Tallinn University of Technology, May 2025

Estonian Doctoral School

# “Potovoltaic energy conversion system”

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Based on the EMR Summer school
and course on Polytech’Lille

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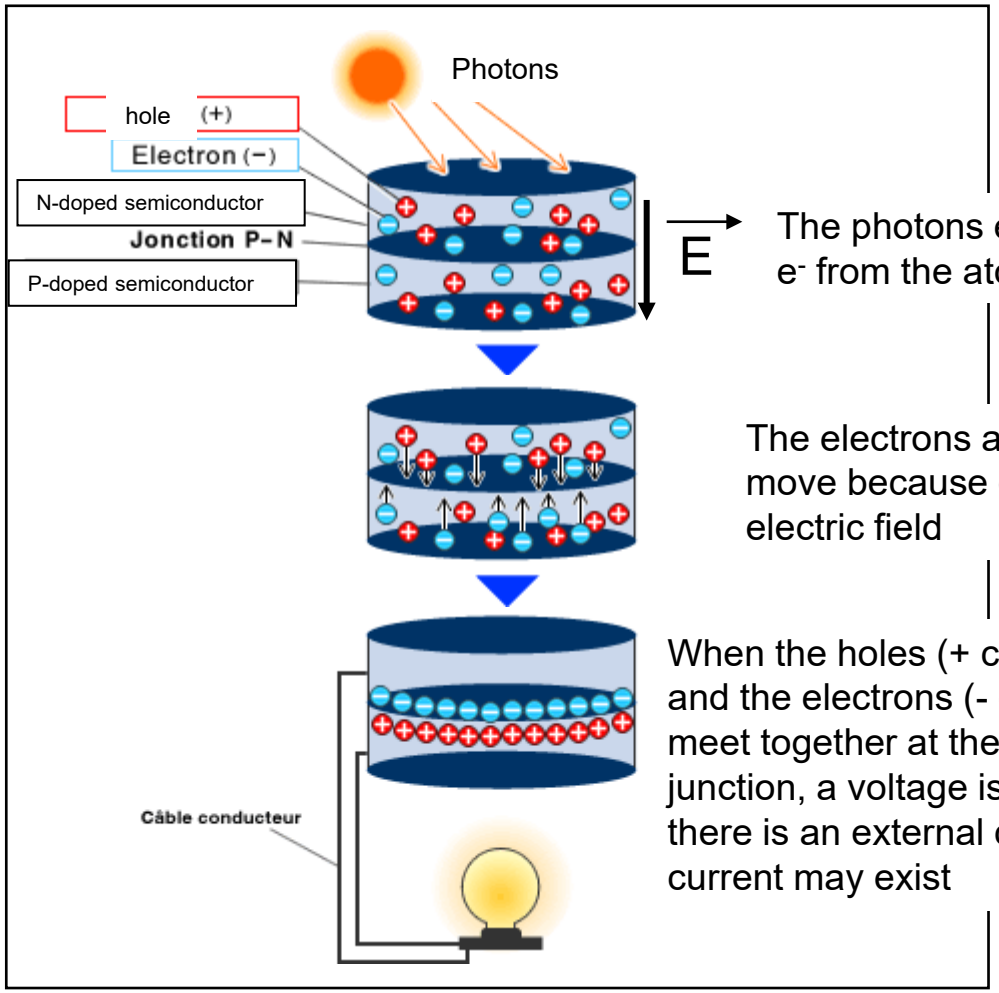
# Photovoltaic effect, how does it work?



- General principle
  - ➢ Specific device which converts solar energy in Electricity




The photons extract $e^-$ from the atoms

The electrons and holes move because of the electric field

When the holes (+ charges) and the electrons (- charges) meet together at the P-N junction, a voltage is created: if there is an external connection, current may exist

Because of the n an p doped zones, there is an electrical field E.

The electrostatic force $\vec{F}=q\vec{E}$ is applied on the electrons and holes.

→ Photovoltaic cell

*Source :*
*Sharp Electronics France*

# Photovoltaic effect, how does it work?



- General principle
  - ➢ Different kinds of materials to achieve PV cells

Single-crystal silicon

Poly-crystal silicon

Amorphus silicon

| Technology | Efficiency (%) |
|---|---|
| Single crystal SI | 12-16 |
| Poly crystal SI | 11-13 |
| AmorphusSI | 5-10 |

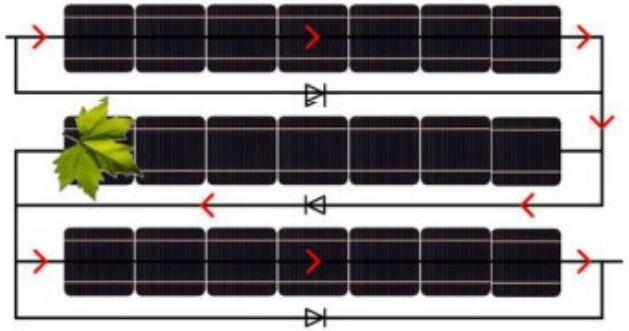
Cost

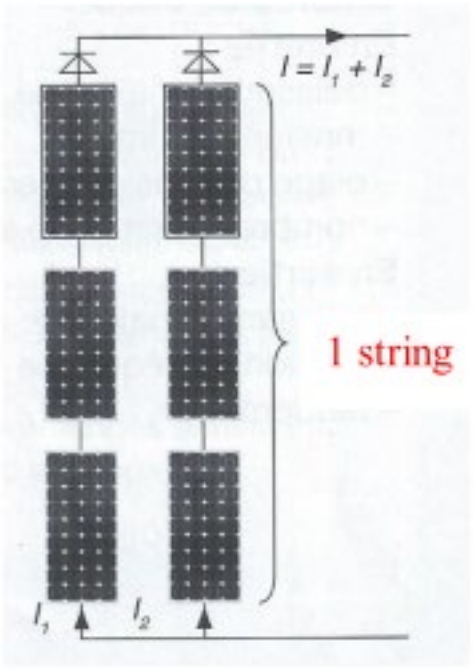
Source: wikipédia

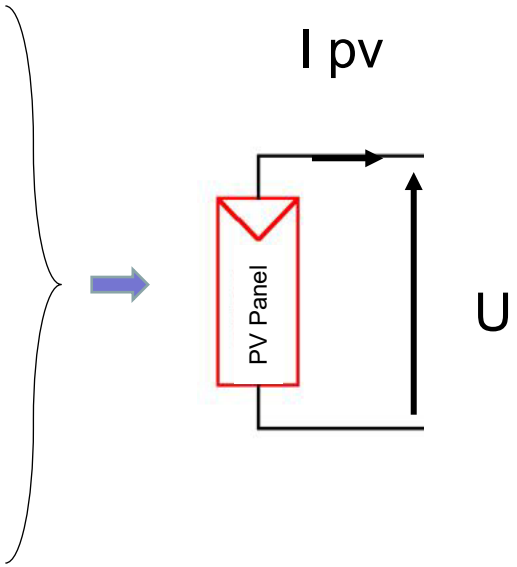
# Photovoltaic effect, how does it work?



- Association of cells to make a PV panel
  - Series and/or parallel association







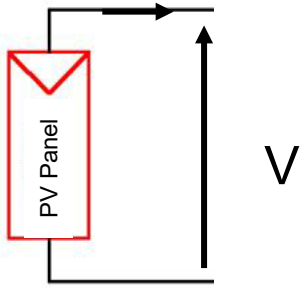

I pv

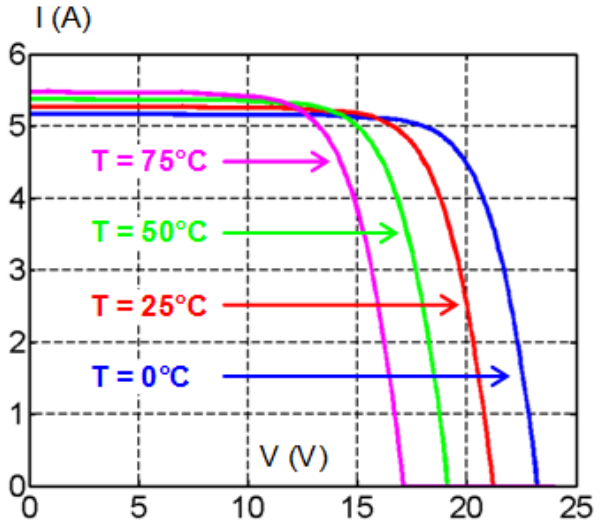
U

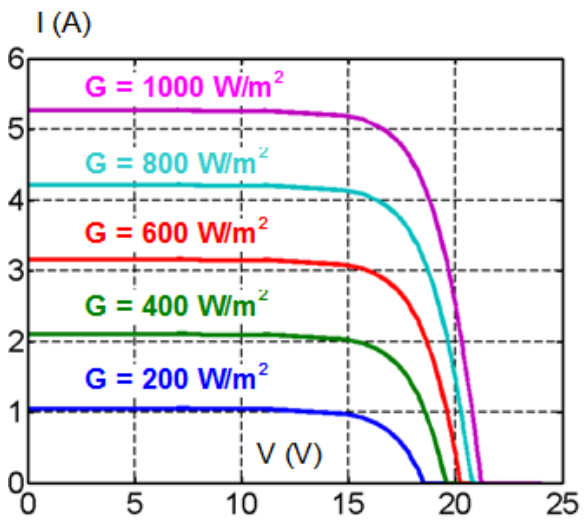
# Photovoltaic effect, how does it work?



- A PV panel is an (unperfect) current source
  - Voltage current characteristics



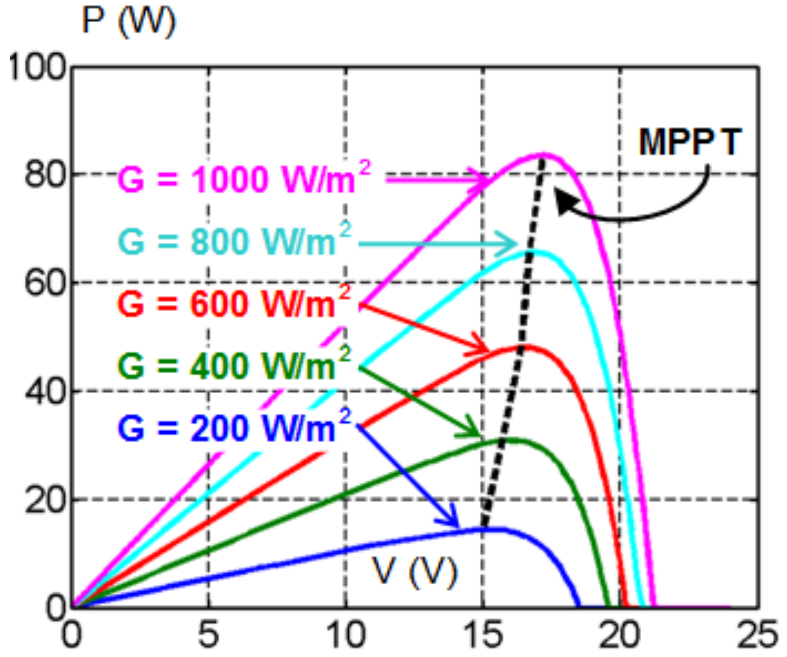




Dependance with

-the temperature

-the irradiance

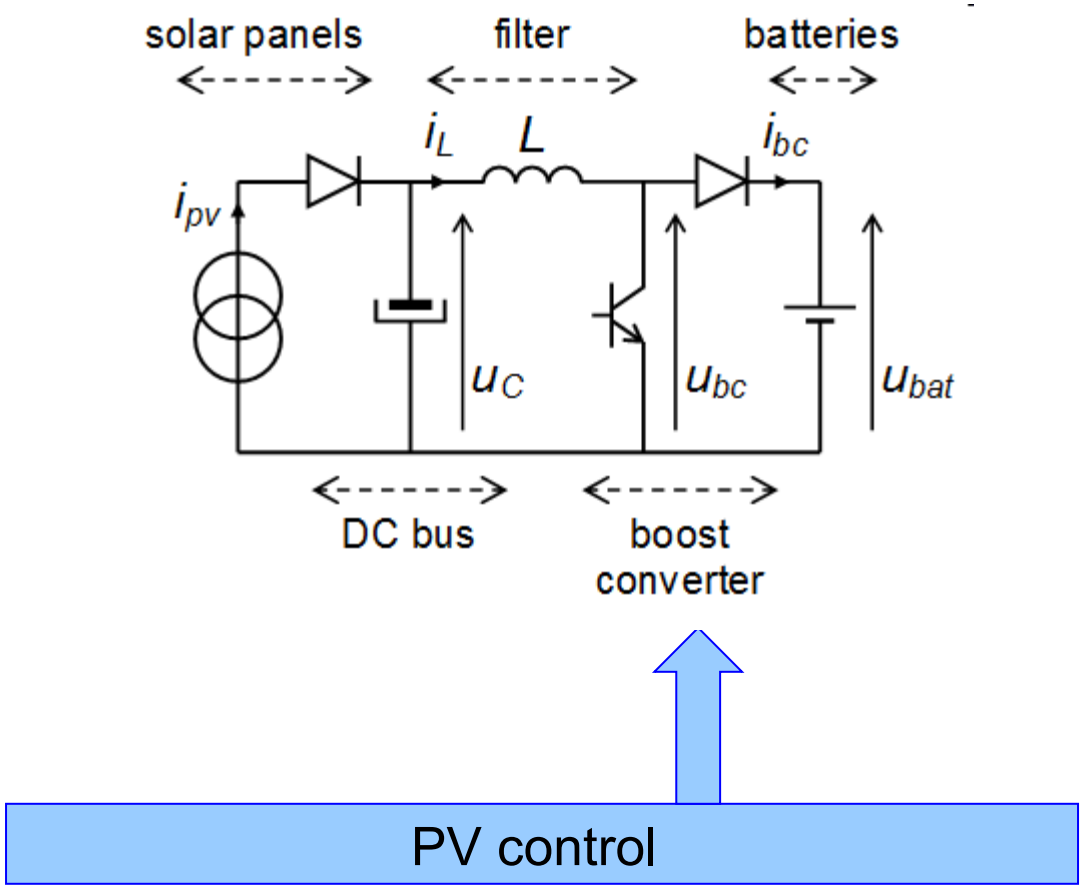
As a consequence, non linear behaviour of the power ($P=V*i_{pv}$) which can be extracted from the PV panel:



# Power extraction from PV panel



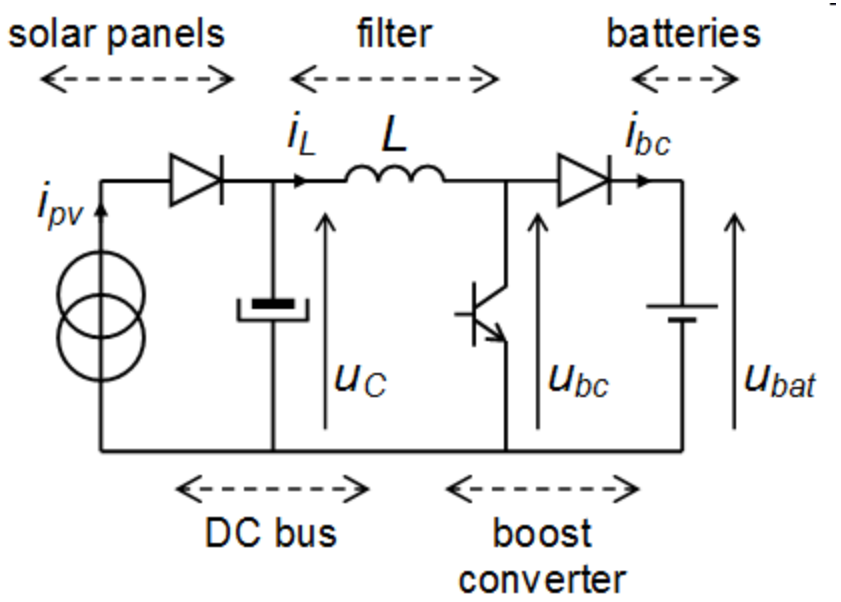
- Power electronics shopper to tune the voltage
- Storage element (battery) to cope with uncertainty of the sun.

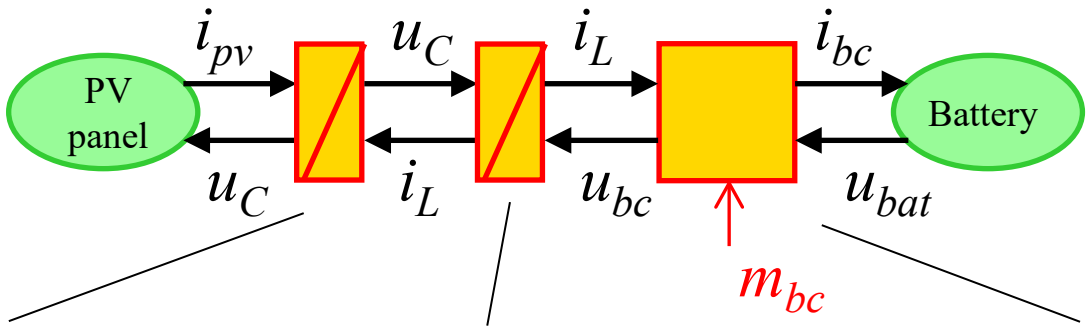



Technical requirements: - provide the maximum active power P

# EMR of a PV panel associated with its typical circuit






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

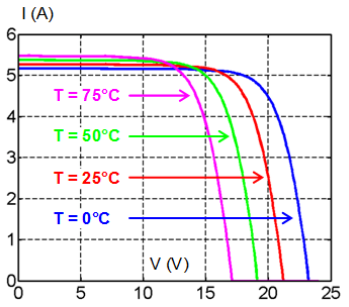
$$L\frac{d}{dt}i_L + R_L i_L = u_C - u_{bc}$$

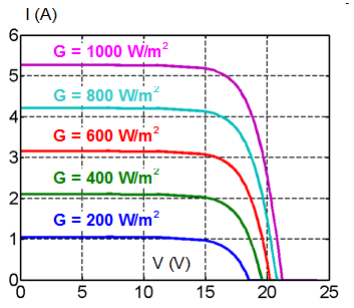
$$\begin{cases} i_{bc} = m_{bc} i_L \\ u_{bc} = m_{bc} u_{bat} \end{cases}$$

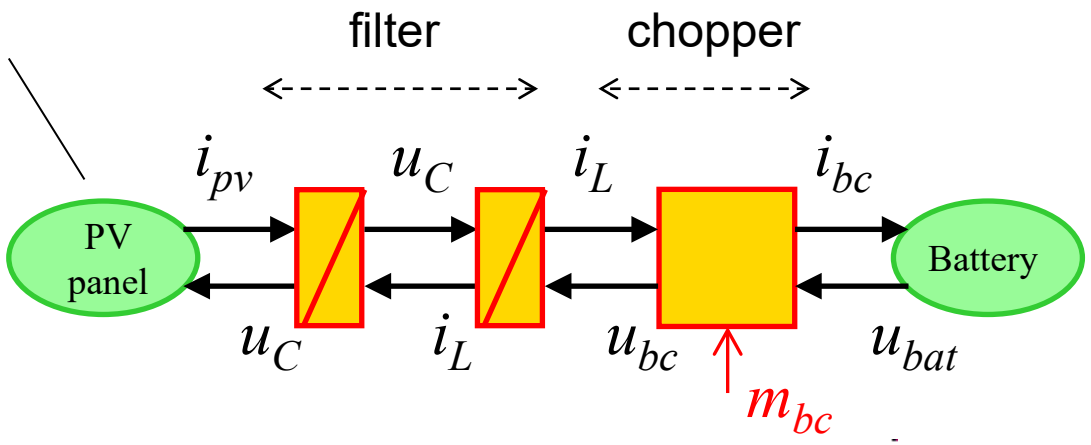
# EMR of a PV panel associated with its typical circuit

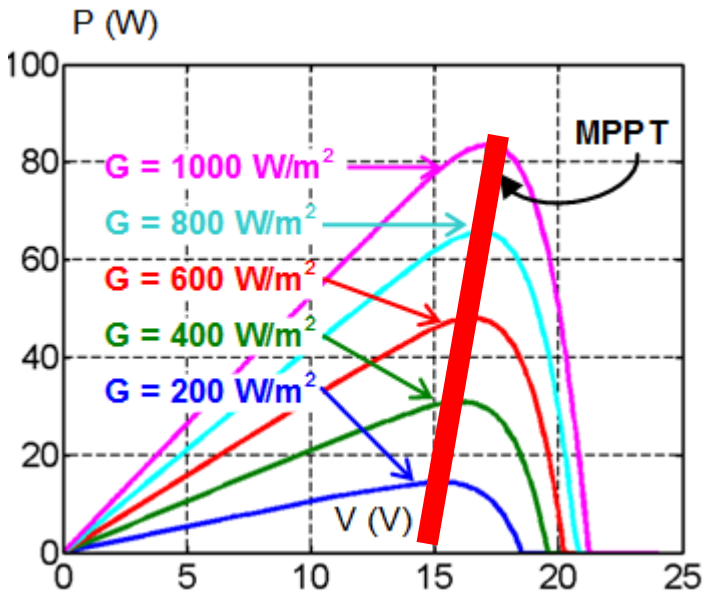


$$i_{pv} = f(u_c, T, G)$$



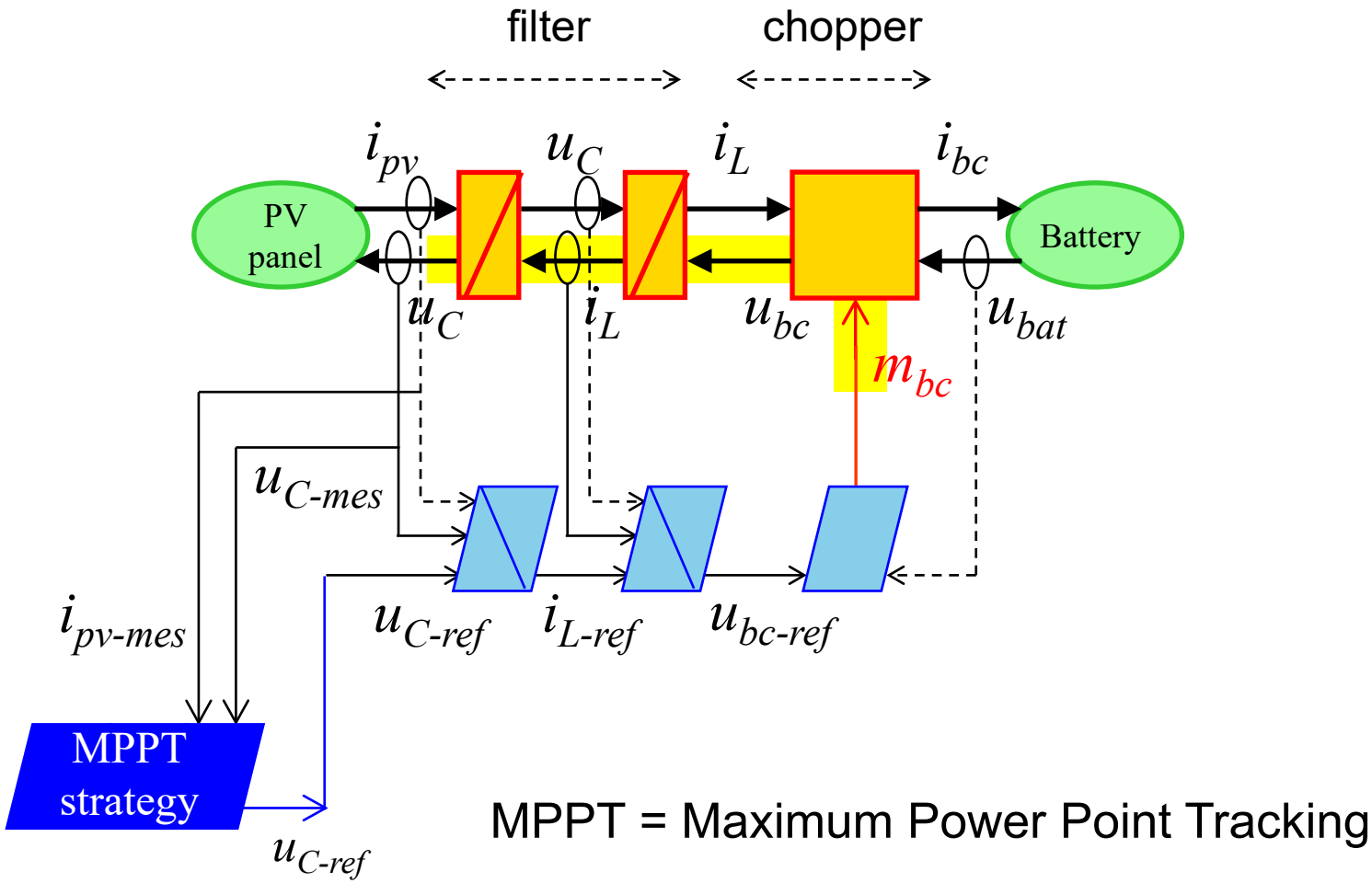




Maximum Power Point Tracking:

→ $u_C$ control

# MCS of a PV panel associated with its typical circuit






MPPT = Maximum Power Point Tracking

# Selected references



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[Bouscayrol 23] A. Bouscayrol, B. Lemaire-Semail, "Energetic Macroscopic Representation and Inversion-Based Control", *Encyclopedia of electrical and electronic power engineering*, Vol. 3, pp 365-375, Elsevier, DOI : 10.1016/B978-0-12-821204-2.00117-3, ISBN : 978-0-12-823211-8, 2023.

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# Thanks for your attention!

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