« EMR AND INVERSION-BASED CONTROL OF RENEWABLE ENERGY CONVERSION SYSTEMS »

Christophe GIRAUD-AUDINE, Alain BOUSCAYROL, Betty LEMAIRE-SEMAIL

[1] L2EP, Art&Métiers, Sceinces et Technolgy Frabce

[3] L2EP, University of Lille, France

Arts et Métiers Sciences et Technologies

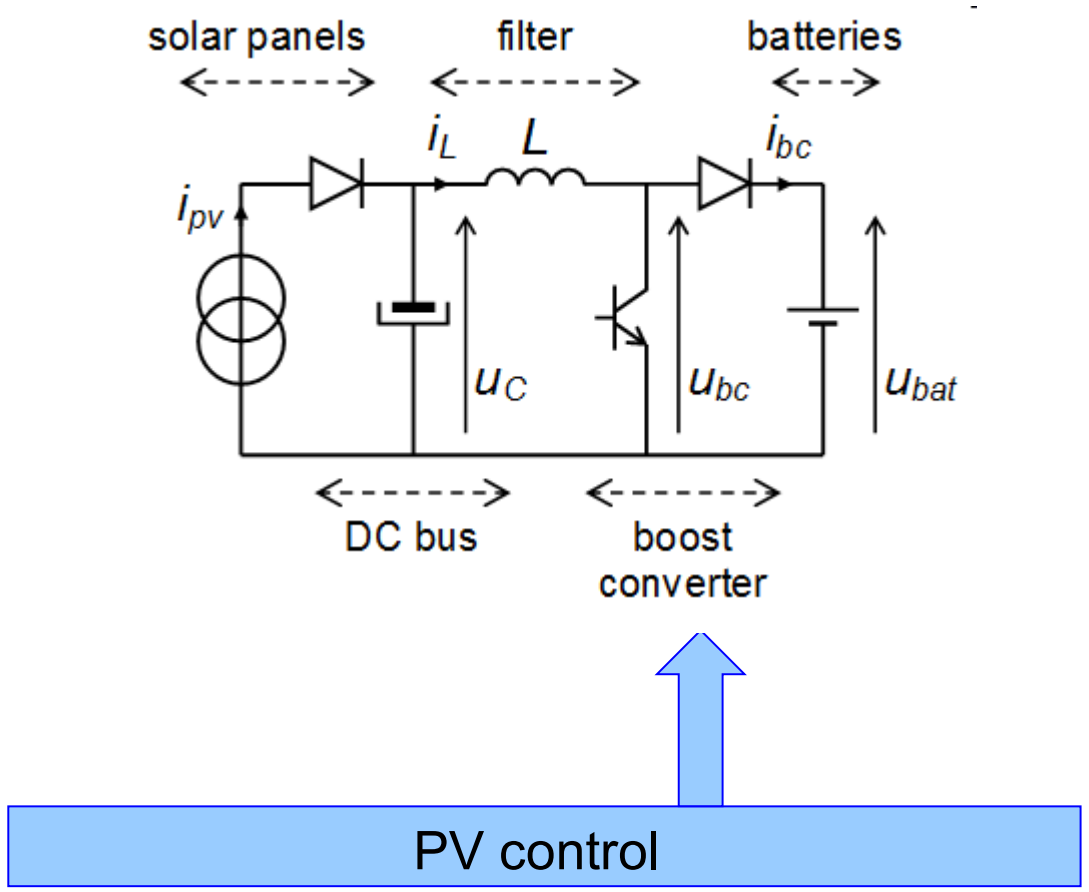
L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

Université de Lille

- Outline -

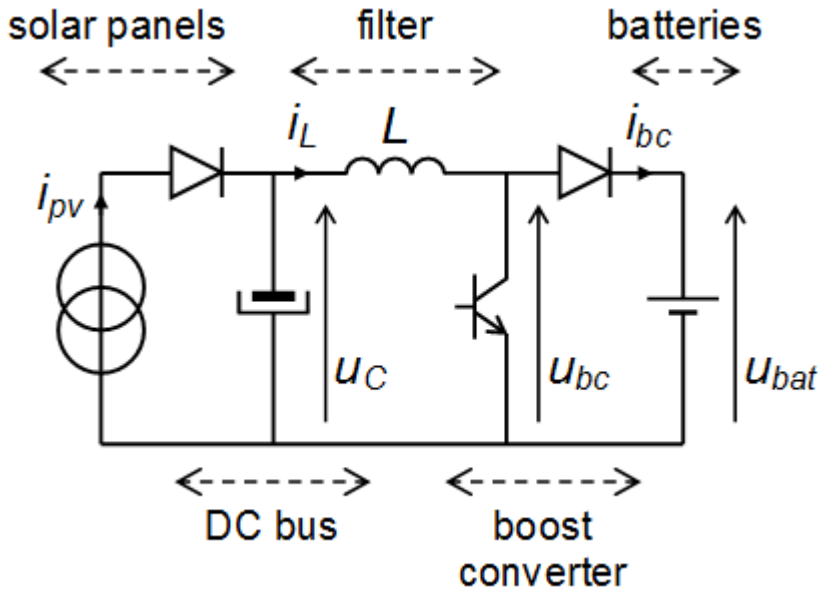
1. PV conversion systems
2. Wind energy conversion systems
3. Conclusion

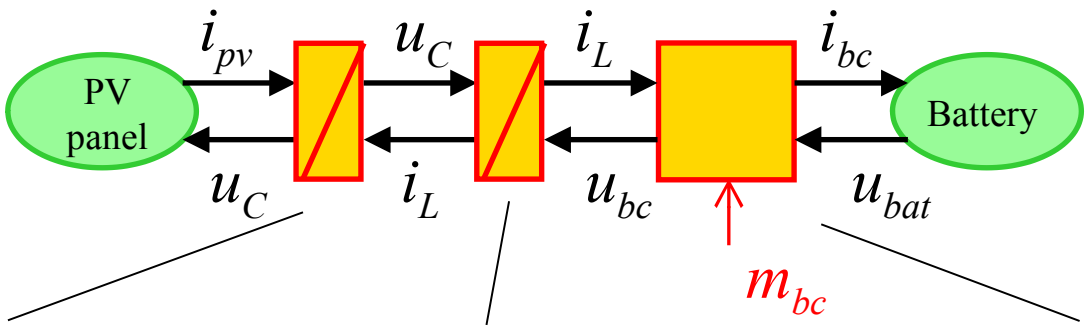
1. PV conversion systems



Technical requirements: - provide the maximum active power P

- EMR of the PV System -



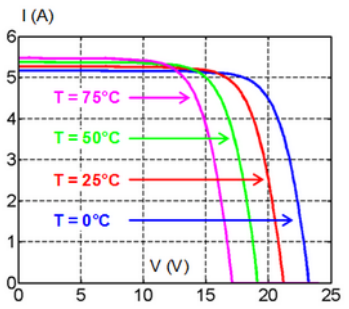


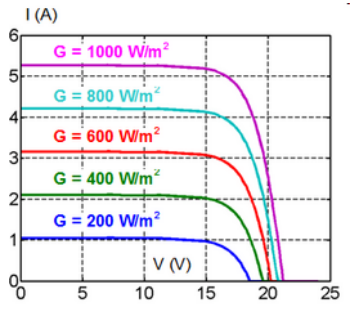
$$C\frac{d}{dt}u_C + \frac{u_C}{R_C} = i_{pv} - i_L$$

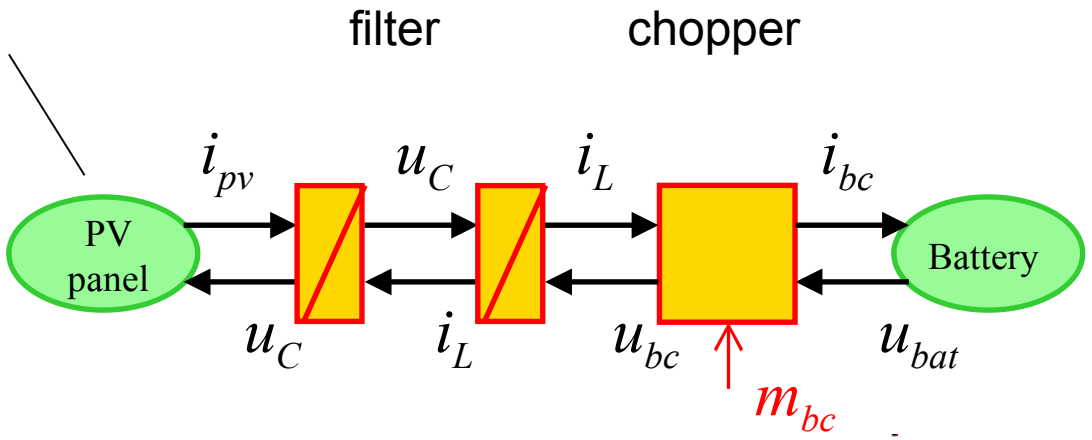
$$L\frac{d}{dt}i_L + R_L i_L = u_C - u_{bc}$$

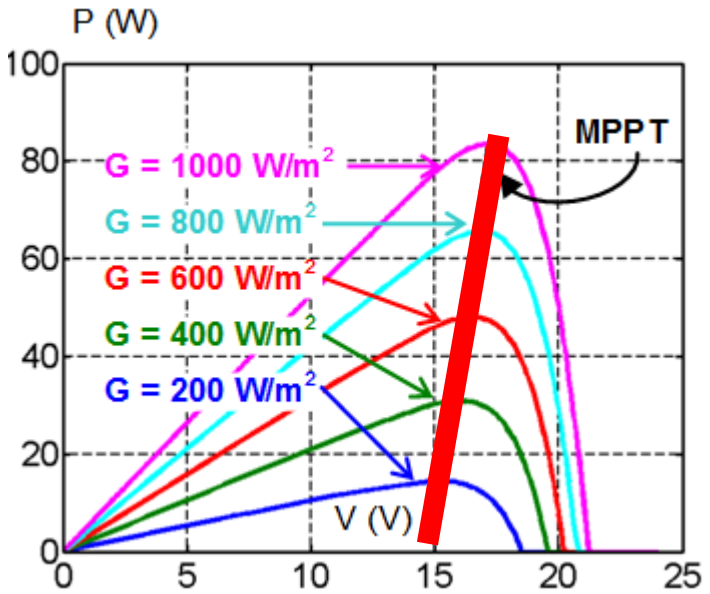
$$\begin{cases} i_{bc} = m_{bc} i_L \\ u_{bc} = m_{bc} u_{bat} \end{cases}$$

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





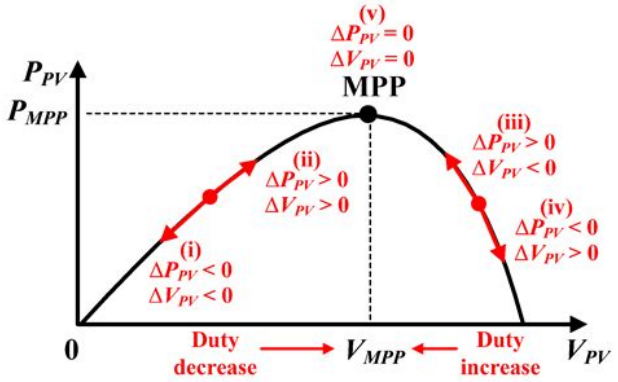


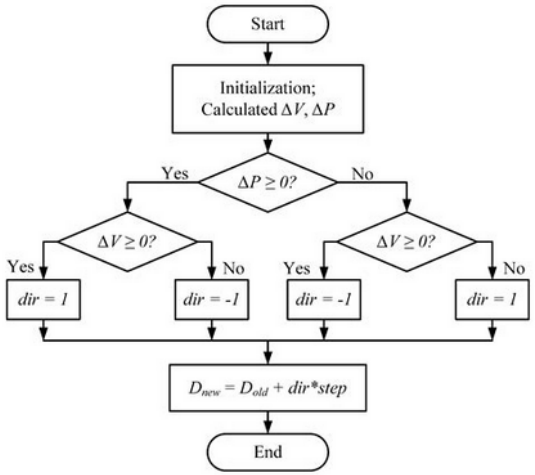


Maximum Power Point Tracking:

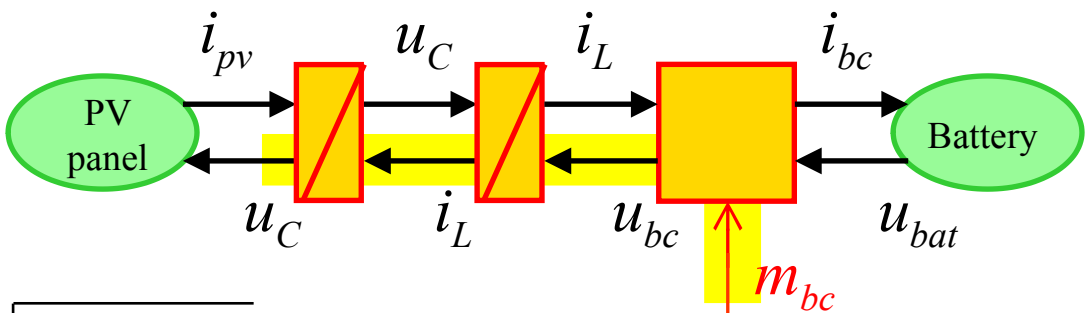
→ u_C control

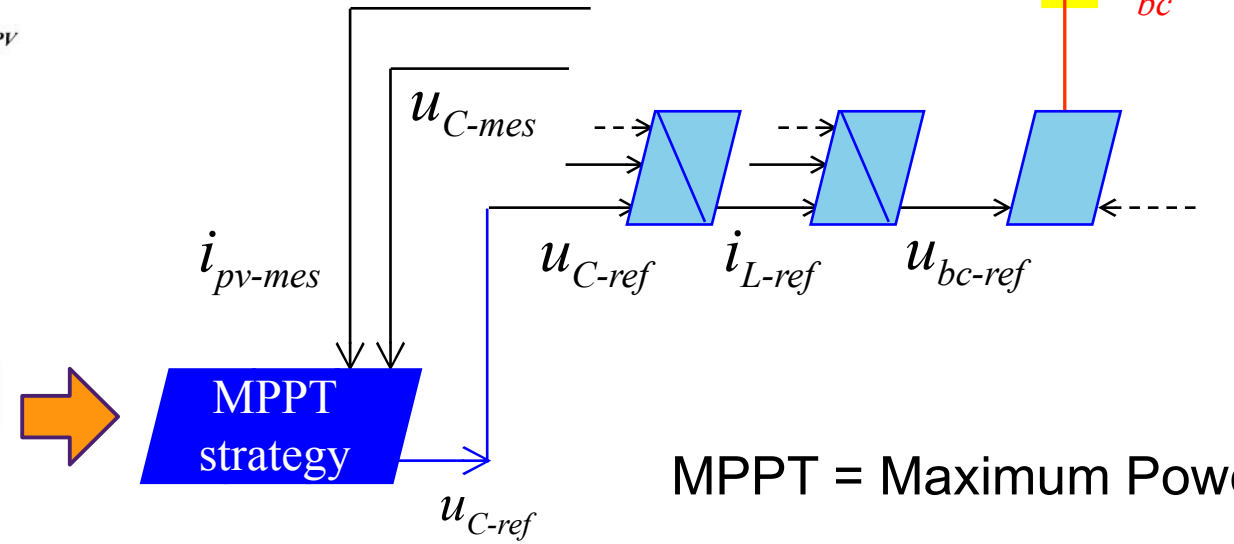
Example : perturb and observe





filter chopper

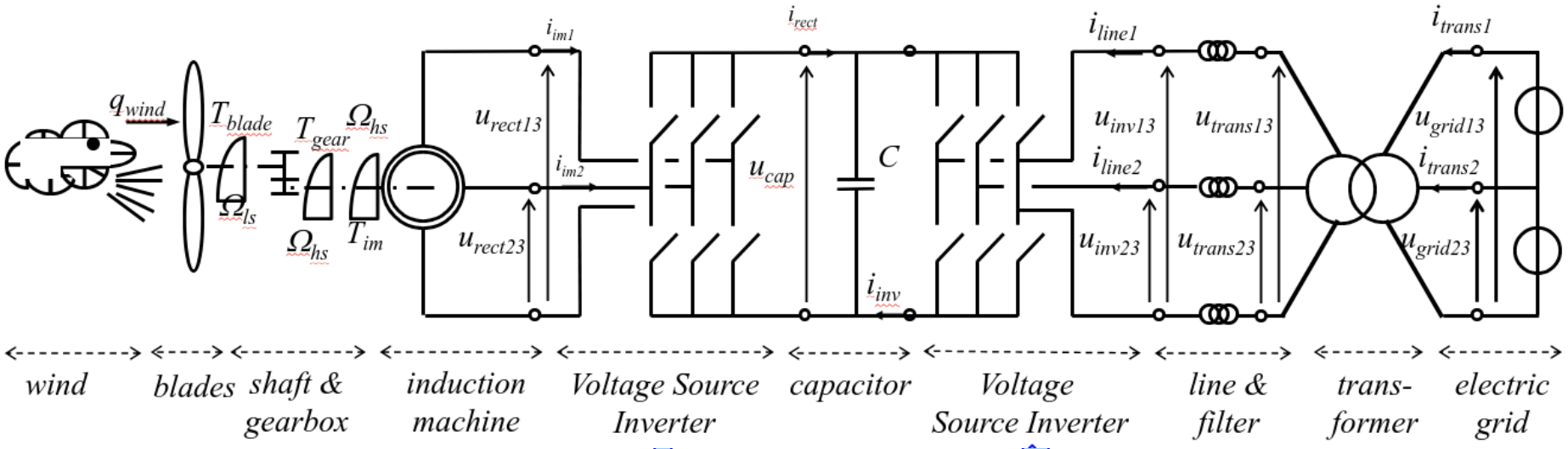




MPPT = Maximum Power Point Tracking

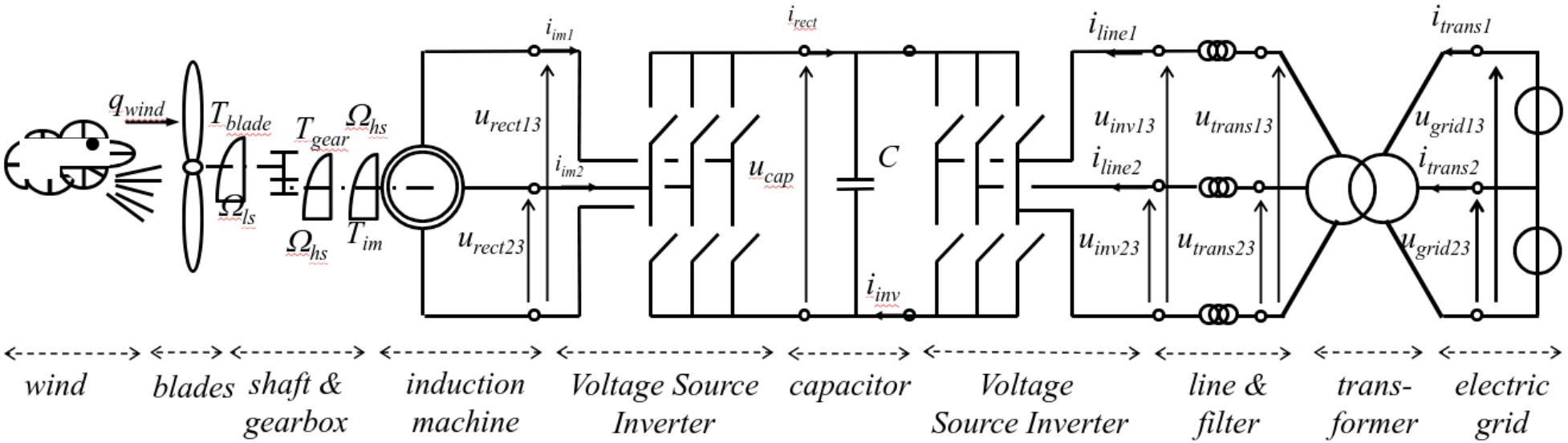
2. Wind energy conversion systems

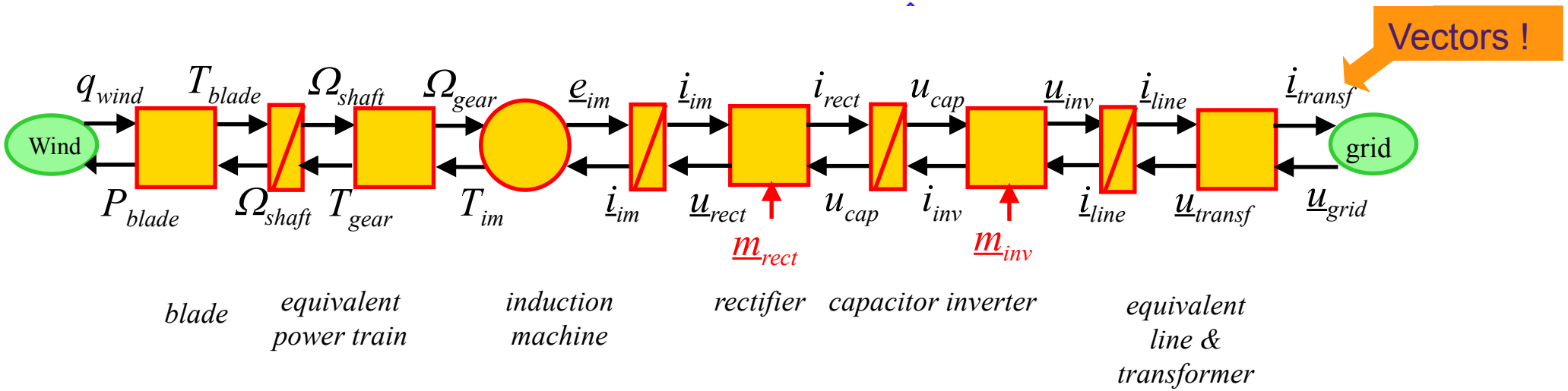
Chosen WECS for variable speed and variable frequency:
a squirrel cage IM and two VSI

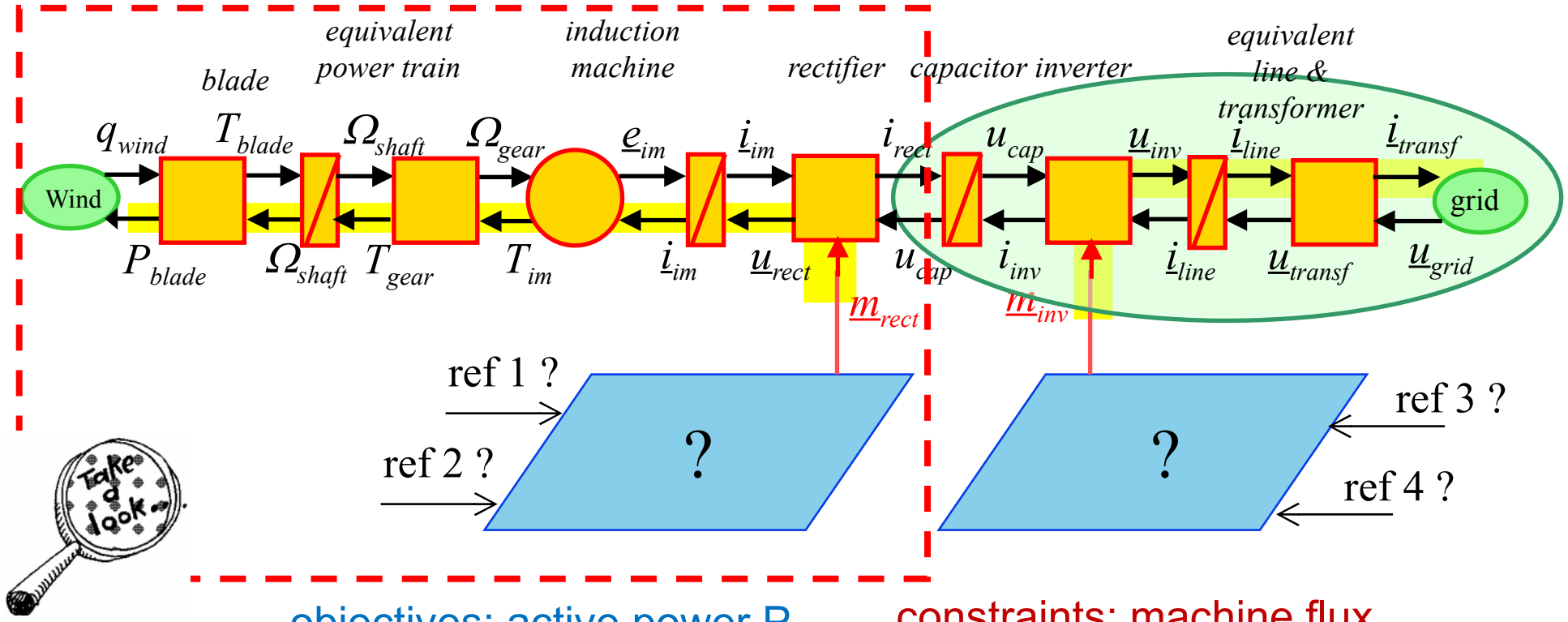


WECS control

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


q_{wind}
T_{blade}
T_{gear}
Ω_{hs}
Ω_{ls}
T_{im}
i_{im1}
i_{im2}
u_{rect13}
u_{rect23}
i_{rect}
u_{cap}
C
i_{inv}
i_{line1}
i_{line2}
u_{inv13}
u_{inv23}
$u_{trans13}$
$u_{trans23}$
i_{trans1}
i_{trans2}
u_{grid13}
u_{grid23}
wind
blades
shaft & gearbox
induction machine
Voltage Source Inverter
capacitor
Voltage Source Inverter
line & filter
trans-former
electric grid

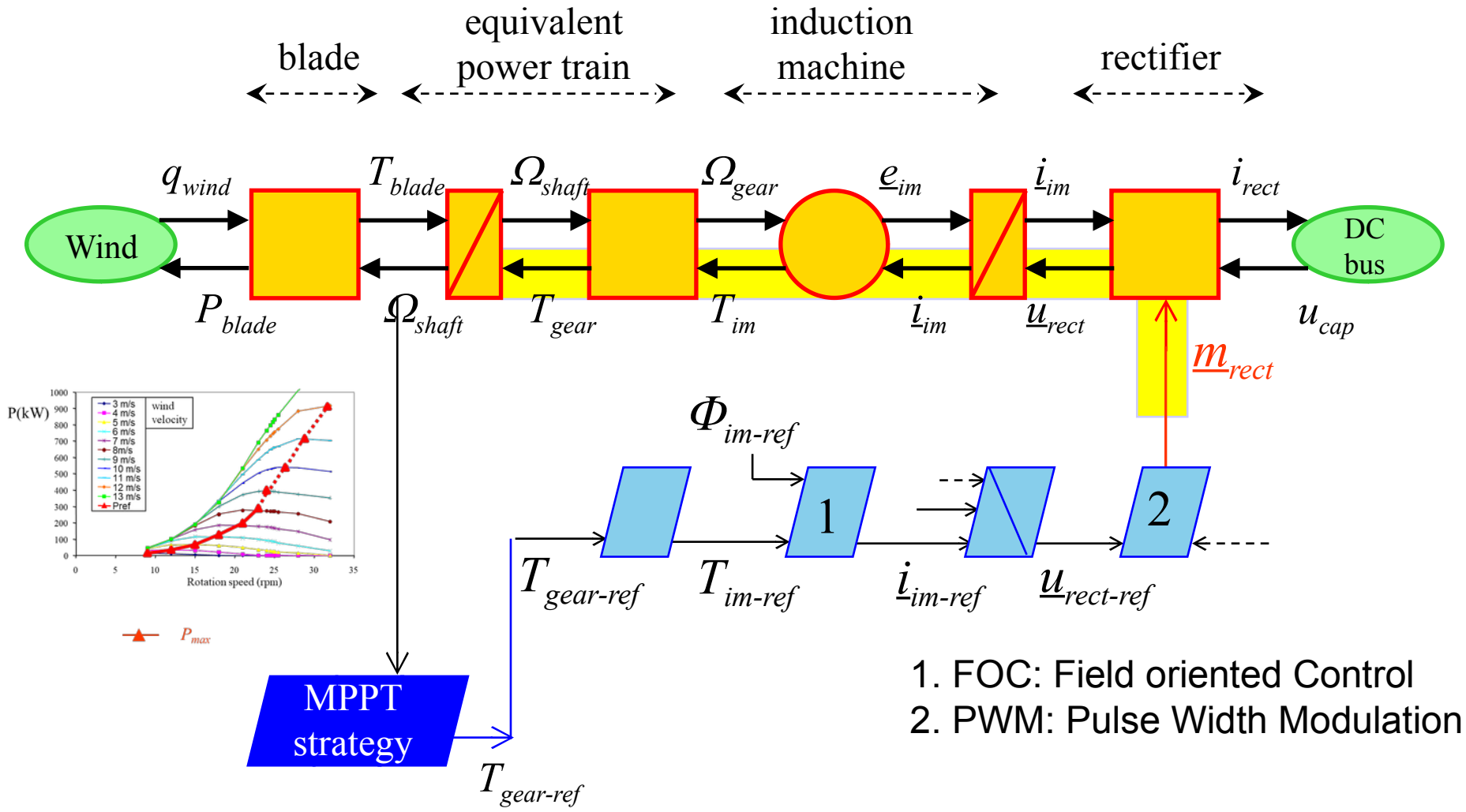

Vectors !
Wind
grid
q_{wind}
T_{blade}
Ω_{shaft}
Ω_{gear}
e_{im}
i_{im}
i_{rect}
u_{cap}
u_{inv}
i_{line}
i_{transf}
P_{blade}
Ω_{shaft}
T_{gear}
T_{im}
i_{im}
u_{rect}
u_{cap}
i_{inv}
i_{line}
u_{transf}
u_{grid}
m_{rect}
m_{inv}
blade
equivalent power train
induction machine
rectifier
capacitor inverter
equivalent line & transformer



objectives: active power P
reactive power Q

constraints: machine flux
capacitor voltage

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



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

MPPT = Maximum Power Point Tracking

Conclusion

- Summary-

- EMR formalism
  - Organization of models of various energy conversion systems
  - Systematic deduction of control organisation
- Renewable Energy Conversions Systems
  - Maximal Power Point Tracking strategy (focus on energy production)
- Other Energy Conversion Systems
  - Energy Management strategies (focus on efficiency)

References

- References -

A. Bouscayrol, P. Delarue, "Simplifications of the Maximum Control Structure of a wind energy conversion system with an induction generator", *International Journal of Renewable Energy Engineering*, vol. 4, no. 2, August 2002, pp. 479-485.

A. Bouscayrol, P. Delarue, X. Guillaud, "Power strategies for Maximum Control Structure of a wind energy conversion system with a synchronous machine", *Renewable Energy*, vol. 30, May 2005, pp. 2273-2288.

A. Bouscayrol, X. Guillaud, R. Teodorescu, P. Delarue, W. Lhomme, "Hardware-in-the-loop simulation of different wind turbines using Energetic Macroscopic Representation", *IEEE-IECON'06*, Paris, November 2006, (common paper of L2EP and University of Aalborg).

A. Bouscayrol, X. Guillaud, P. Delarue, B. Lemaire-Semail, "Energetic Macroscopic Representation and inversion-based control illustrated on a wind energy conversion systems using Hardware-in-the-loop simulation", *IEEE trans. on Industrial Electronics*; vol. 56, no. 12, pp. 4826-4835, December 2009.

P. Delarue, A. Bouscayrol, A. Tounzi, X. Guillaud, G. Lancigu, "Modelling, control and simulation of an overall wind energy conversion system", *Renewable Energy*, vol. 28, no. 8, pp. 1159-1324, July 2003, (common paper L2EP Lille and Jeumont SA).

W. Lhomme, P. Delarue, F. Giraud, B. Lemaire-Semail, A. Bouscayrol, "Simulation of a photovoltaic conversion system using Energetic Macroscopic Representation", *EPE'PEMC'12*, Novi Sad (Serbia), September 2012.

Thanks for your attention !