« EMR and Inversion-based Control of Renewable Energy Conversion Systems »

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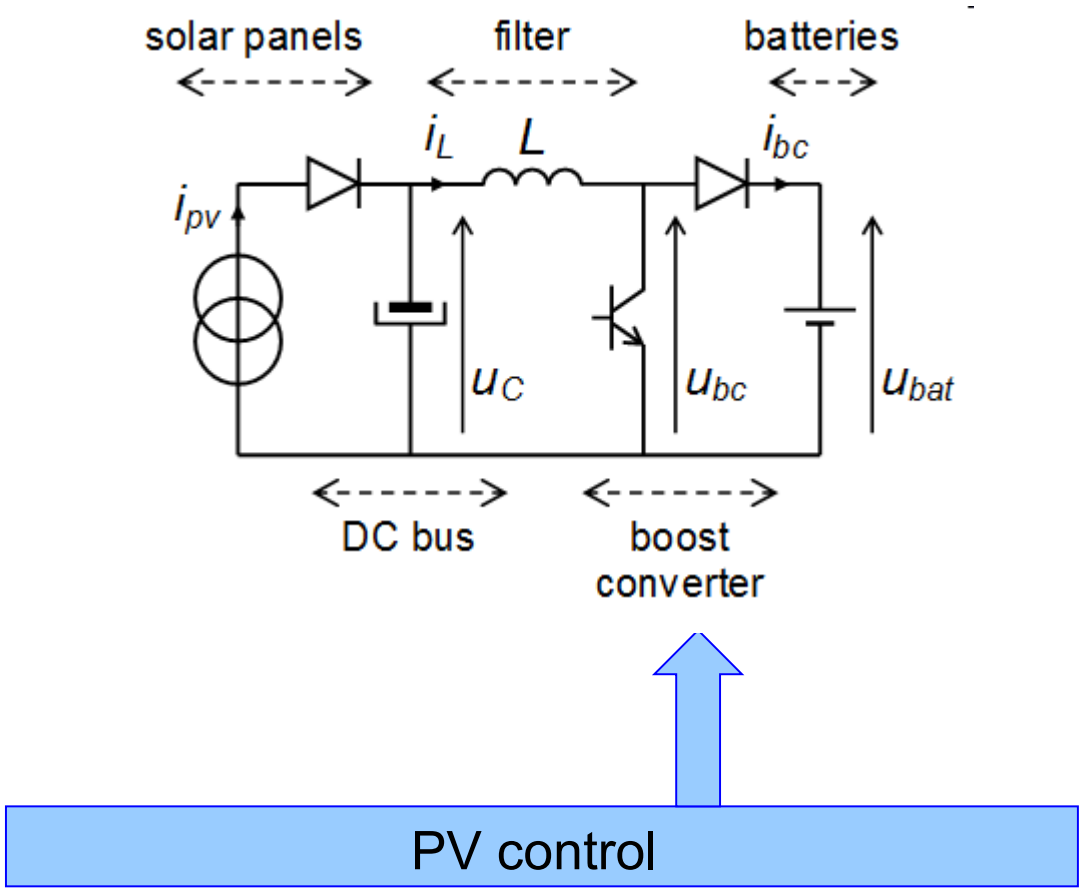
- Outline -

1. PhotoVoltaic Conversion System
   - Studied System
   - EMR of the PV system
   - Inversion-based control of the PV system

1. Wind Energy Conversion System
   1. Studied System
   2. EMR of the WECS
   3. Inversion-based control of the WECS

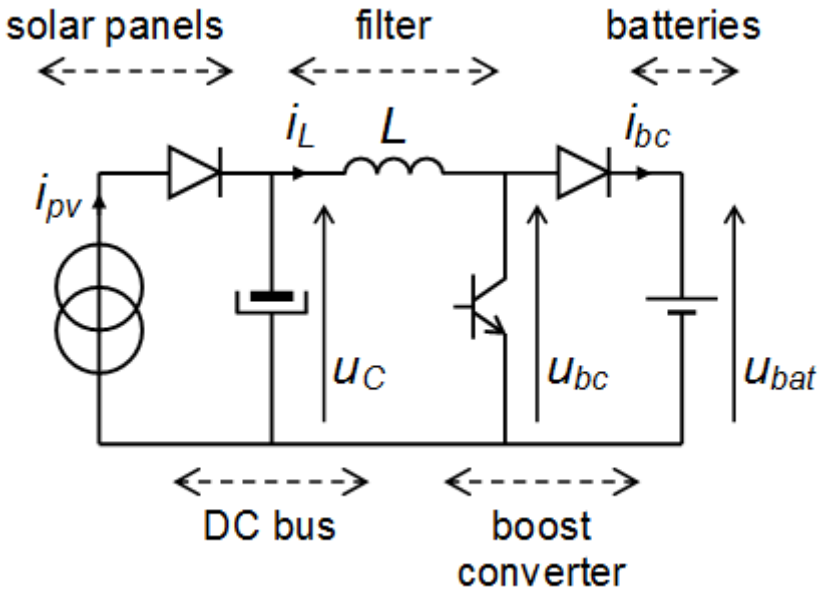
« PHOTOVOLTAIC CONVERSION SYSTEM »

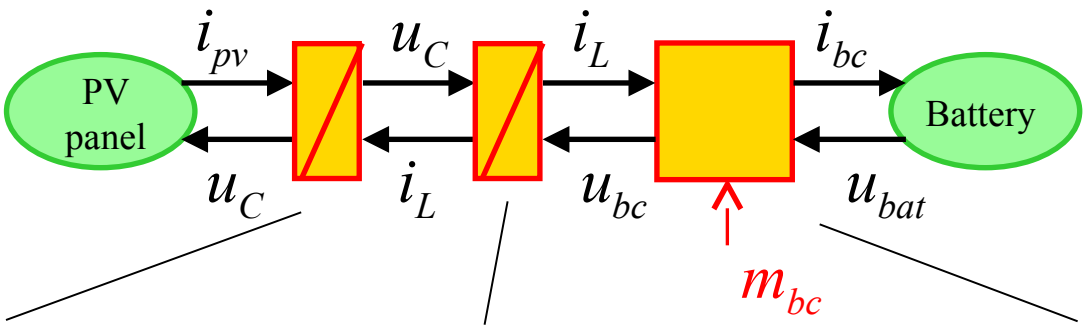
- Studied PV System -



Technical requirements: - provide the maximum active power P

- EMR of the PV System -





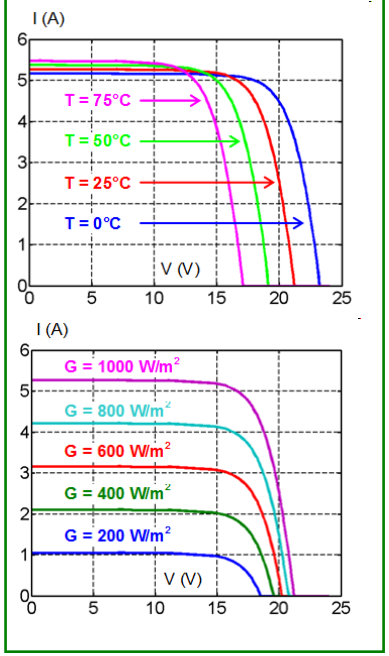
$$C\frac{d}{dt}u_C + \frac{u_C}{R_C} = i_{pv} - i_L$$

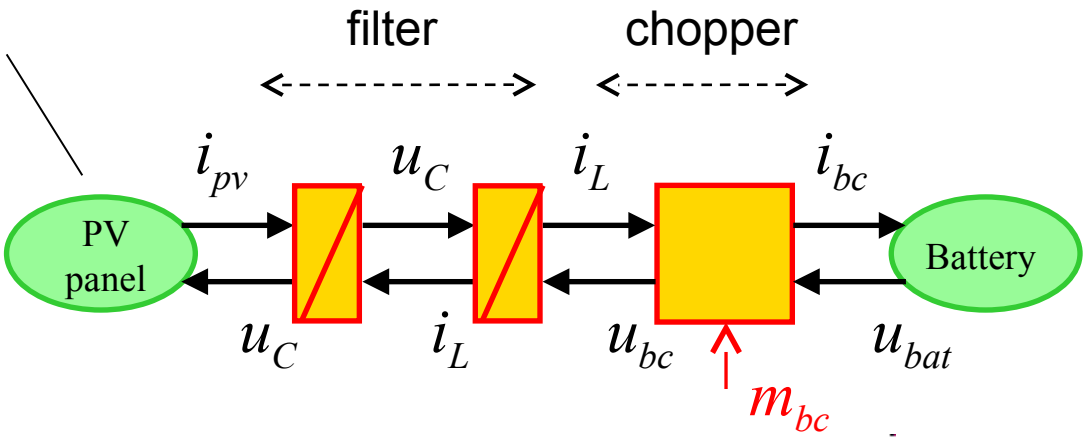
$$L\frac{d}{dt}i_L + R_L i_L = u_C - u_{bc}$$

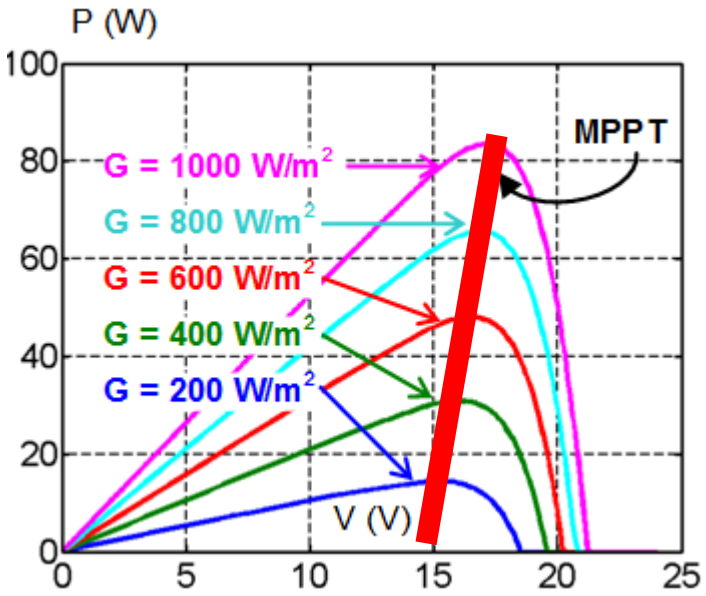
$$\begin{cases} i_{bc} = m_{bc} i_L \\ u_{bc} = m_{bc} u_{bat} \end{cases}$$

- EMR of the PV System -

$i_{pv} = f(u_c, T, G)$



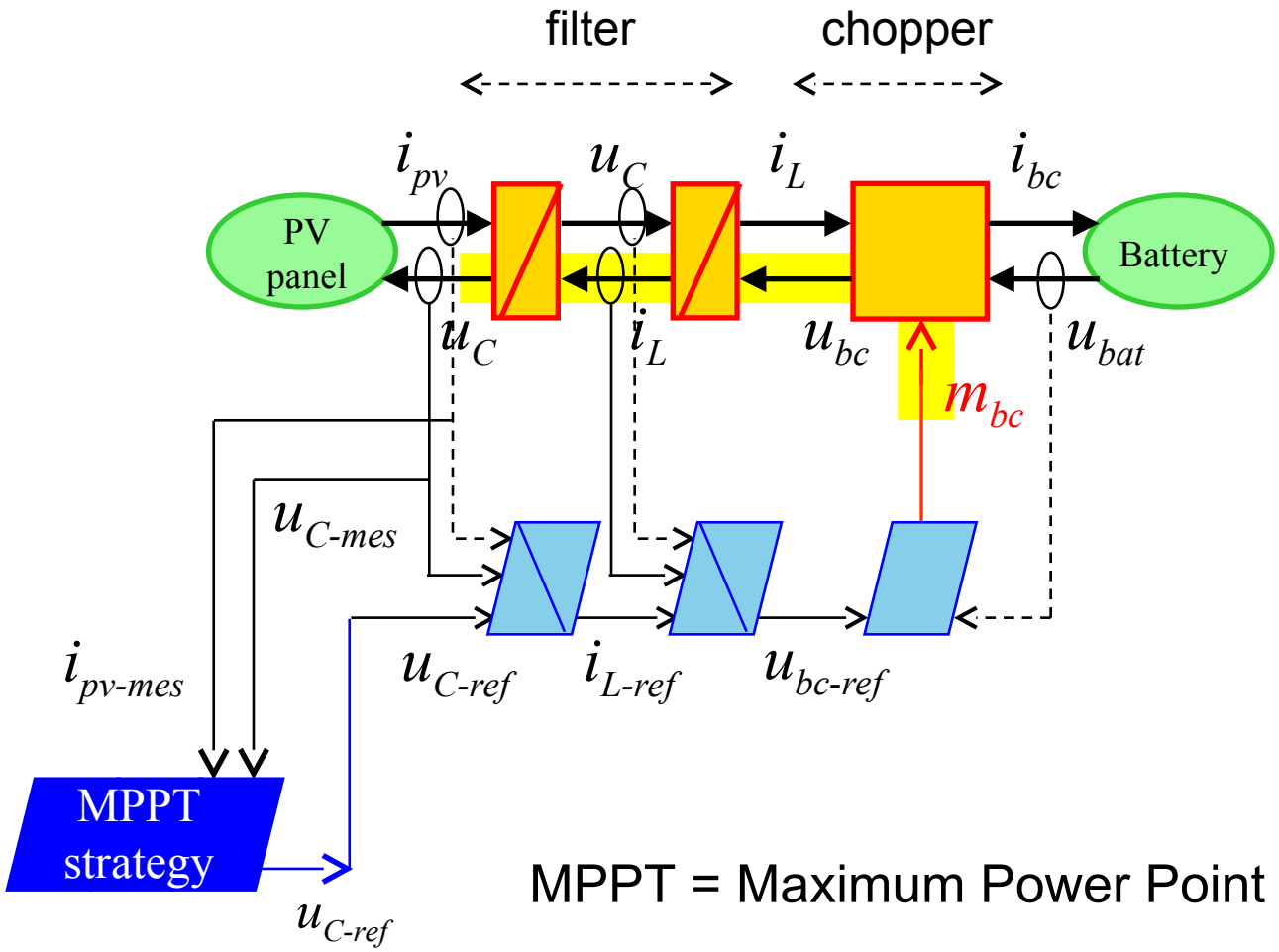




Maximum Power Point Tracking:

→ u_C control

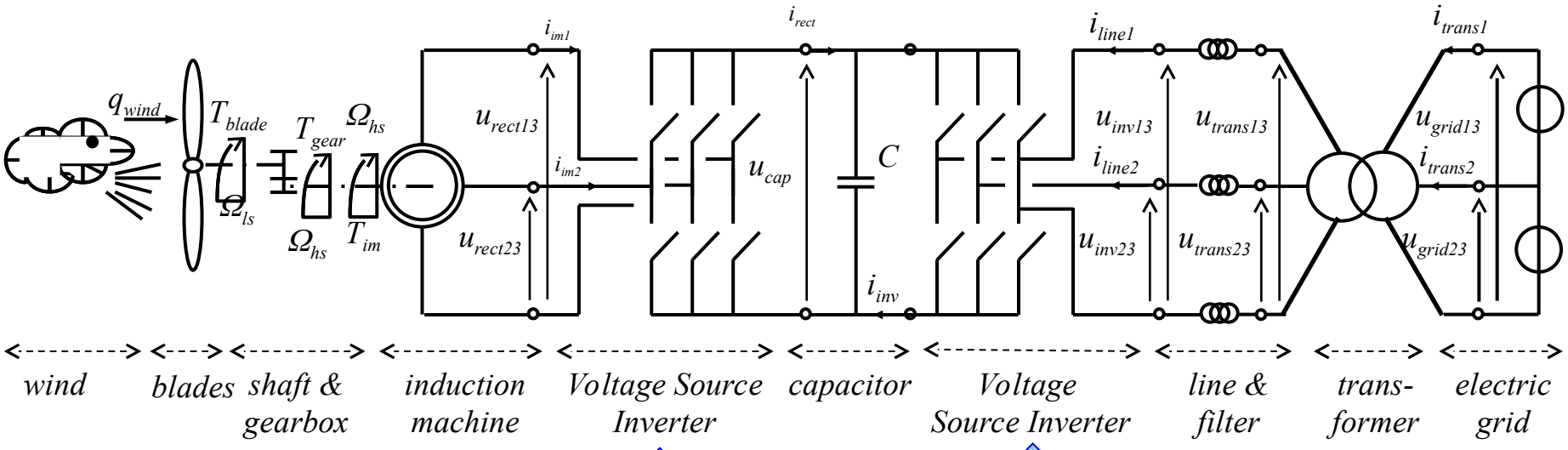
- Inversion-based control of the PV System -



MPPT = Maximum Power Point Tracking

« Wind Energy Conversion System »

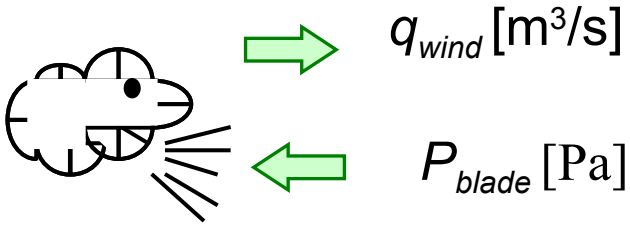
Chosen WECS for variable speed and variable frequency:
a squirrel cage IM and two VSI

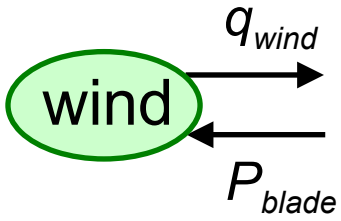


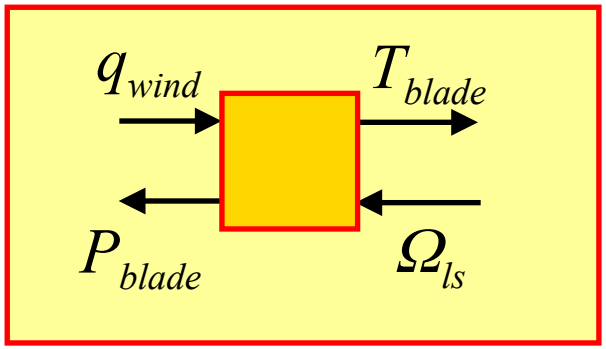
WECS control

Technical requirements: - provide the maximum active power P
- control the reactive power Q

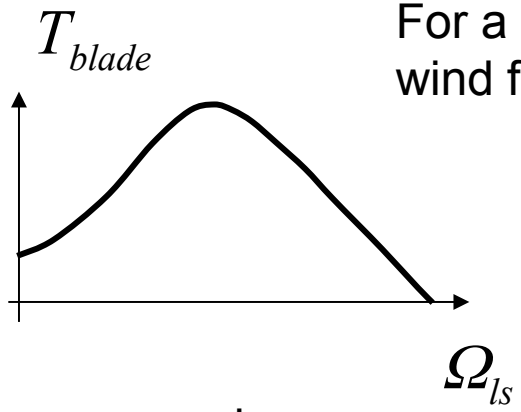
- EMR of the blades -



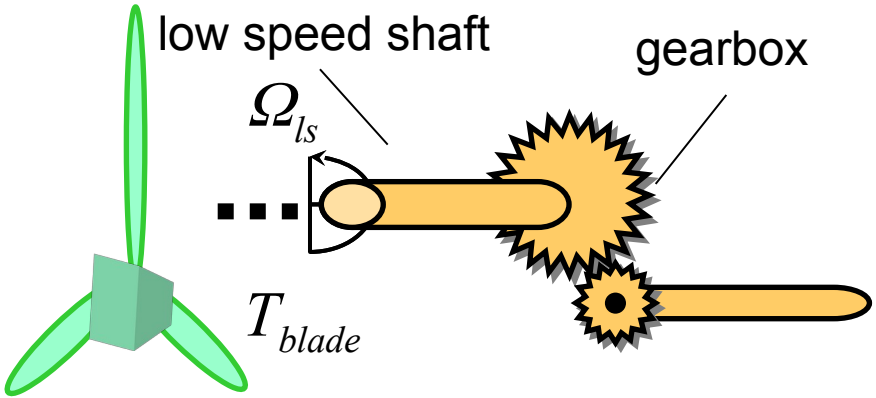




EMR of the blades



For a given wind flow rate

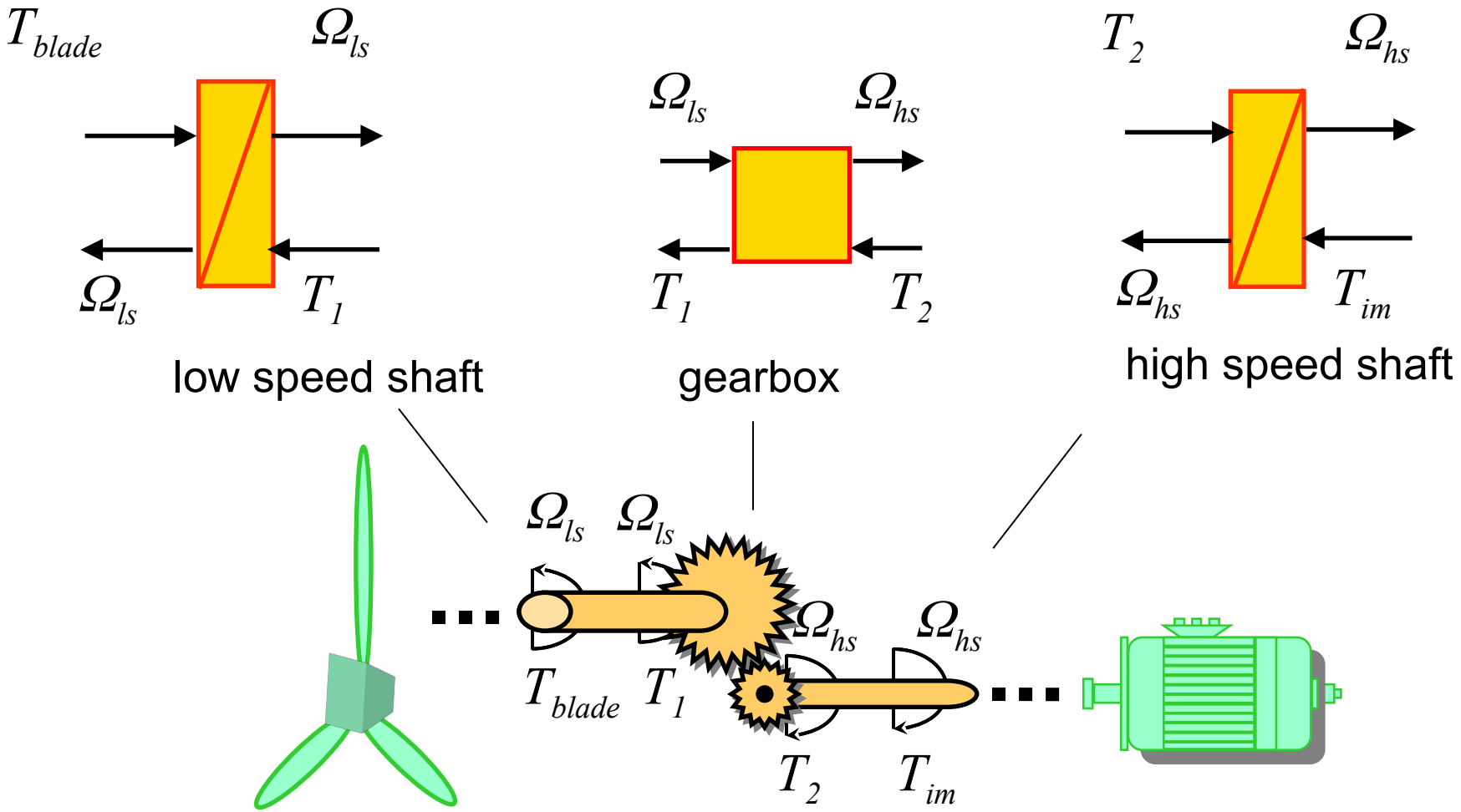


- EMR of the mechanical power train -

$$J_1 \frac{d}{dt}\Omega_{ls} + f_1\Omega_{ls} = T_{blade} - T_1$$

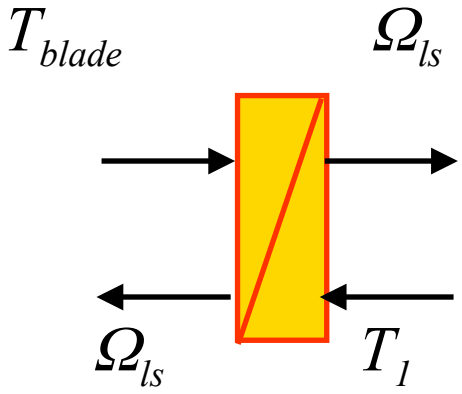
$$\begin{cases} T_1 = k_{gear} T_2 \\ \Omega_{hs} = k_{gear}\Omega_{ls} \end{cases}$$

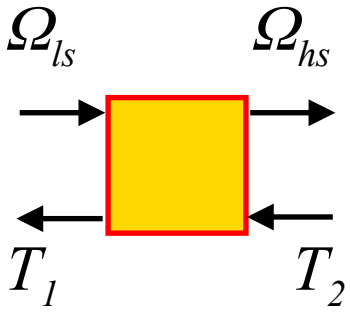
$$J_2 \frac{d}{dt}\Omega_{hs} + f_2\Omega_{hs} = T_2 - T_{im}$$



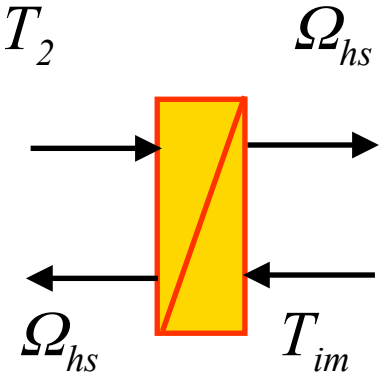
- EMR of the mechanical power train -

$$J_1 \frac{d}{dt}\Omega_{ls} + f_1\Omega_{ls} = T_{blade} - T_1 \qquad \begin{cases} T_1 = k_{gear} T_2 \\ \Omega_{hs} = k_{gear}\Omega_{ls} \end{cases} \qquad J_2 \frac{d}{dt}\Omega_{hs} + f_2\Omega_{hs} = T_2 - T_{im}$$

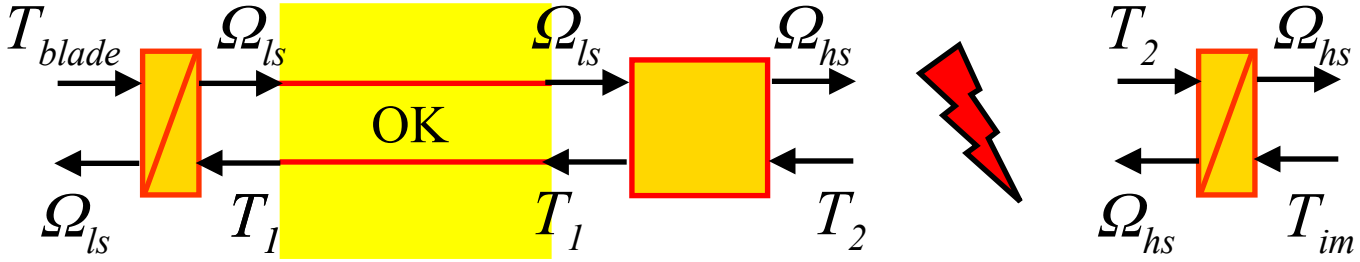




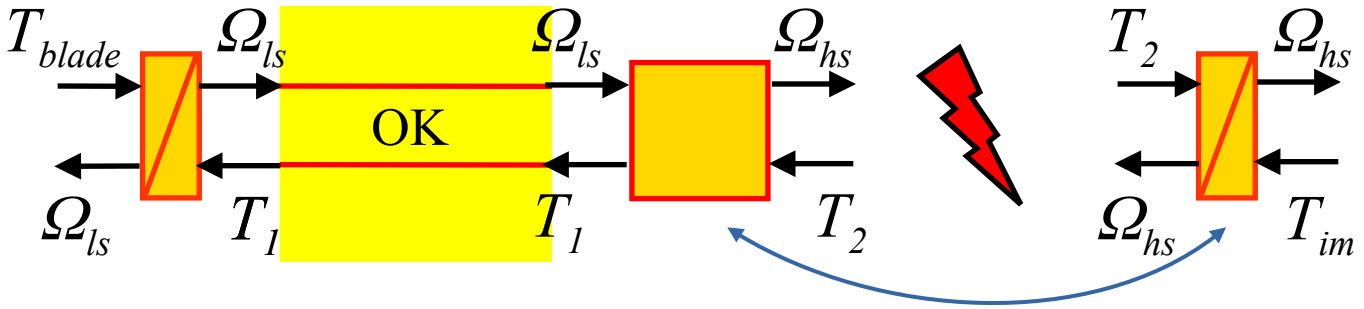
Element association?



high speed shaft

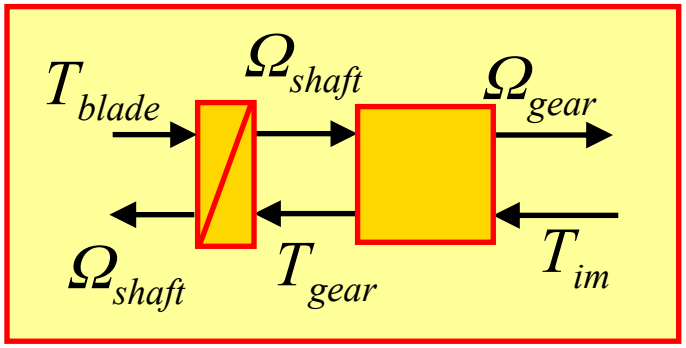


Element association?

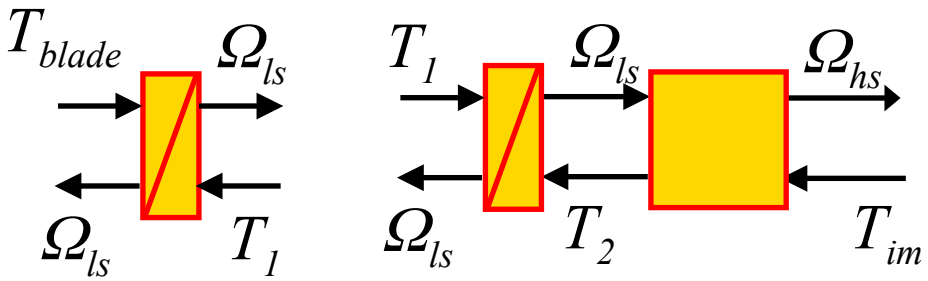


1. permutation

Equivalent power train $=\Omega_{hs}$



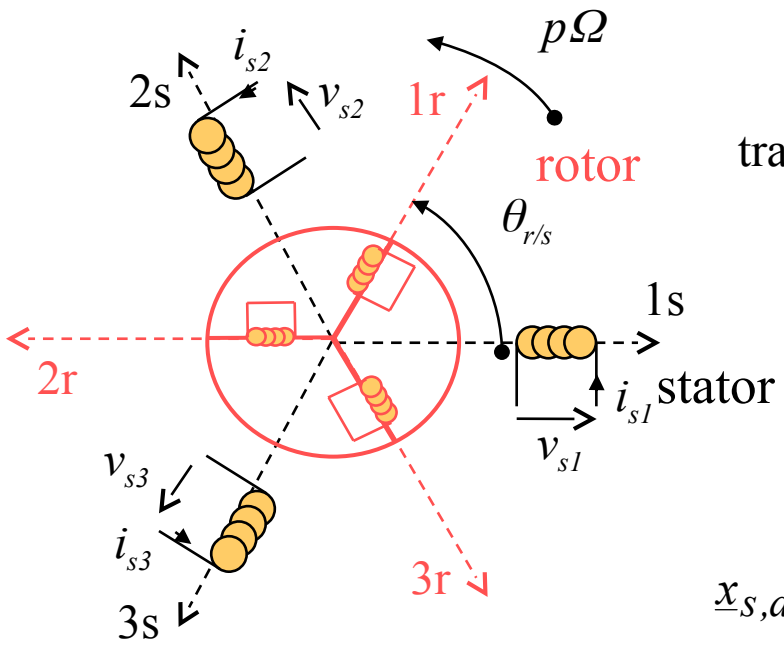
$=\Omega_{ls}$ $=T_1$



2. merging $J_{eq} = J_1 + \frac{J_2}{k^2}$

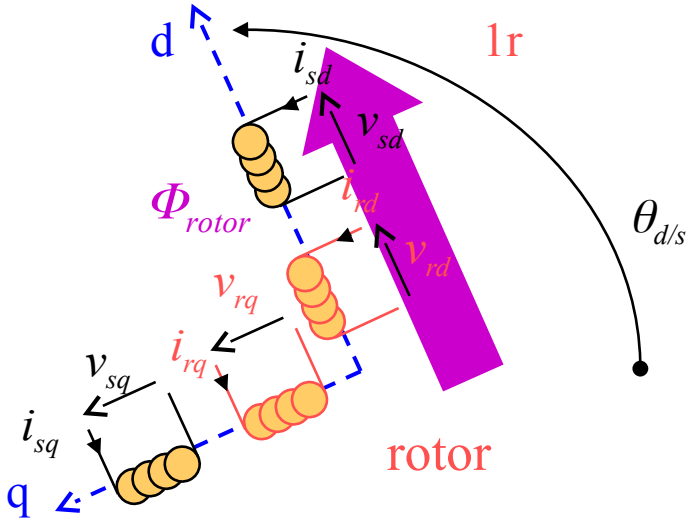
- EMR of the squirel cage induction machine -

1 – IM: difficult to control AC currents
2 – strong interaction between the 3 phases



Park's transformation

New d,q frame attached to the rotor flux



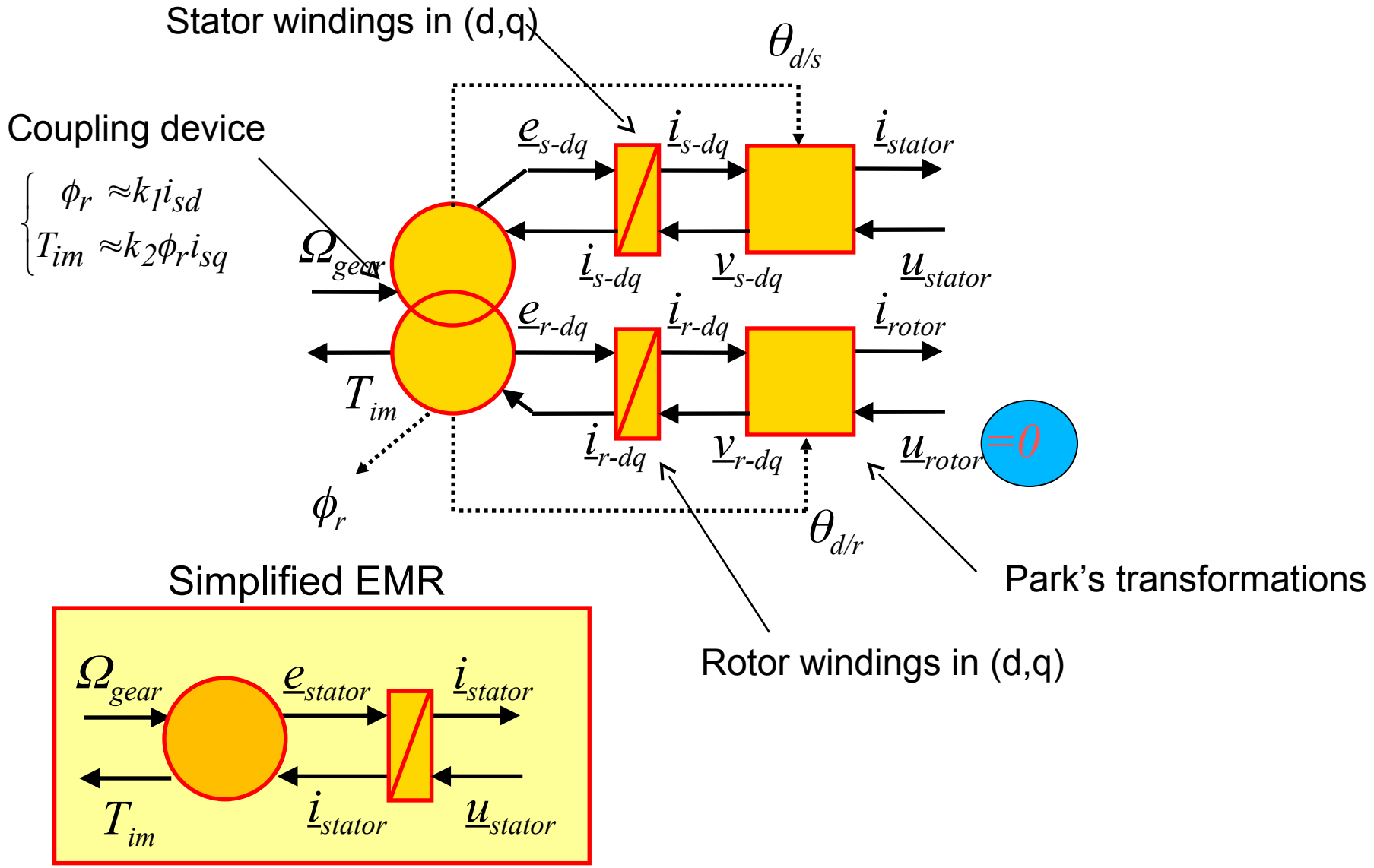
$$\underline{x}_{s,dq} = \left[P(\theta_{d/s})\right]\underline{x}_{s,123}$$
$$\underline{x}_{r,dq} = \left[P(\theta_{d/r})\right]\underline{x}_{r,123}$$

Modelling simplifications:

$$\begin{cases} \phi_r \approx k_1 i_{sd} \\ T_{im} \approx k_2 \phi_r i_{sq} \end{cases}$$

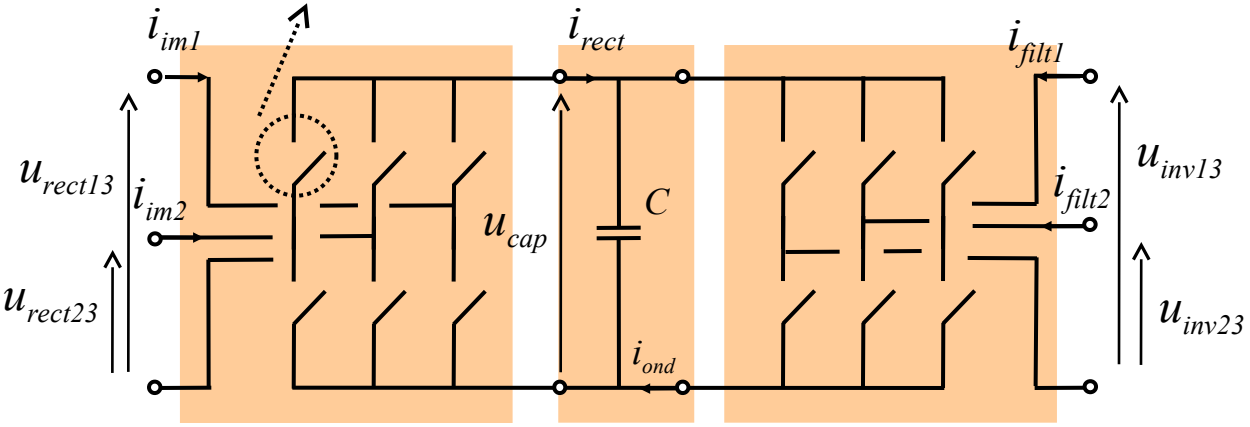
d, q rotating reference frame:
- DC current
- interaction simplification

- EMR of the squirel cage induction machine -



- EMR of the back-to-back VSI -

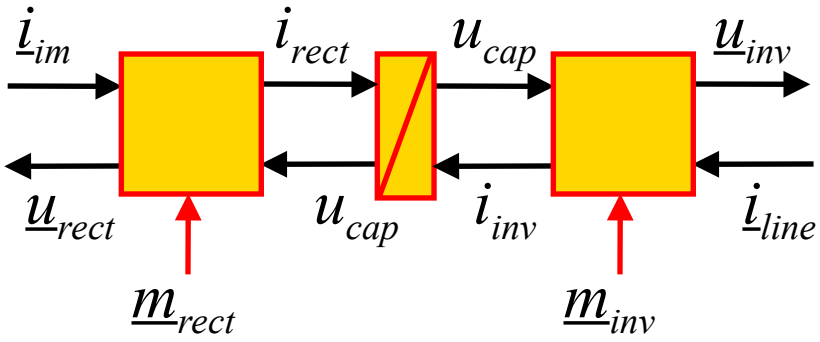
$$s_{11} = \begin{cases} 1\,(closed) \\ 0\,(open) \end{cases}$$



$$\underline{m}_{rect} = \begin{bmatrix} s_{11} - s_{13} \\ s_{12} - s_{13} \end{bmatrix}$$

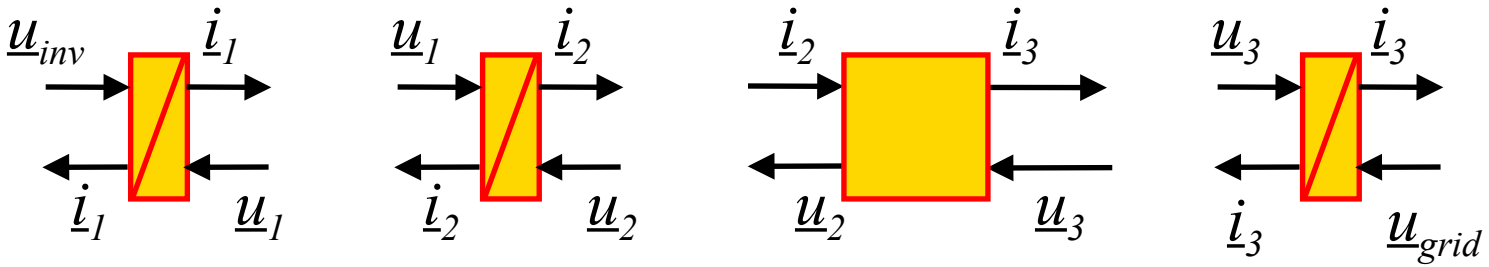
$$\begin{cases} \underline{u}_{rect} = \underline{m}_{rect} u_{cap} \\ i_{rect} = \underline{m}_{rect}^{t} \underline{i}_{im} \end{cases}$$

$$C \frac{d}{dt} u_{cap} = i_{rect} - i_{inv}$$



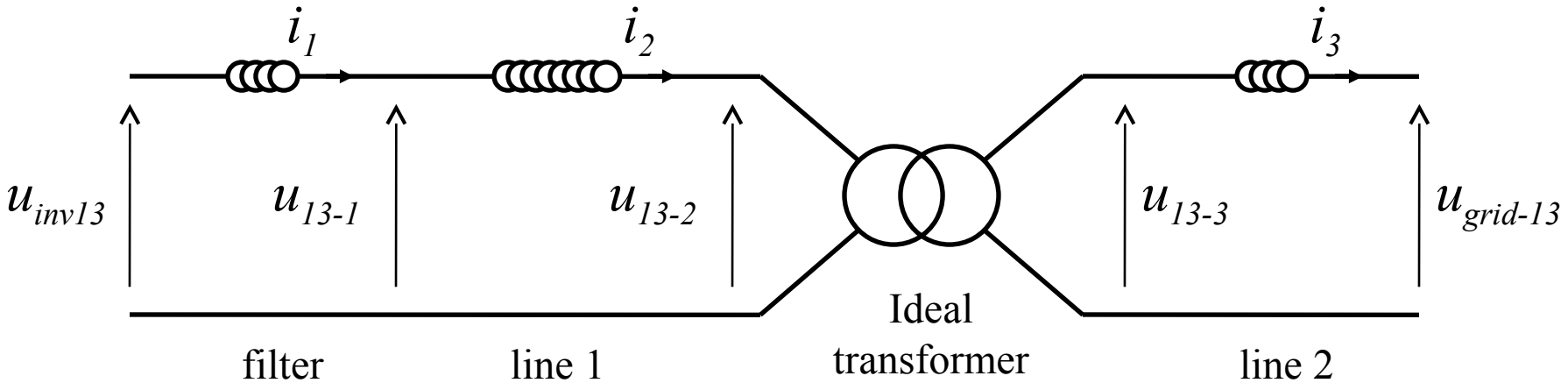
$$L_1 \frac{d}{dt} \underline{i}_1 + R_3 \underline{i}_1 = \underline{u}_{inv} - \underline{u}_1$$

$$\begin{cases} \underline{u}_2 = m_{trans} \underline{u}_3 \\ \underline{i}_3 = m_{trans} \underline{i}_2 \end{cases}$$

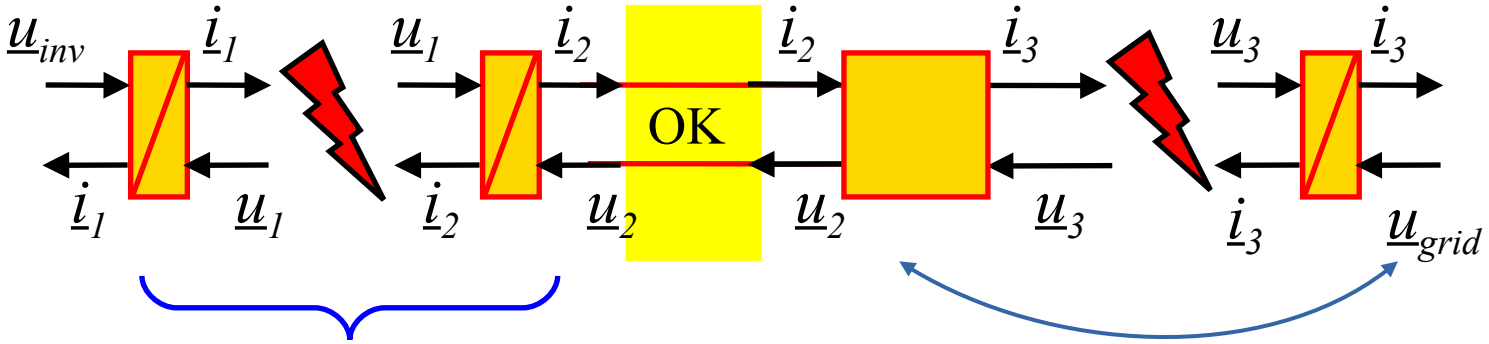


$$L_2 \frac{d}{dt} \underline{i}_2 + R_3 \underline{i}_2 = \underline{u}_1 - \underline{u}_2$$

$$L_3 \frac{d}{dt} \underline{i}_3 + R_3 \underline{i}_3 = \underline{u}_3 - \underline{u}_{grid}$$

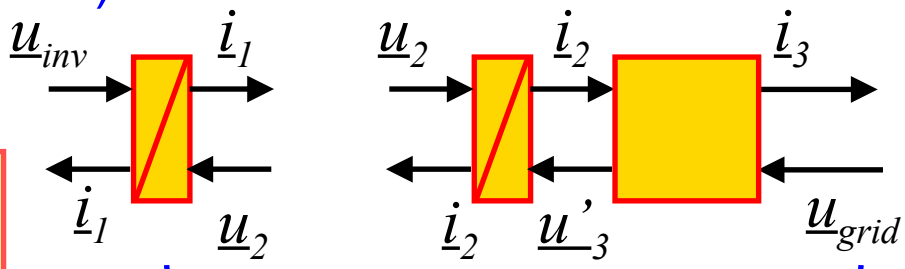


Element association?

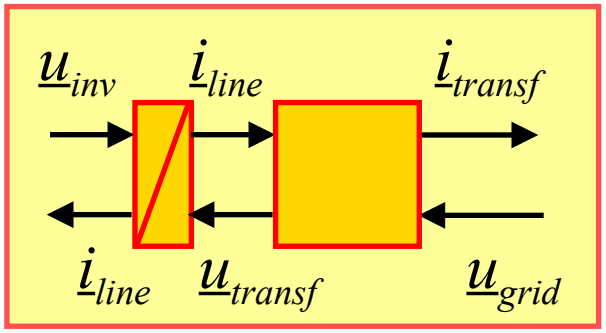


1. merging (equi. Coil)

2. Permutation (bring *L3* to primary side)

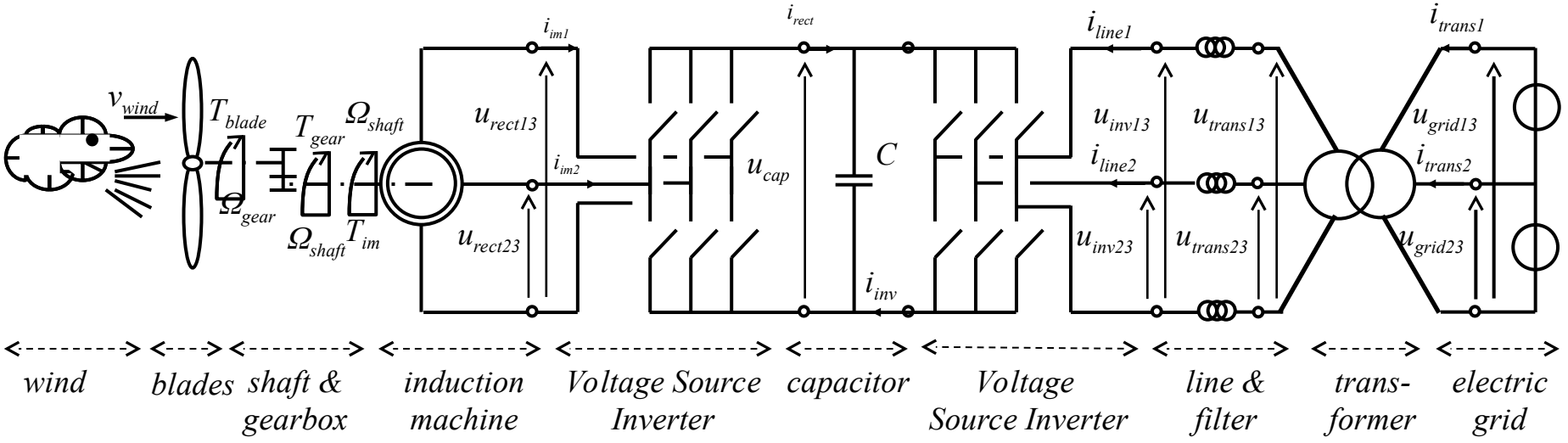


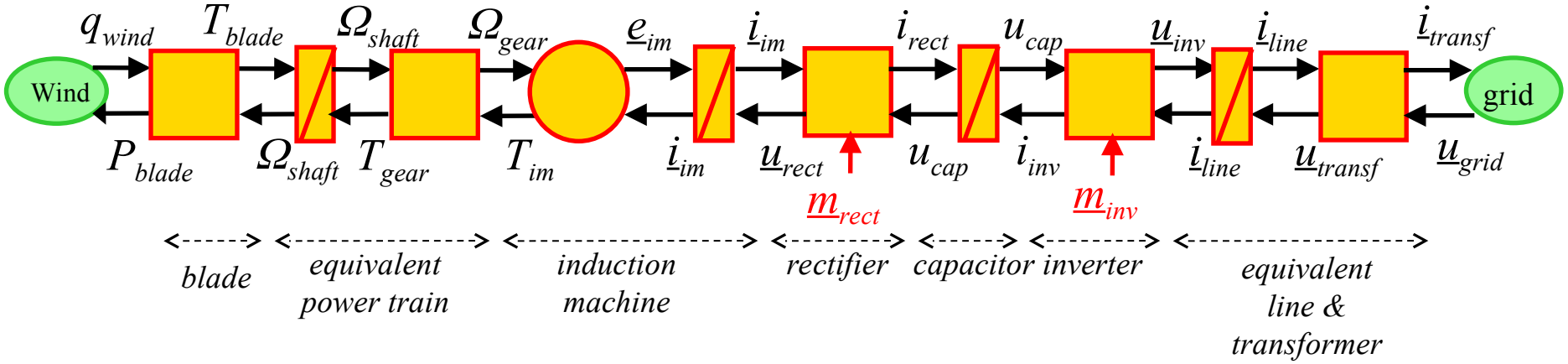
3. merging (equi. Coil)



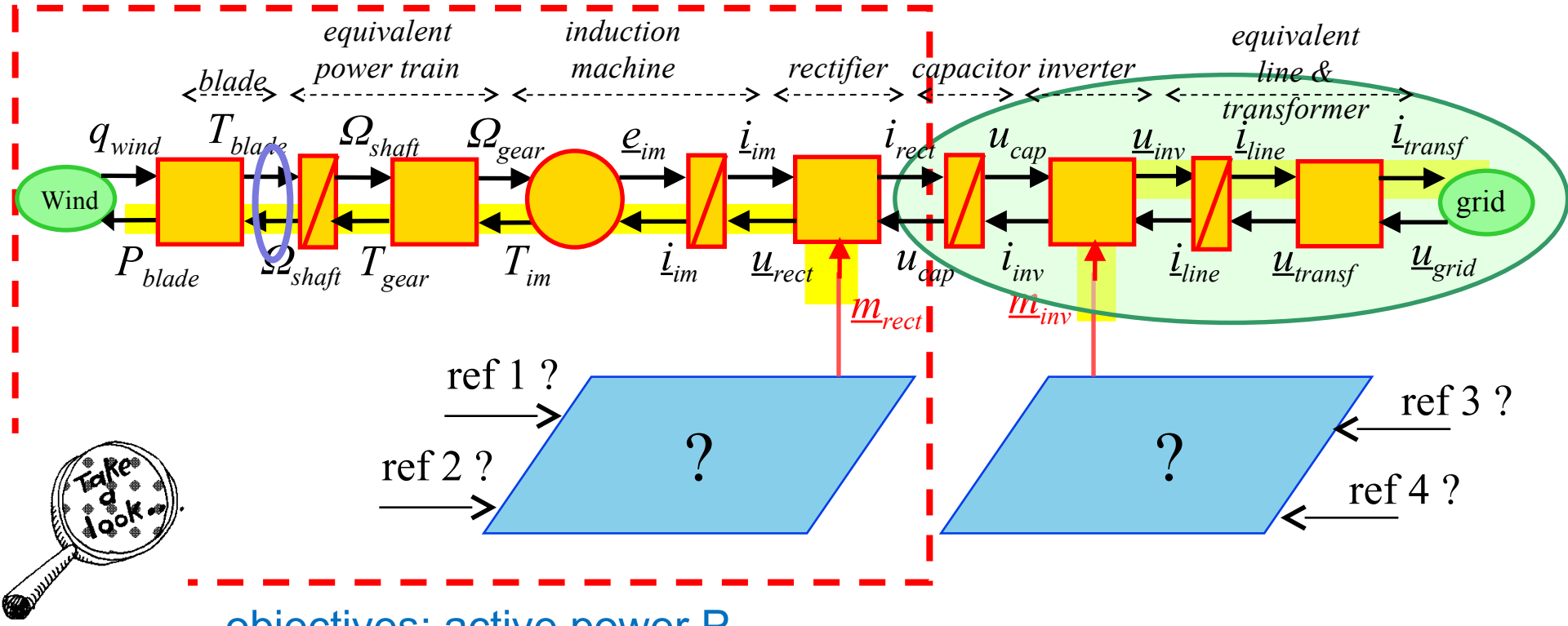
$$L_{eq} = L_1 + L_2 + \frac{L_3}{m_{trans}^2}$$

- EMR of the WECS -





- Tuning chains of the WECS -



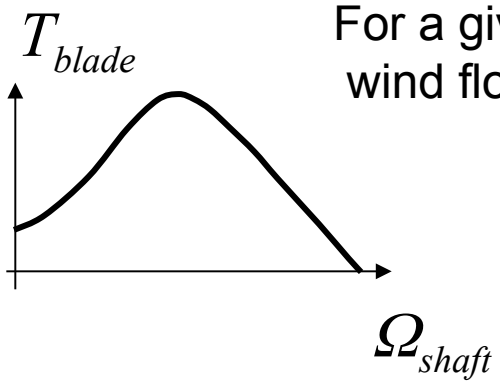
objectives: active power P
reactive power Q

constraints: capacitor voltage
machine flux

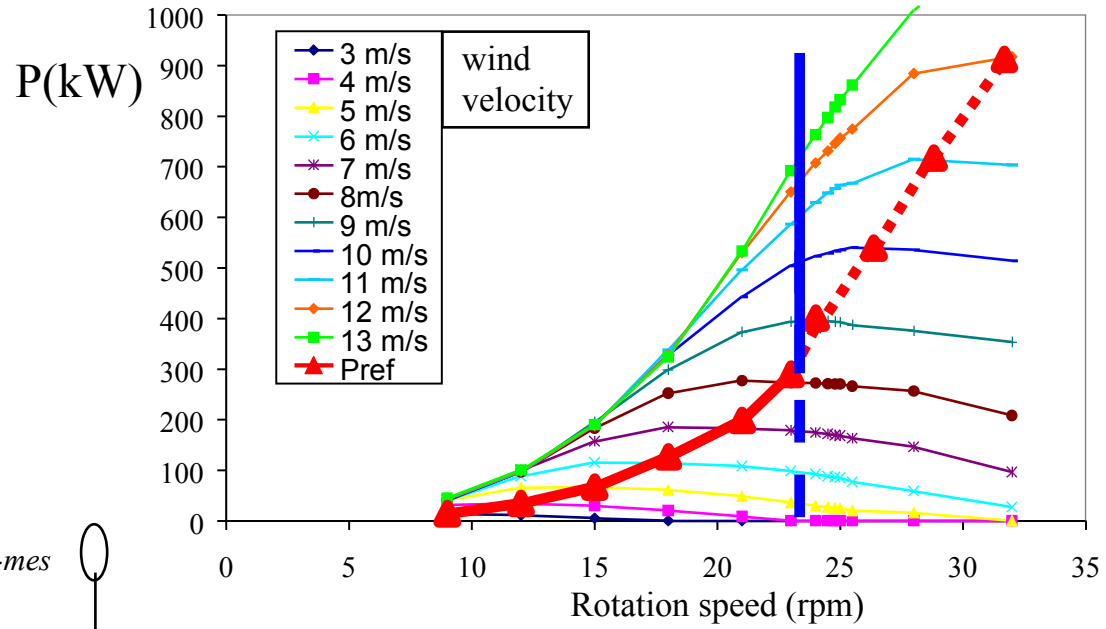
$$\underline{m}_{rect} = \begin{bmatrix} m_{13} \\ m_{23} \end{bmatrix} \Rightarrow \text{2 dof}$$

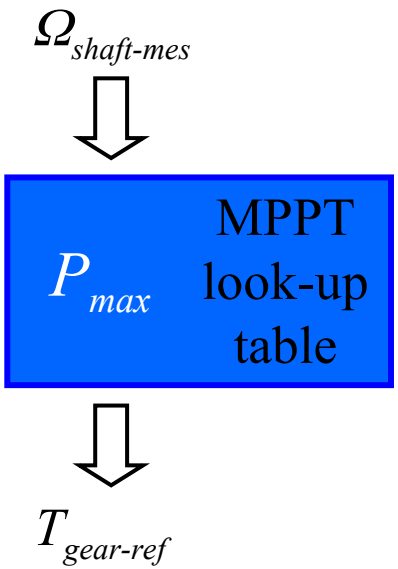
$$\underline{m}_{inv} = \begin{bmatrix} m'_{13} \\ m'_{23} \end{bmatrix} \Rightarrow \text{2 dof}$$

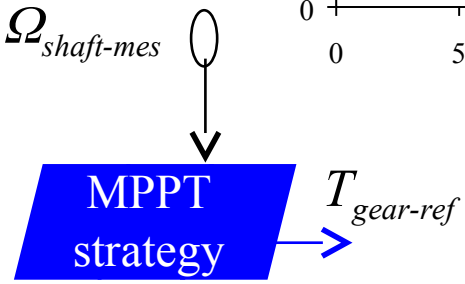
- MPPT strategy -

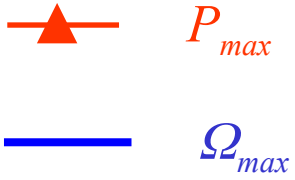


For a given wind flow



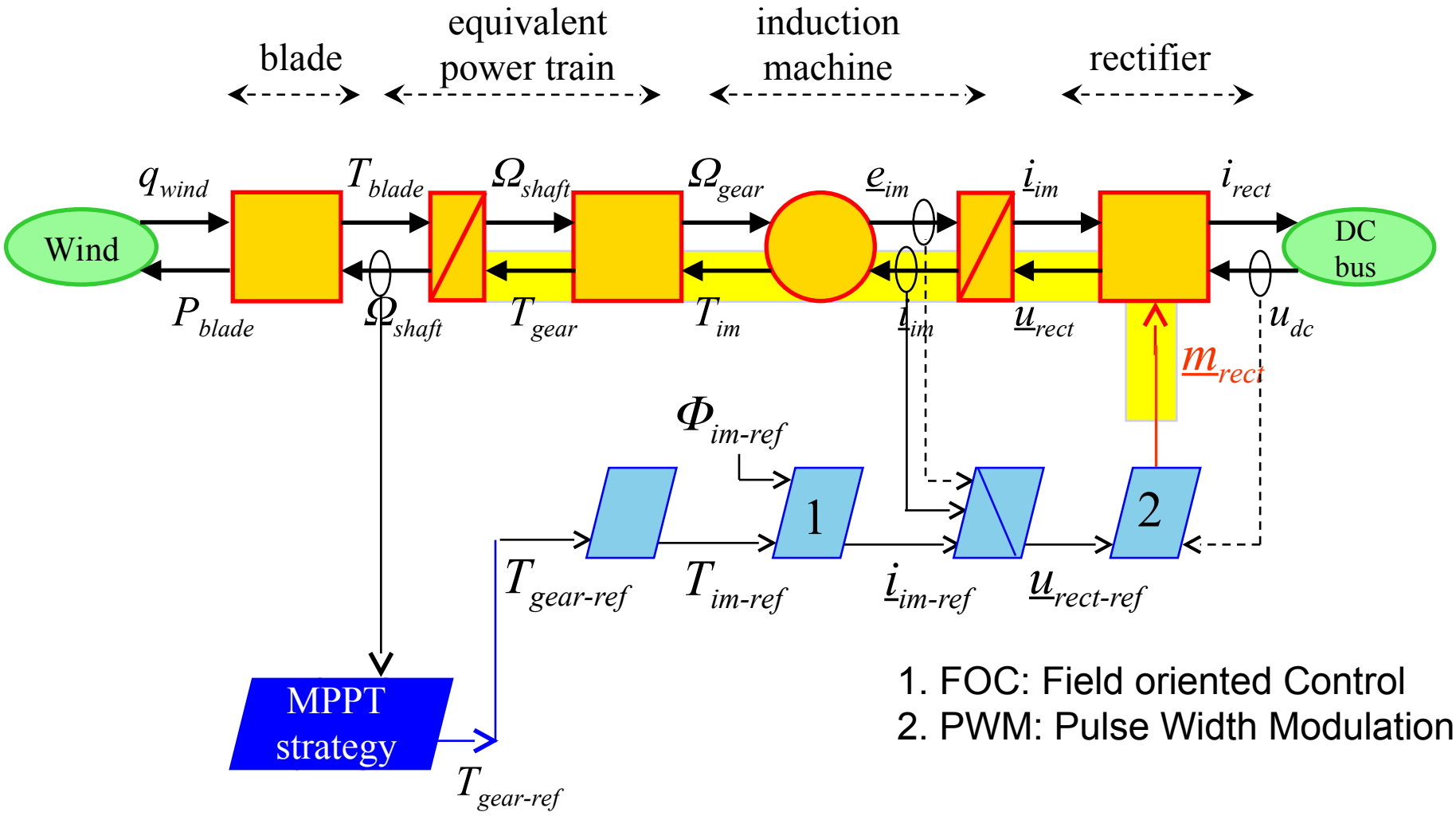






MPPT = Maximum Power Point Tracking

- WECS control with MPPT -



1. FOC: Field oriented Control
2. PWM: Pulse Width Modulation

MPPT = Maximum Power Point Tracking

« REFERENCES »

- References -

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