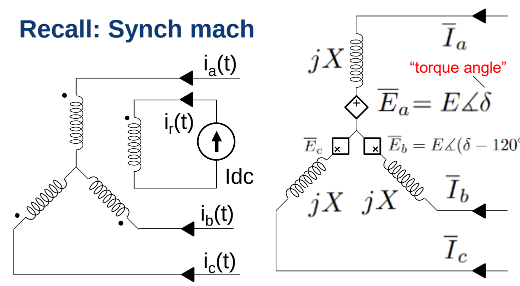
Recall: Synch mach



$$v_a(t) = L_a\frac{di_a}{dt} + M_{ar}(\theta)\frac{di_r}{dt} + M'_{ar}(\theta)i_r(t)\frac{d\theta}{dt}$$

0 M cos(ωt) Idc ω

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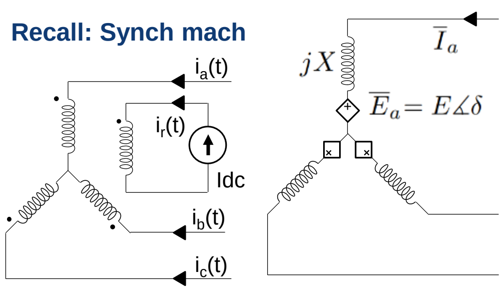
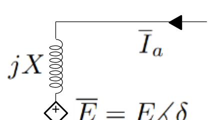
Recall: Synch mach



Single-phase
equivalent circuit
(this is a physical model)



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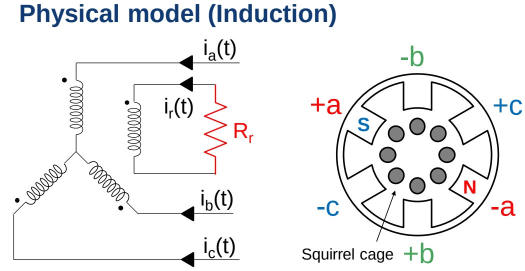
Physical model (Induction)



Still technically true

$$v_a(t) = L_a\frac{di_a}{dt} + M_{ar}(\theta)\frac{di_r}{dt} + M'_{ar}(\theta)i_r(t)\frac{d\theta}{dt}$$

..but now very complicated b/c rotor current is no longer fixed.

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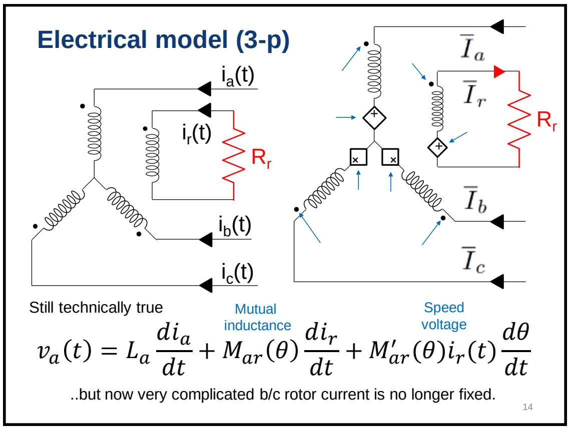

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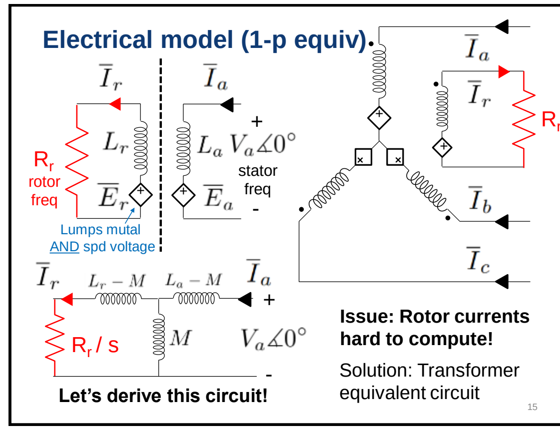

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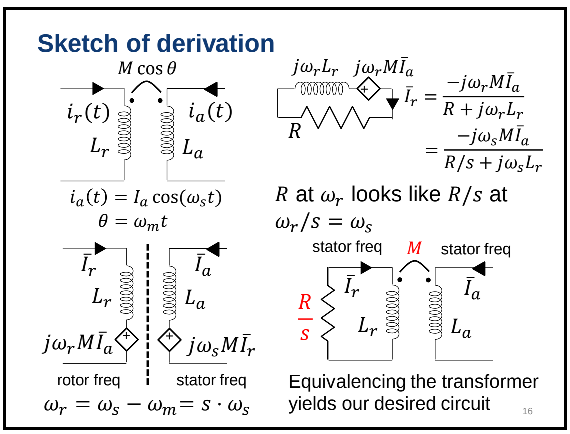

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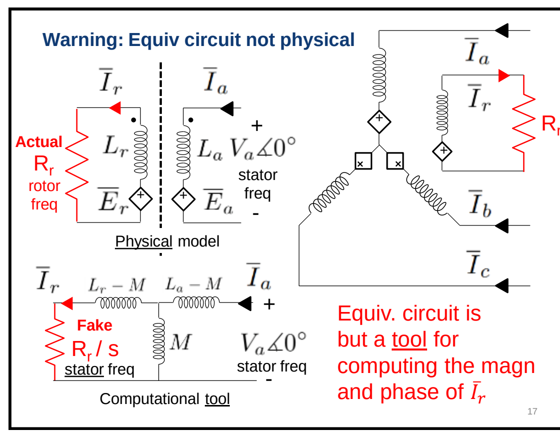

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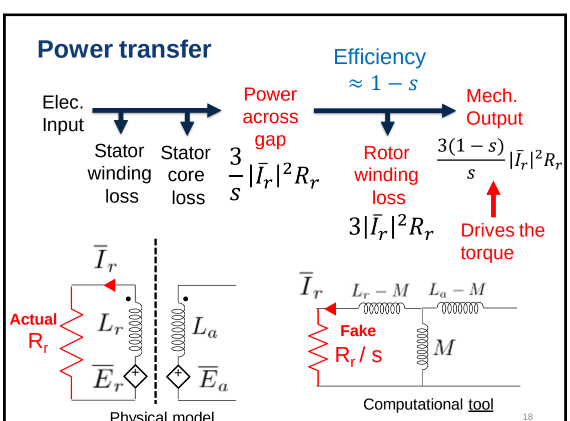

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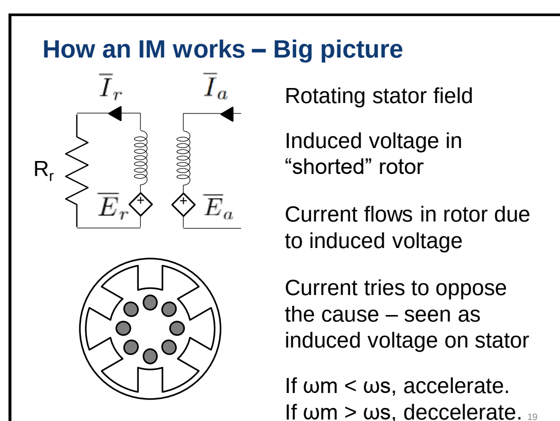

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Today

- ~~Electrical model~~
- Mechanical model

Next lecture: Torque-speed characteristic

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Torque [Nm] = $\frac{\text{Mechanical power [W]}}{\text{Mechanical speed [rad/s]}}$

Power across gap → Mech. Output

Rotor winding loss

Numerator $\frac{3}{s}|\bar{I}_r|^2R_r$ $\frac{3(1-s)}{s}|\bar{I}_r|^2R_r$

$3|\bar{I}_r|^2R_r$

Denominator $\omega_m = \frac{2}{p}(1-s)\omega_s$

3 phases

more poles = more torque

synch frequency [rad/s]

Torque [N/m] $T_e = 3\left(\frac{p}{2}\right)\left(\frac{|\bar{I}_r|^2R_r}{s\cdot\omega_s}\right)$

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A 460V (line-line), 60 Hz, 3 phase, 6-pole machine has a rated speed of 1140 rpm. The rotor has resistance 2Ω and leakage j3Ω. The stator has negligible resistance and leakage.

a) What is the frequency of rotor currents in Hz?

b) What is the torque at rated speed?

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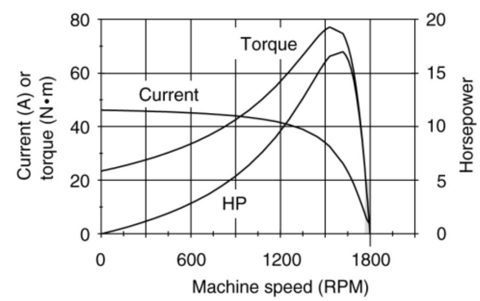
Next time:

Torque-Speed / Power-Speed Curve



http://electricalacademia.com/induction-motor/torque-speed-characteristics-induction-motor/

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