EE-362 ELECTROMECHANICAL ENERGY CONVERSION-II

Power and Torque in Induction Machines

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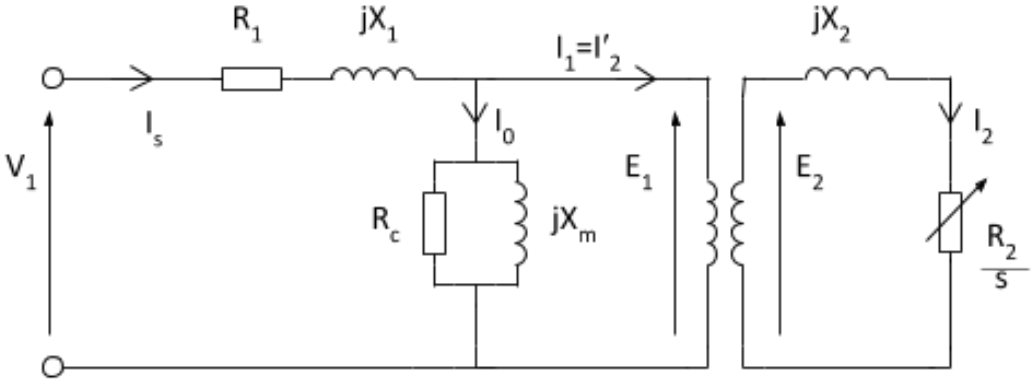
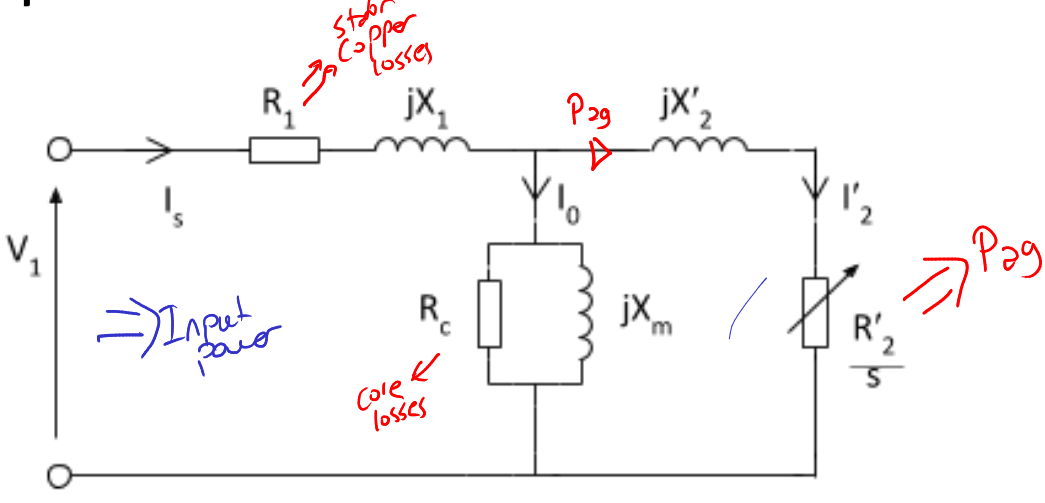
Equivalent Circuit of Induction Motors



The rotor can be referred to the stator side

Equivalent Circuit with Referred Rotor



Power Flow in Induction Motors

- Total Power: $P_{in} = 3V_1 I_1 cos(\theta)$
- Stator Copper Loss: $P_{cu1} = 3I_1^2 r_1$
- Core Loss: $P_c = 3\frac{E_1^2}{R_c} \approxeq 3\frac{V_1^2}{R_c}$

Power Flow in Induction Motors

Electrical Power Transferred to Rotor?

- Air-gap Power:

$$P_{ag} = P_{in} - P_{cu1} - P_c$$

or

$$P_{ag} = 3I_2'^2 \frac{r_2'}{s}$$

Power Flow in Induction Motors

Not all the air-gap power dissipates as heat, most of it is converted to mechanical power

The equivalent circuit ($\frac{r_2'}{s}$) can be separated into two components:

$$\frac{r_2'}{s} = r_2' + \frac{1-s}{s} r_2'$$

not a real resistance but a component to represent P_{mech}.

$$P_{ag} = P_{cu2} + P_{mech}$$

$P_{cu2} = 3I_2'^2 \cdot r_2'$ — rotor copper losses

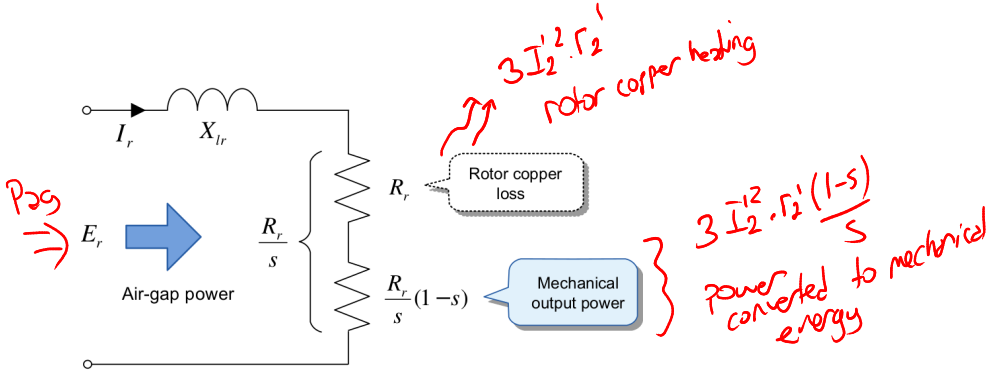
$P_{ag} = 3I_2'^2 \cdot \frac{r_2'}{s}$

$P_{ag} - P_{cu2} = P_{mech}$

$3I_2'^2 \cdot \frac{r_2'}{s} - 3I_2'^2 \cdot r_2'$

$P_{mech} = 3I_2'^2 \left(r_2' \frac{(1-s)}{s} \right)$

Rotor Side Equivalent Circuit



$3I_2'^2 \cdot r_2'$ rotor copper heating

P_{ag}

$3I_2'^2 \cdot r_2' \frac{(1-s)}{s}$ power converted to mechanical energy

$(\frac{r_2'}{s})$ is separated into two components

$r_2' + \frac{(1-s)}{s} \cdot r_2' = \frac{r_2'}{s}$

$s=1$ (rotor not rotating)

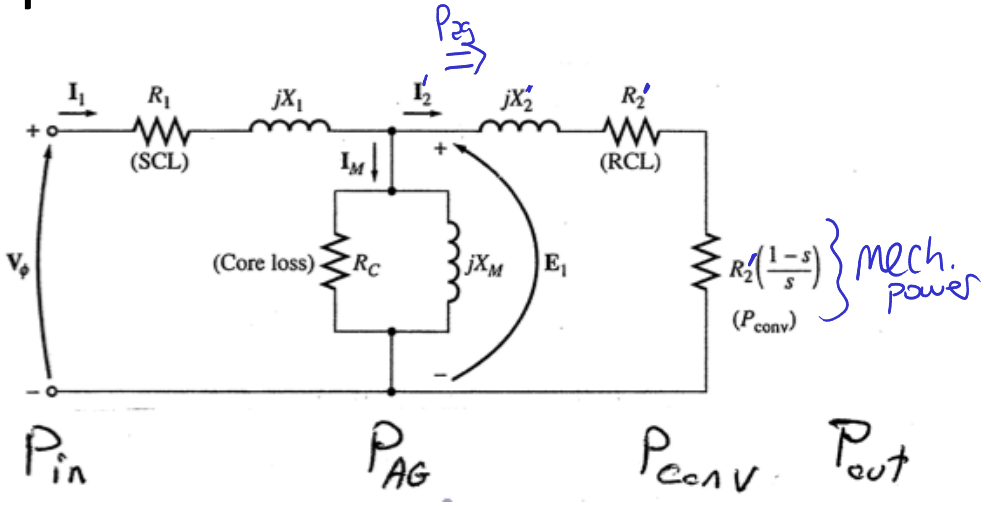
$r_2' \Rightarrow$ rotor heating $\quad \frac{r_2'(1-s)}{s} = 0$

$s=0$ (rotor at synch. speed

$r_2' \Rightarrow \quad \frac{r_2'(1-s)}{s} = \infty$ (open circuit)

$P_{ag}=0$

Equivalent Circuit of Induction Motors



Mechanical Power

Gap Power: $P_{ag} = 3I_2'^2 \frac{r_2'}{s}$

Rotor Copper Loss: $P_{cu2} = 3I_1^2 r_2'$

P_{cu2} can also be expressed in terms of P_{ag}

$$P_{cu2} = sP_{ag}$$

slip

Mechanical Power

Gross Mech. Power = Gap Power - Rotor Copper Loss

Gap Power: $$P_{ag} = 3I_2'^2 \frac{r_2'}{s}$$

$$P_{mech} = 3I_2'^2 \frac{(1-s)}{s} r_2'$$

P_{ag}

$$P_{mech} = (1-s)P_{ag}$$

Mechanical Power

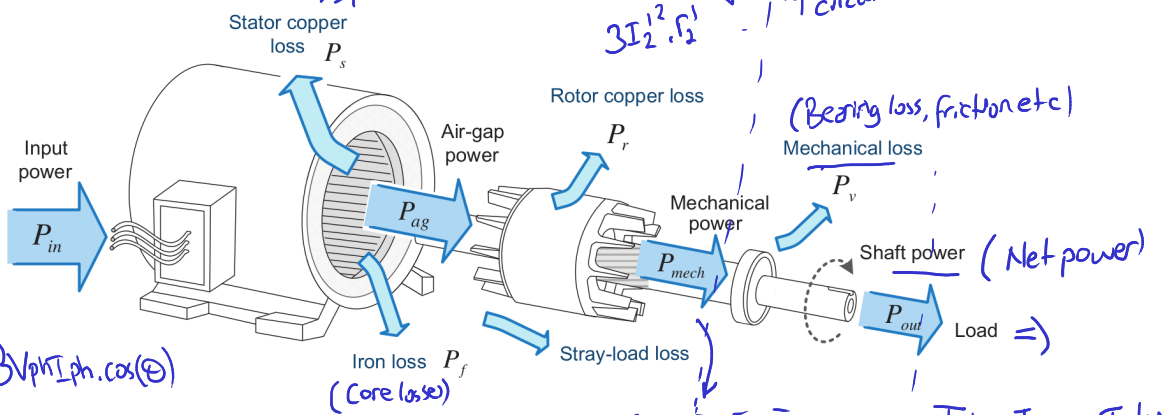
Gross mechanical power is the power converted into mechanical form

Net power is the useful mechanical energy to drive the mechanical load

Net Power = Gross Power - Rotational Losses

$$P_{net} = P_{mech} - P_{rot}$$

Power Flow in Induction Motors



Efficiency

Output Power / Input Power

$$\eta = \frac{P_{out}}{P_{in}}$$

Don't forget the rotational losses!