Controllo non lineare di circuiti per applicazioni fotovoltaiche

Giovanni Spagnuolo
Unità di Salerno

gspagnuolo@unisa.it

Collaborazione internazionale ed industriale

Attività svolta in collaborazione con:

Bitron Industrie S.p.A.

Universitat Rovira i Virgili

Universidad Nacional de Colombia

References

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Enrico Bianconi, Javier Calvente, Roberto Giral, Carlos Andres Ramos Paja, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli: "Improving the Perturb and Observe maximum power point tracking by using Sliding Mode Control", to be presented at IEEE ISIE 2011, Gdansk, June 2011.

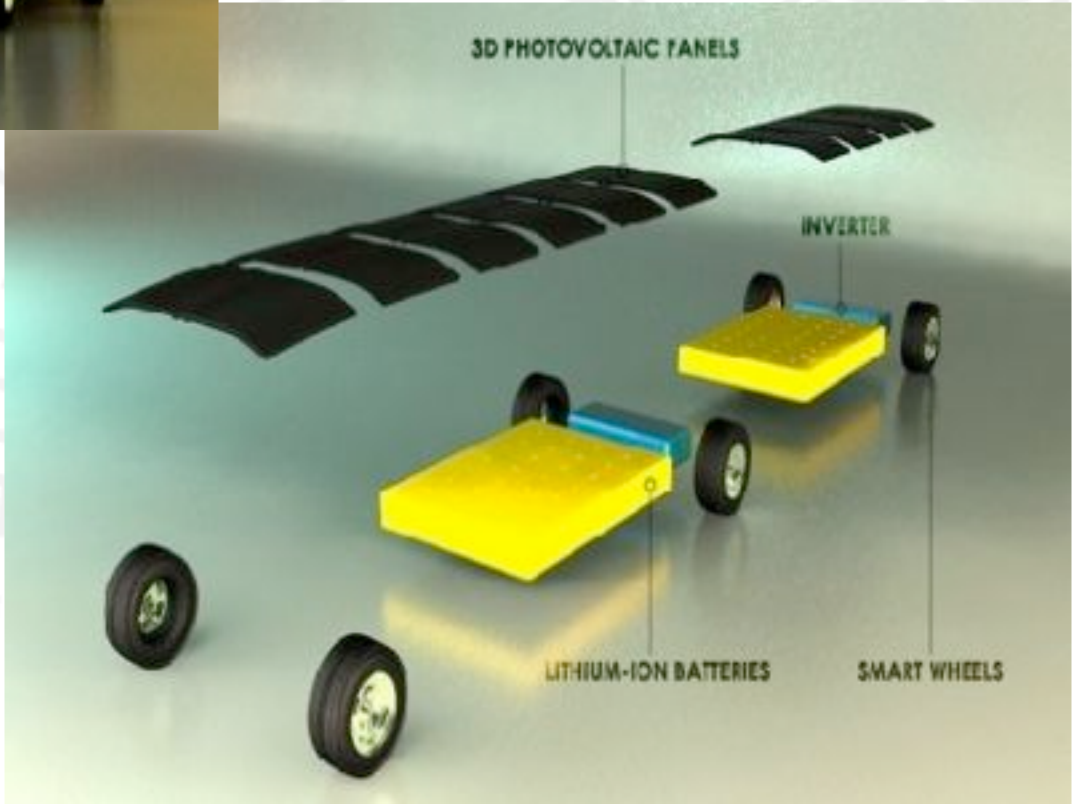
Enrico Bianconi, Javier Calvente, Roberto Giral, Carlos Andres Ramos Paja, Giovanni Petrone, Giovanni Spagnuolo, Massimo Vitelli: "A fast current-based MPPT technique based on sliding mode control", to be presented at IEEE ISIE 2011, Gdansk, June 2011.

"Non-conventional" applications

G.Spagnuolo - gspagnuolo@unisa.it

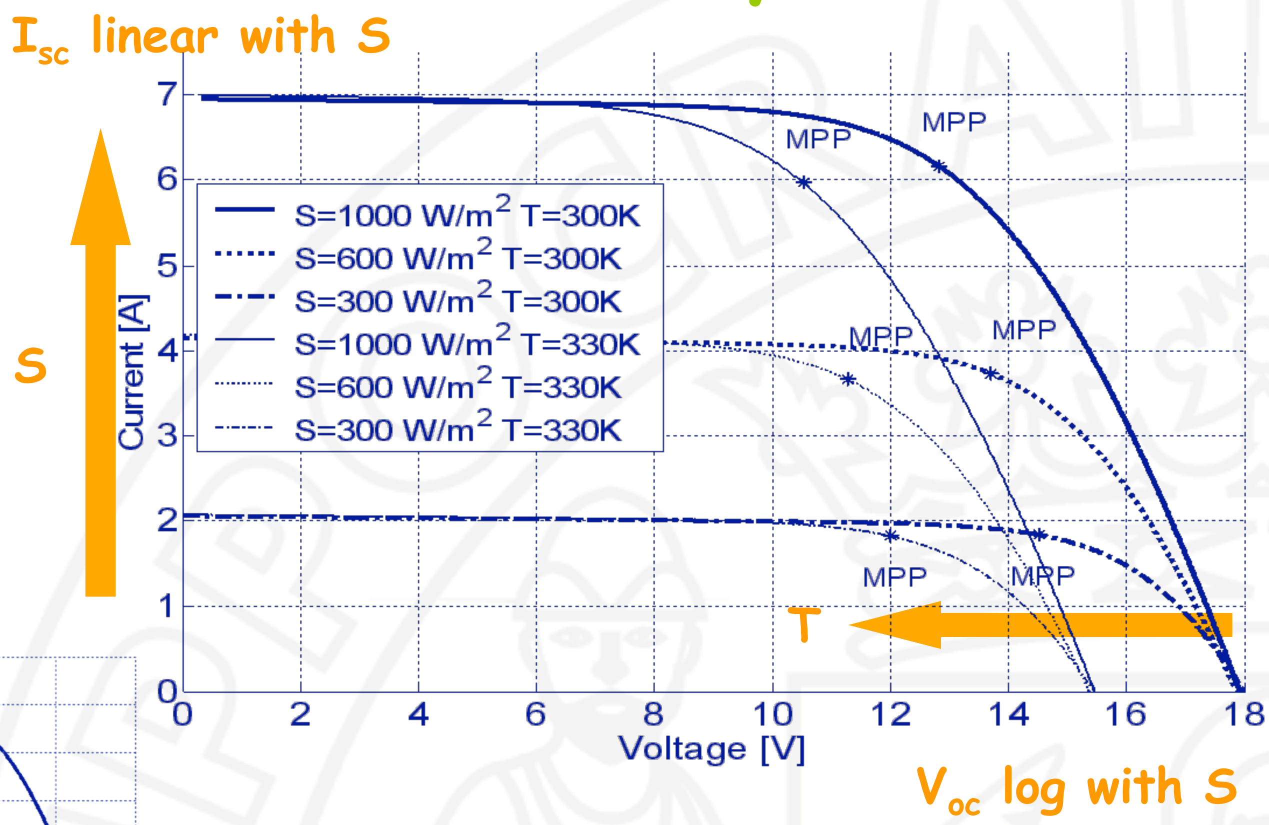
Quickly variable shadowing

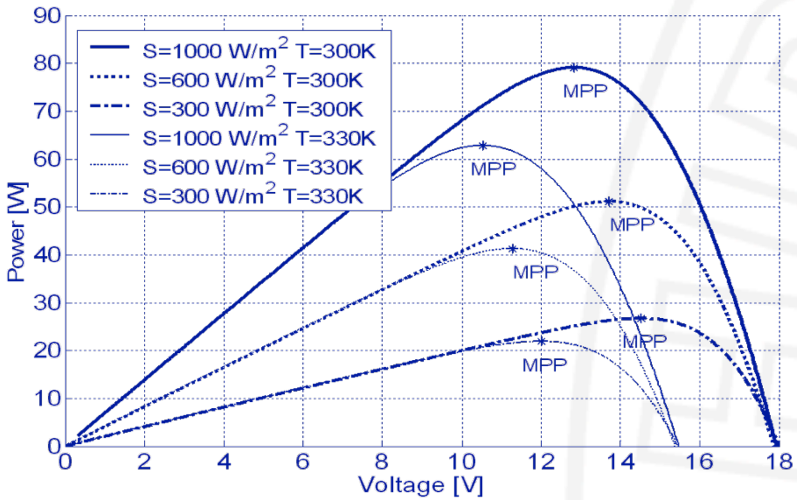
The 'Takht Lahori' Zero-Emissions Bus



G.Spagnuolo - gspagnuolo@unisa.it

PV curves non linearity





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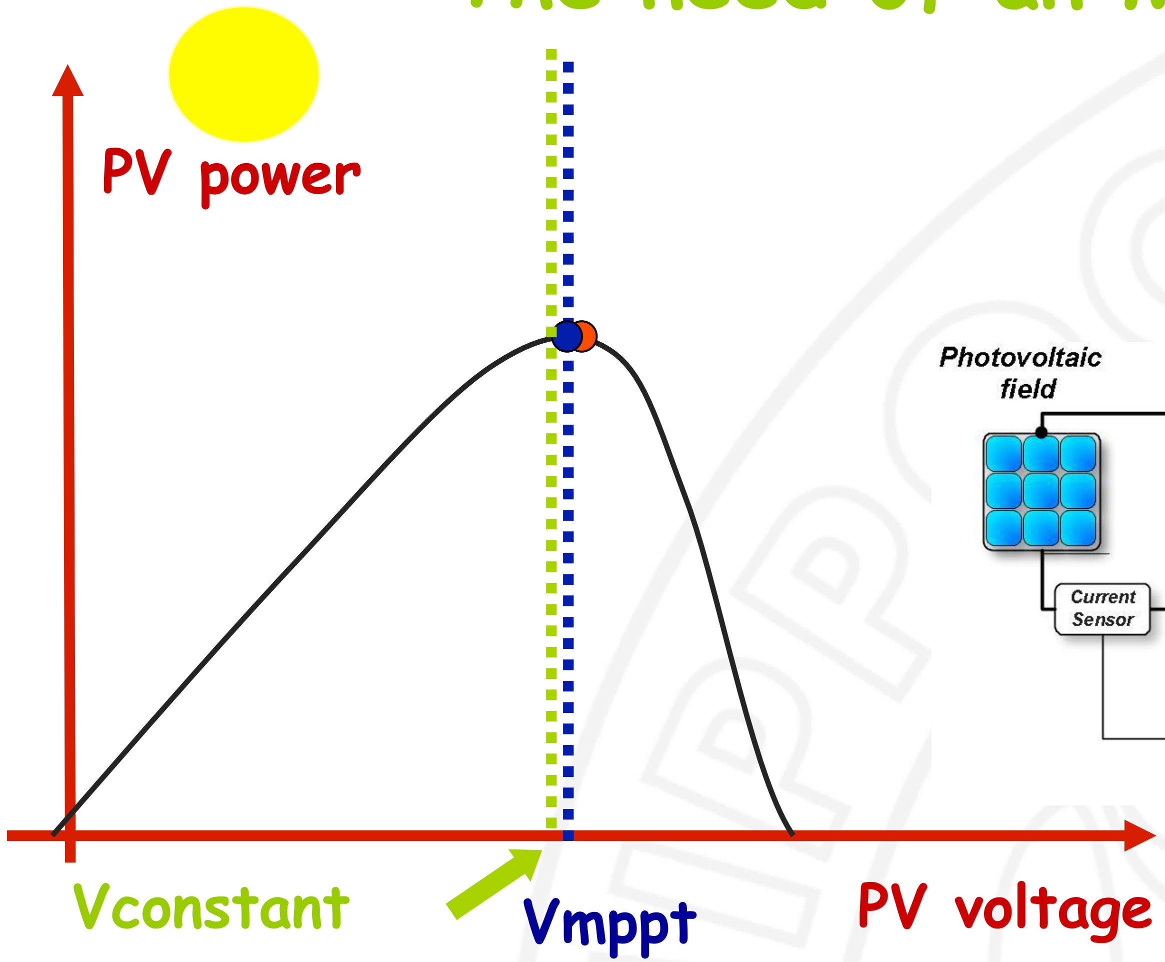
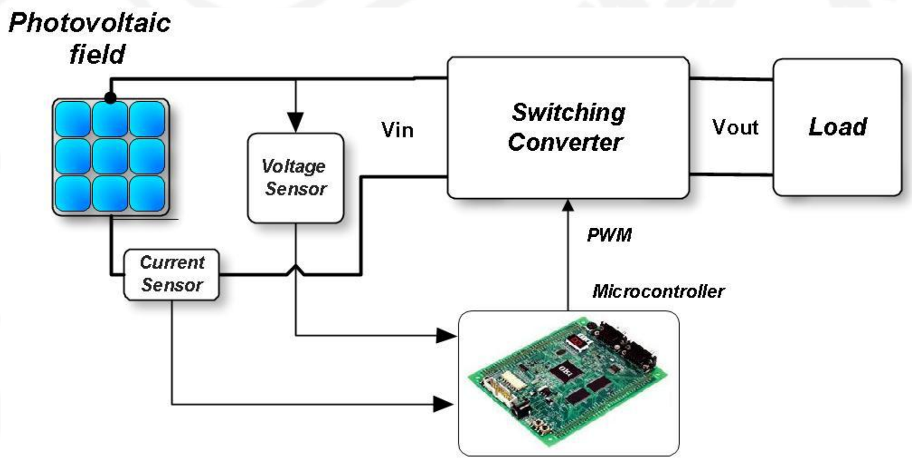
The need of an MPPT





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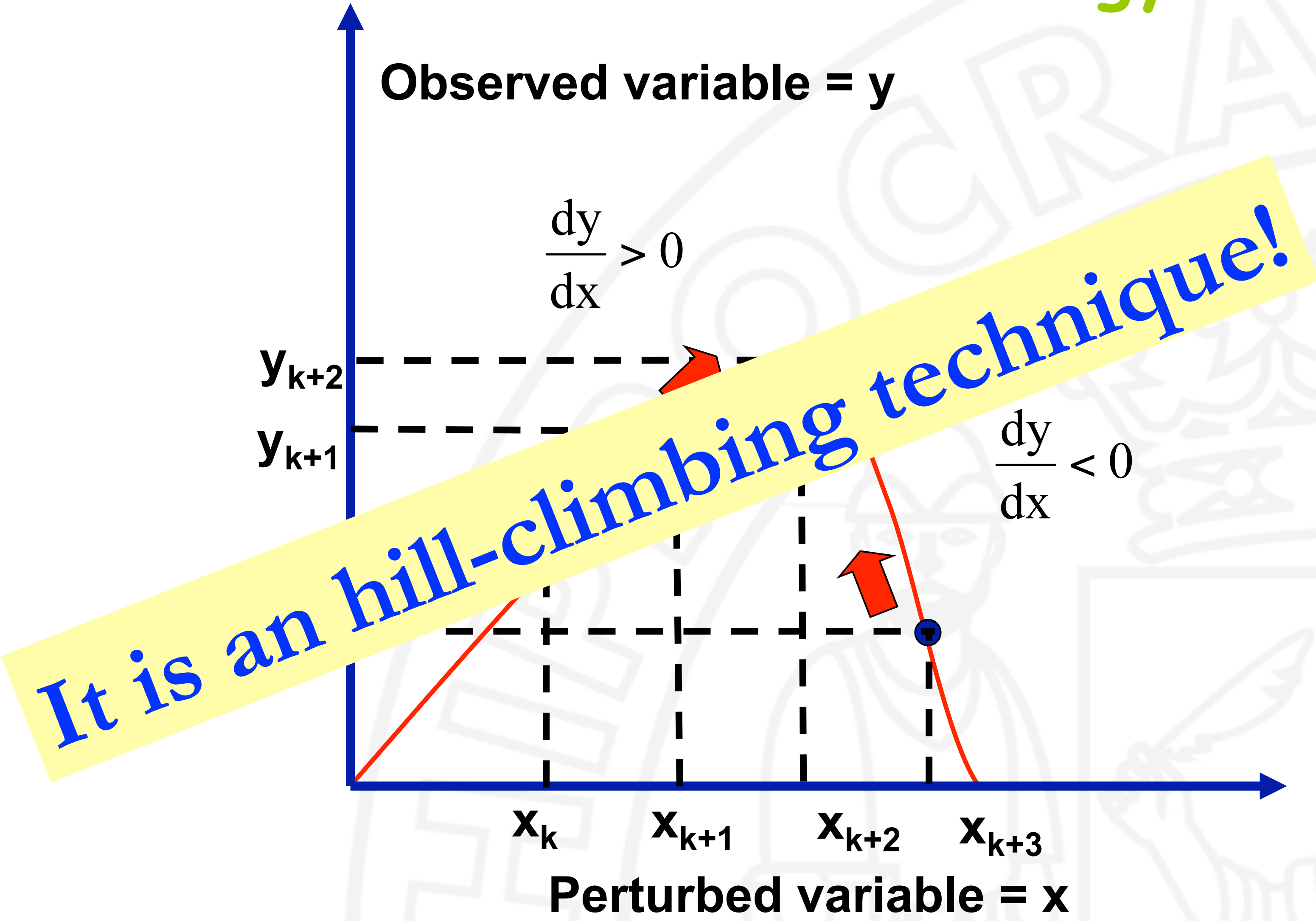
Perturb & Observe strategy



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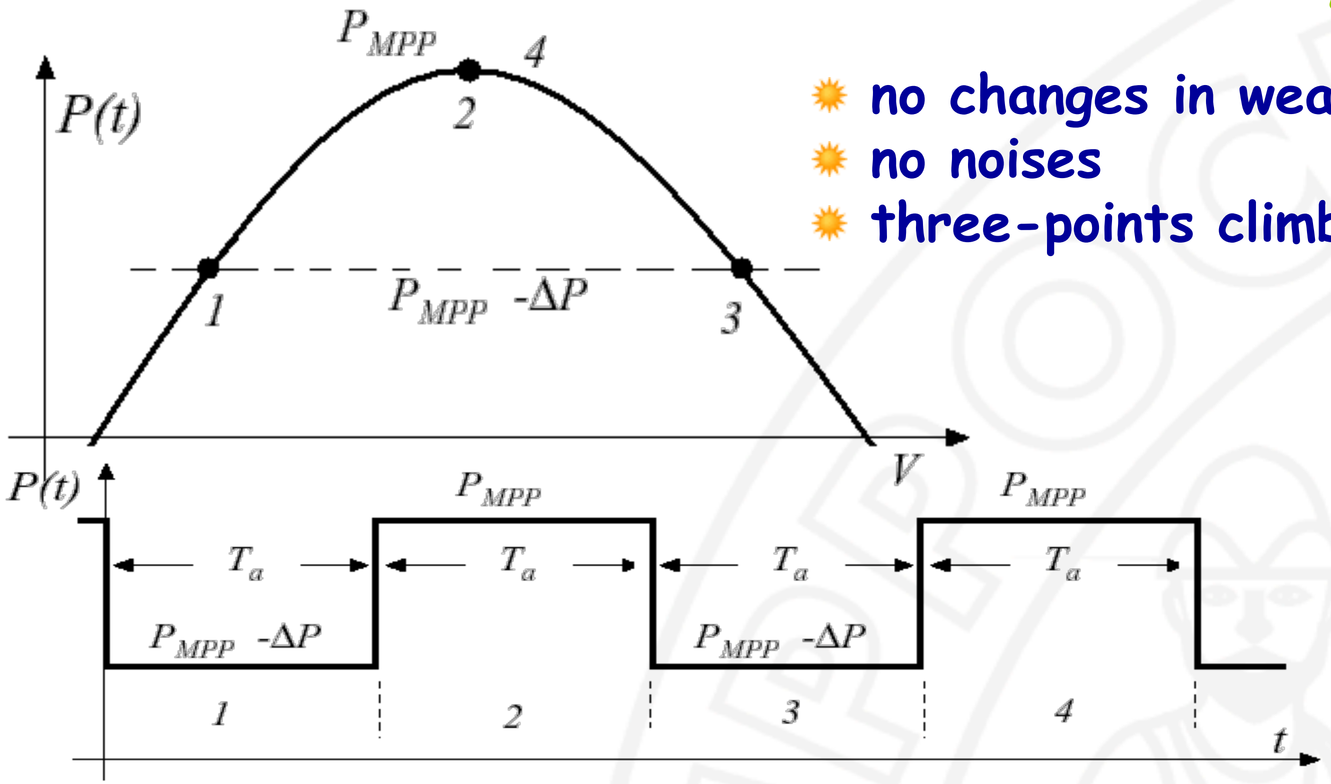
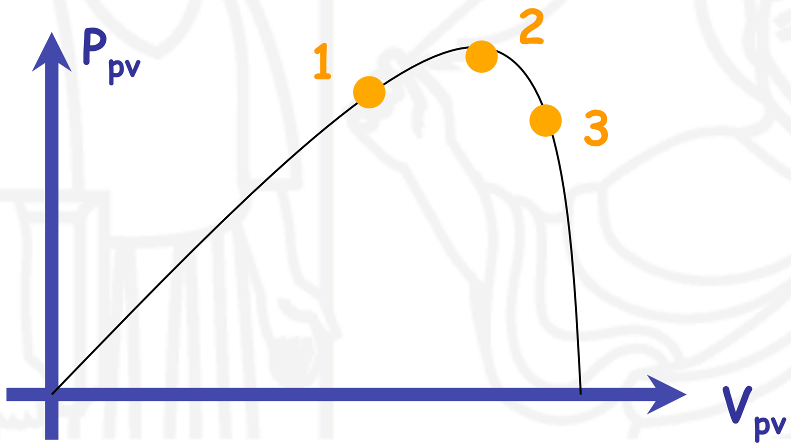
MPPT efficiency: it is not the conversion efficiency!!!

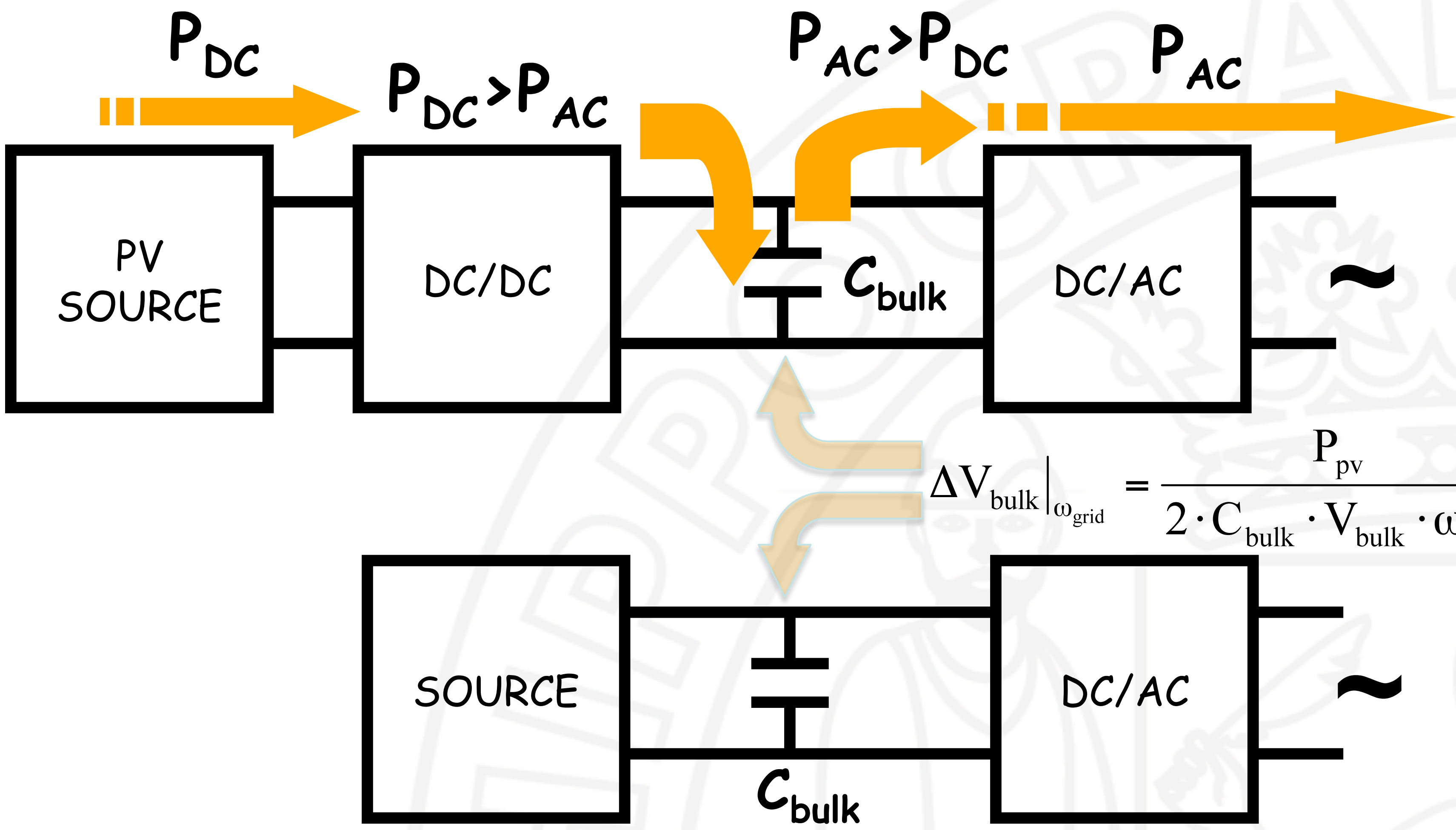


- no changes in weather conditions
- no noises
- three-points climbing (MPP included)

$$\eta_{MPPT} = \frac{< P(t) >_{4Ta}}{P_{MPP}} = 1 - \frac{1}{2} \cdot \frac{\Delta P}{P_{MPP}}$$



Effects of AC load/grid in PV & FC



$$\Delta V_{bulk}\Big|_{\omega_{grid}} = \frac{P_{pv}}{2 \cdot C_{bulk} \cdot V_{bulk} \cdot \omega_{grid}}$$

Lower C_{bulk}:

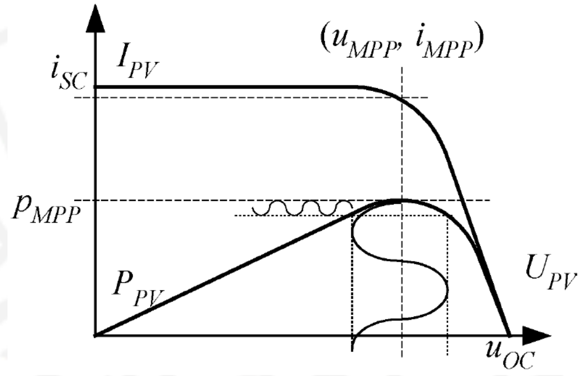
☺ no electrolytic capacitance C_{bulk}

☹ increased oscillation amplitude

☹ electrolytic C_{pv} might be required

Bulk voltage oscillation back-propagation

At a constant value of the dc/dc converter's duty cycle, in the MPP:



bulk voltage oscillation

↓

Vpv oscillation

↓

Ppv oscillation

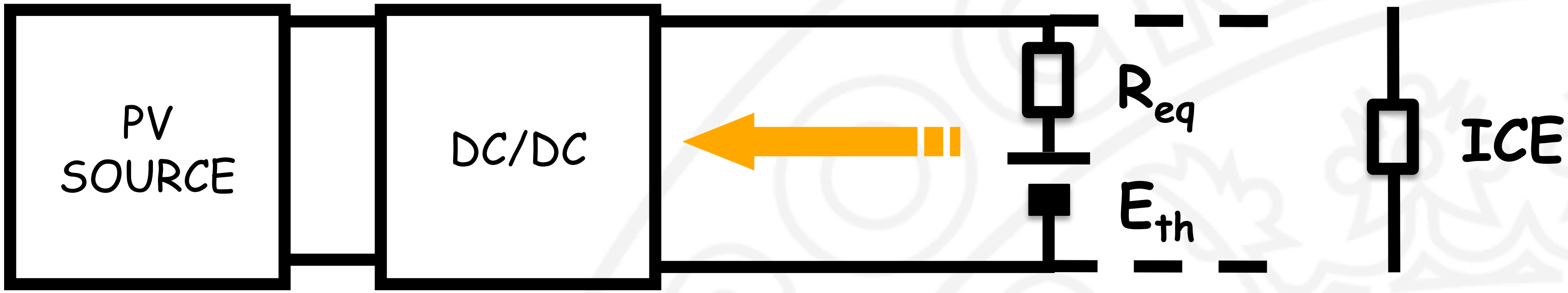
↓

Power losses

$$\eta_{EU} = 0.03 \cdot \eta_{5\%} + 0.06 \cdot \eta_{10\%} + 0.13 \cdot \eta_{20\%} + 0.10 \cdot \eta_{30\%} + 0.48 \cdot \eta_{50\%} + 0.20 \cdot \eta_{100\%}$$

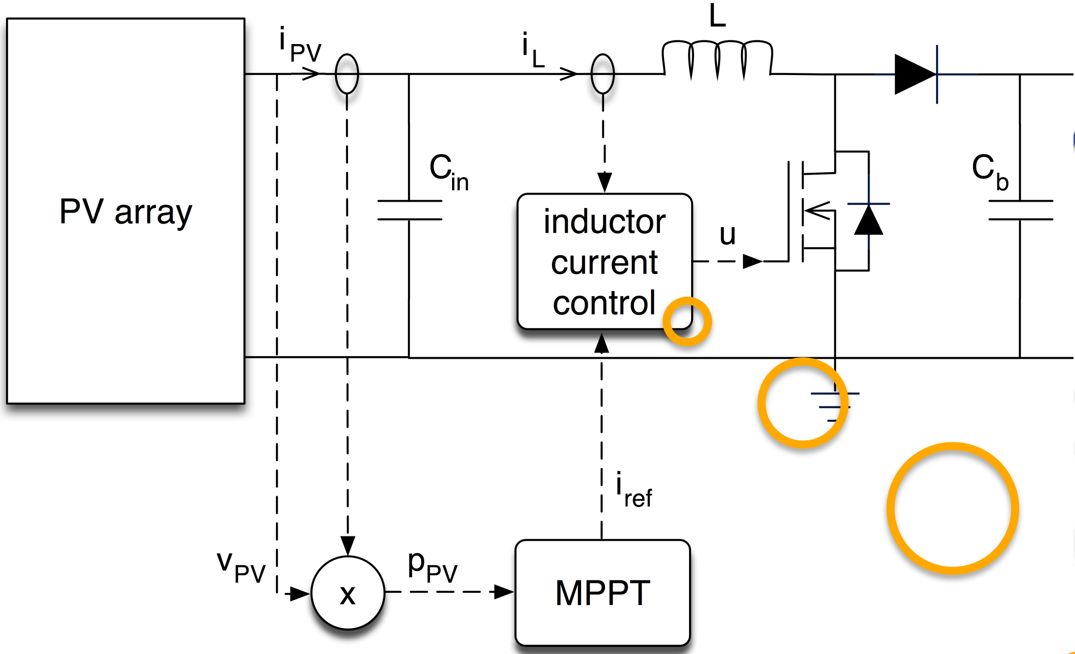
η_{EU}	$\Delta V_{\%} = \frac{\Delta V}{V_{MPP}} \cdot 100$
99.9	2.0
99.2	5.5
96.8	10.6

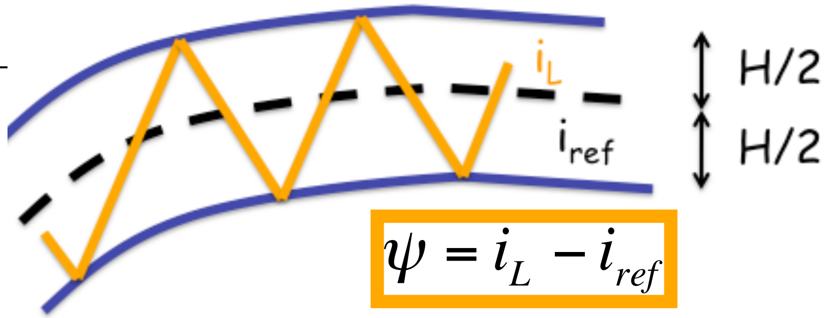
Effects of disturbances in off-grid systems



R_{eq} is significantly dependent on the battery SOC

Noise reduction by sliding mode control

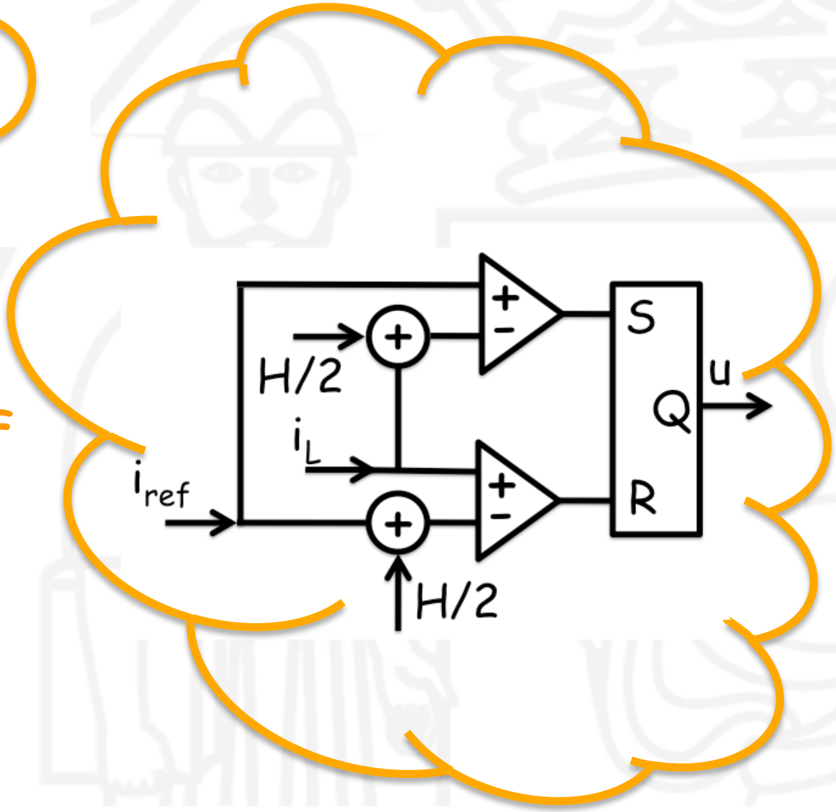




$$\psi = i_L - i_{ref}$$

sliding surface

$$\begin{cases} i_L < i_{ref} - H(t)/2 & \text{mosfet turned ON} \\ i_L > i_{ref} + H(t)/2 & \text{mosfet turned OFF} \end{cases}$$



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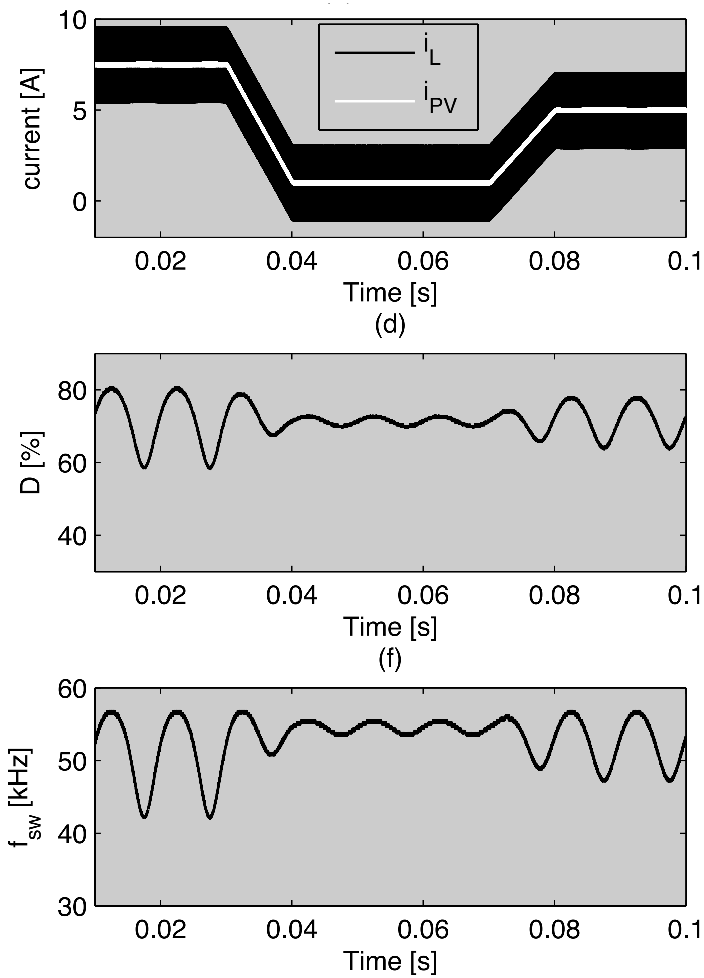
Simulation results: synchronous boost



parameter	value
v_{PV}	120 V
v_{b0}	450 V
f_{grid}	50 Hz
P_{MPP}	1 kW
Δv_b	160 V
L	409 μH
C_{in}	50 μF
C_b	22 μF

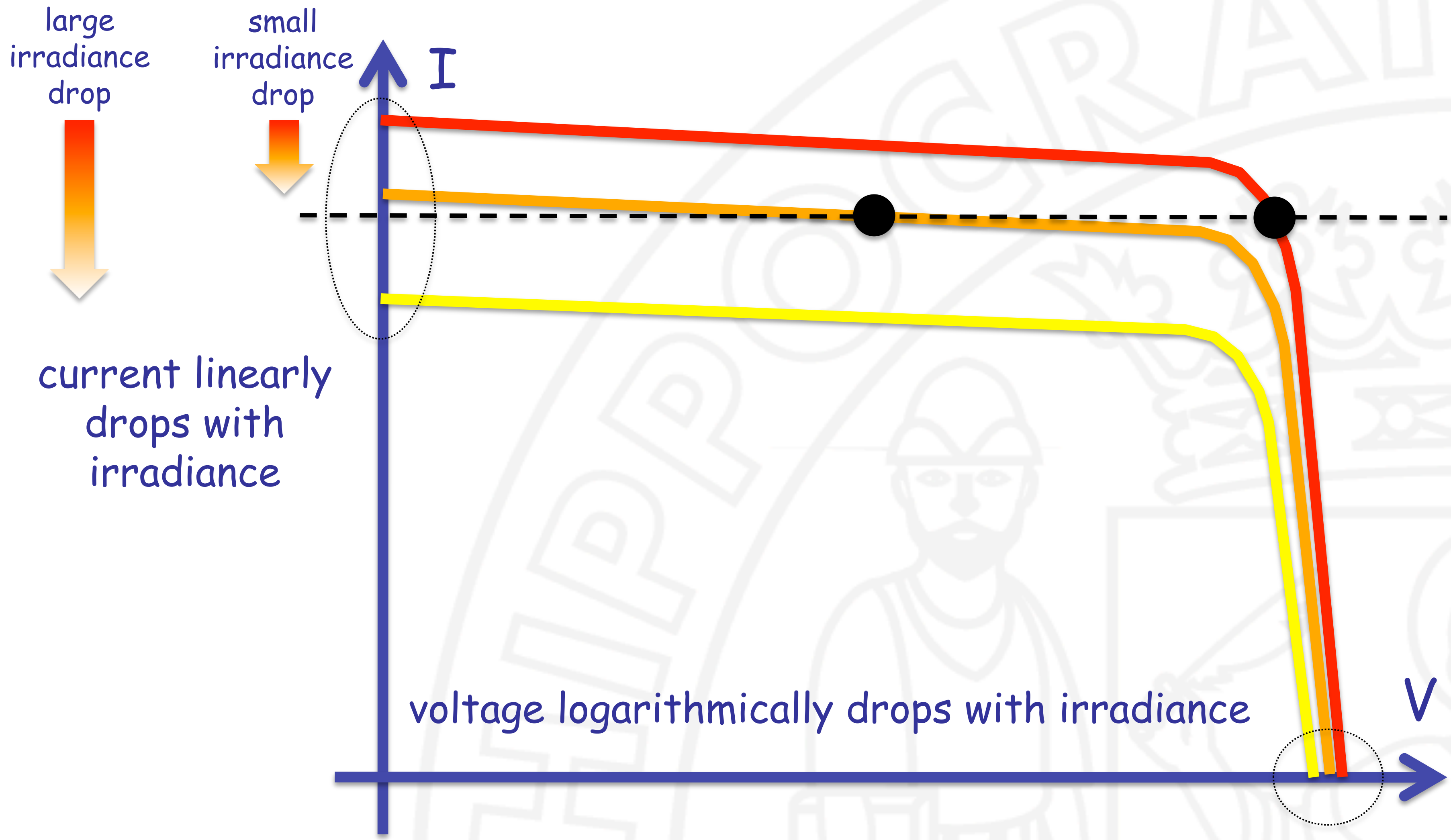
No disturbance affecting the inductor current

$$\Delta f_{sw}(t) = \frac{v_{PV}}{L \cdot H_0} \cdot \frac{v_{PV}}{v_{b0}} \cdot \frac{\Delta v_b(t)}{v_{b0} + \Delta v_b(t)}$$

bulk voltage oscillation amplitude

G.Spagnuolo - gspagnuolo@unisa.it

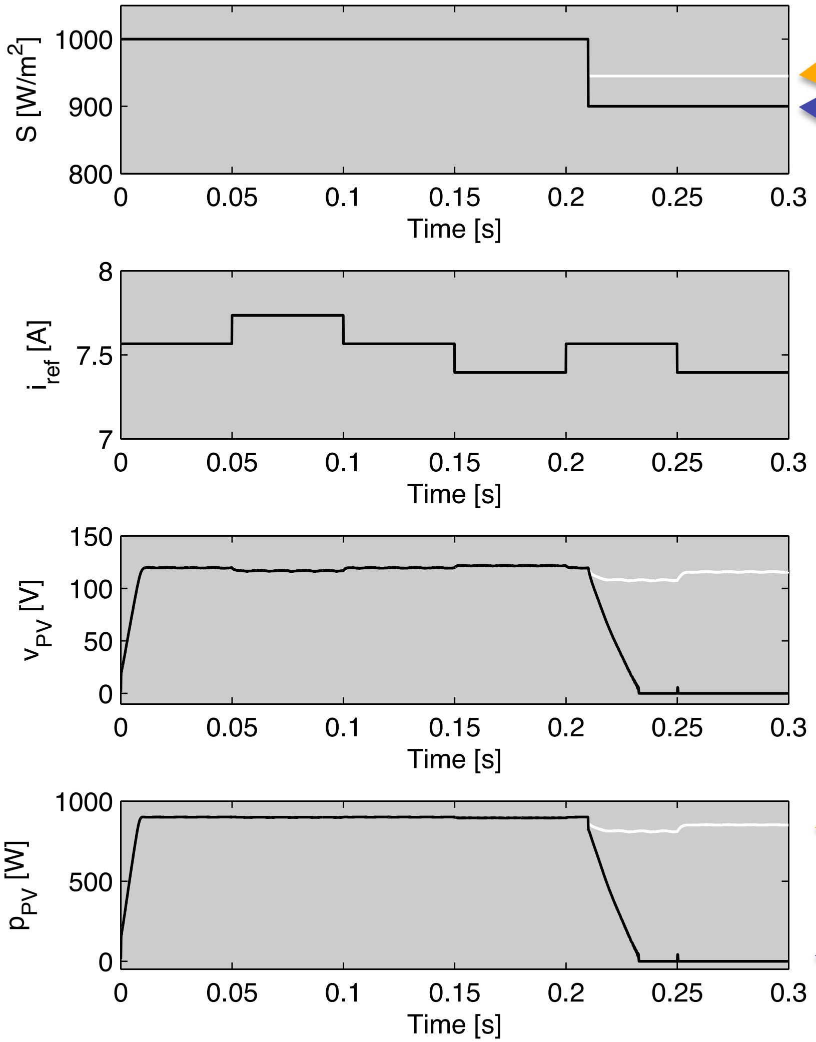
Why not current-based MPPT?

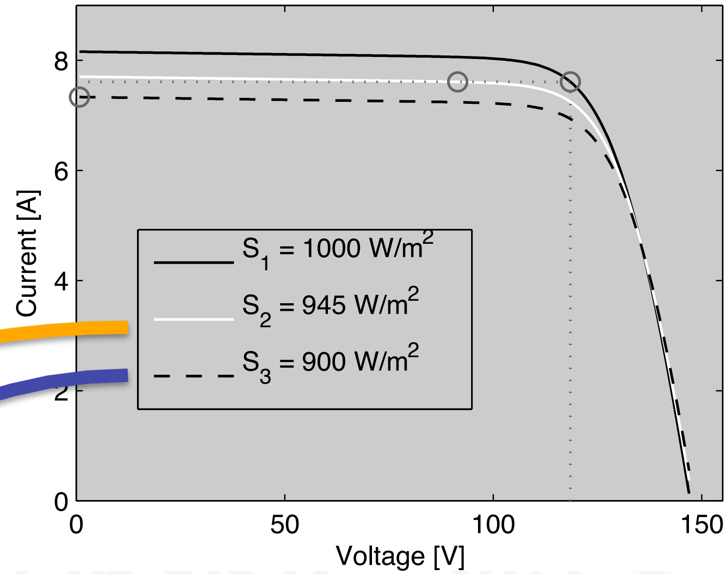


Transient performances

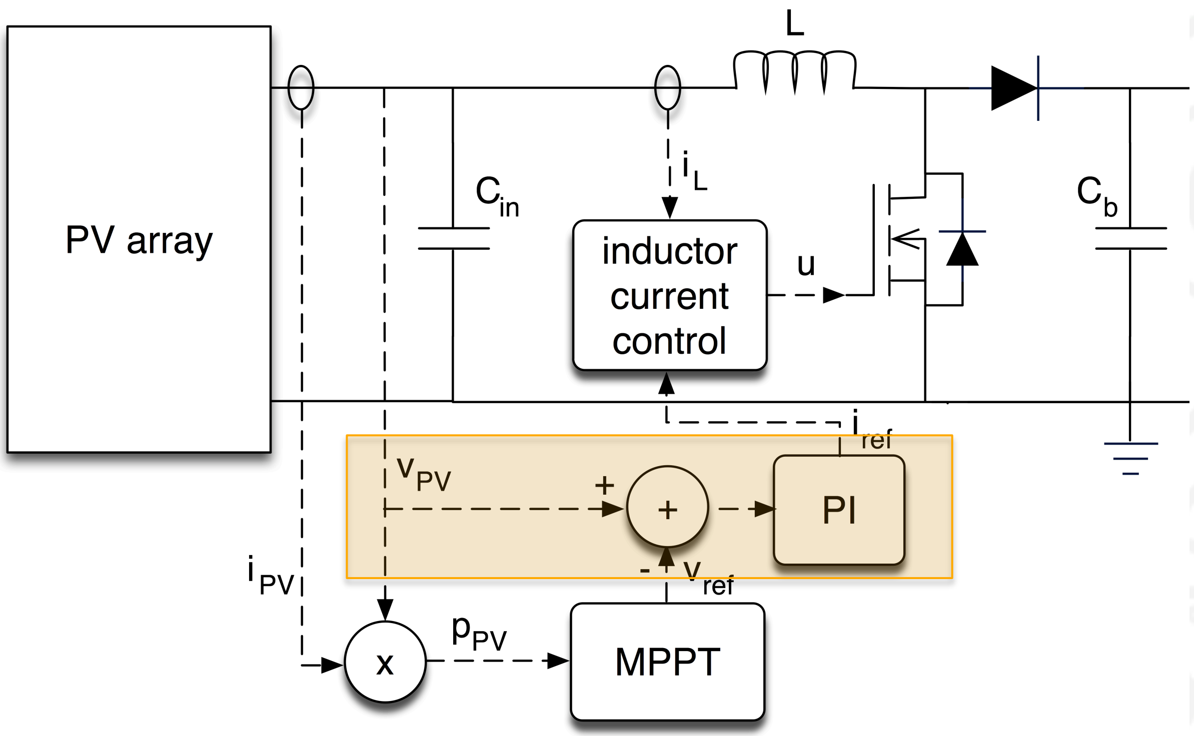
With a ΔS=55W/m² no problems in MPPT

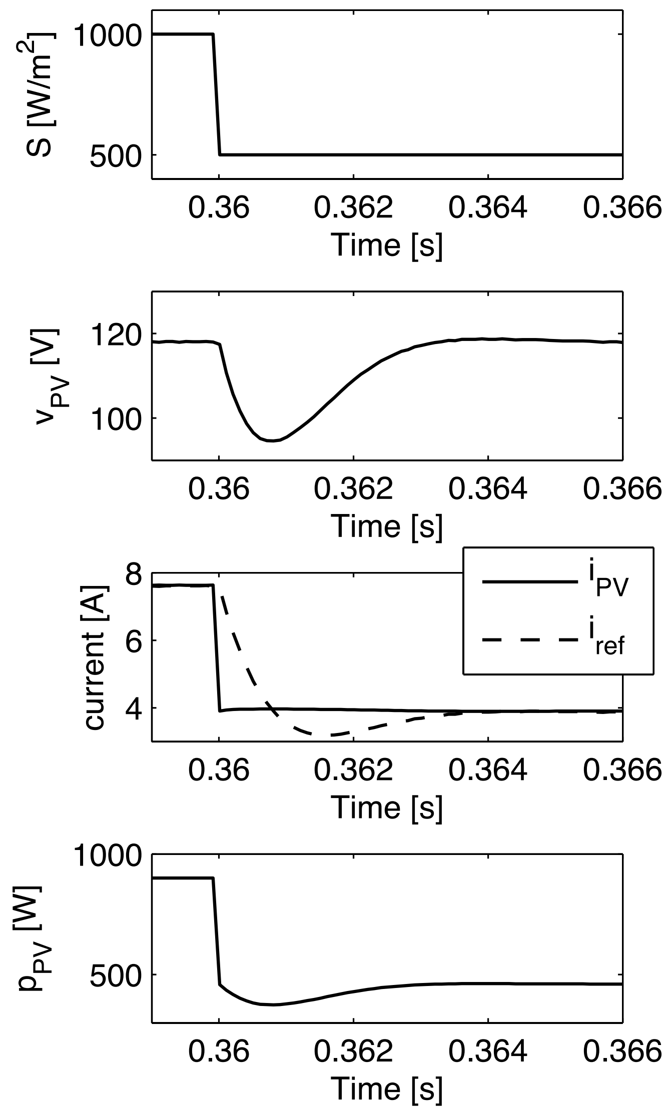
With a ΔS=100W/m² the reference current is higher than the short circuit current and the upper bound i_{ref}+H/2 is never reached.





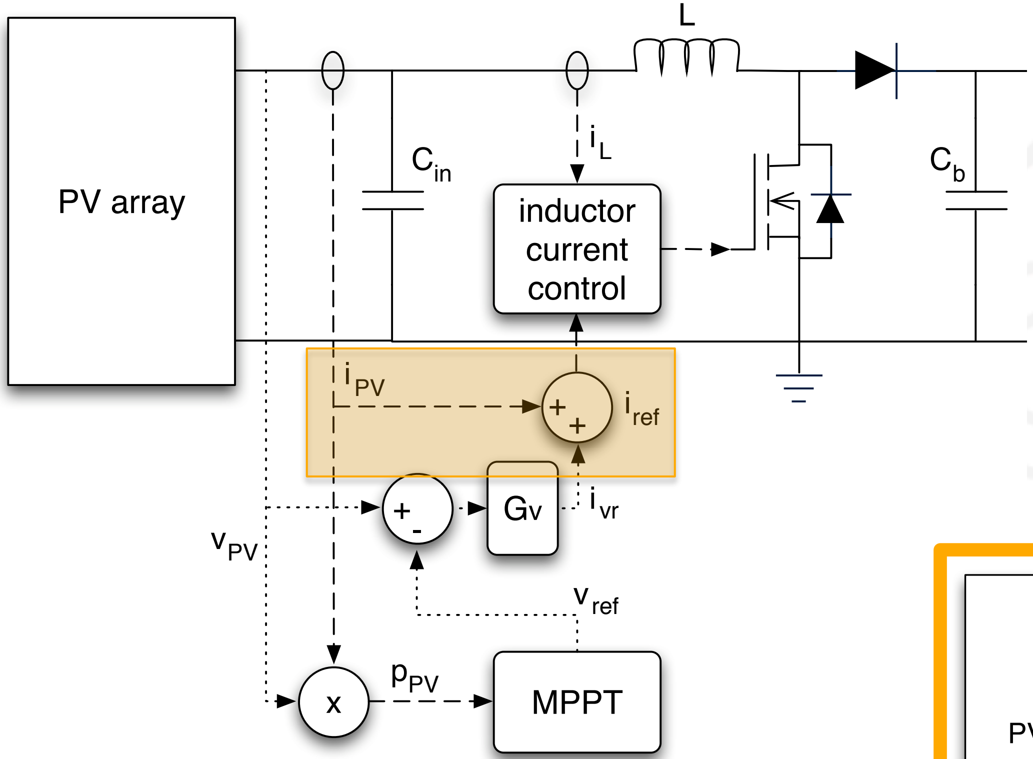
Improved MPPT performances





$$\frac{V_{pv}(s)}{I_{ref}(s)} = -\frac{R_{MPP}}{1 + R_{MPP} \cdot C_{in} \cdot s}$$

Can the MPPT promptness be improved?

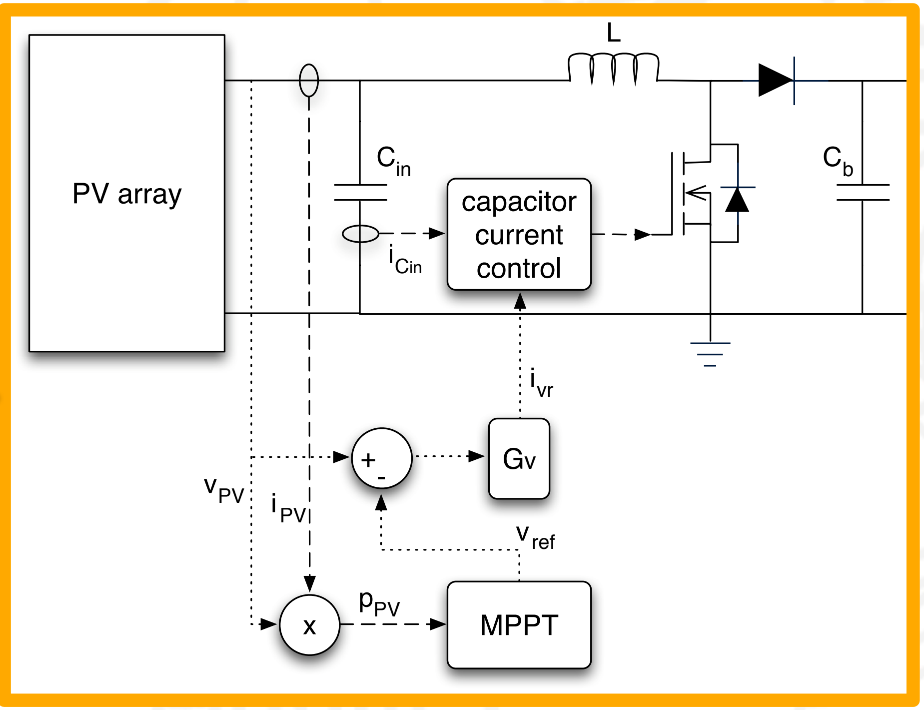


$$i_{PV} = i_{Cin} + i_L$$

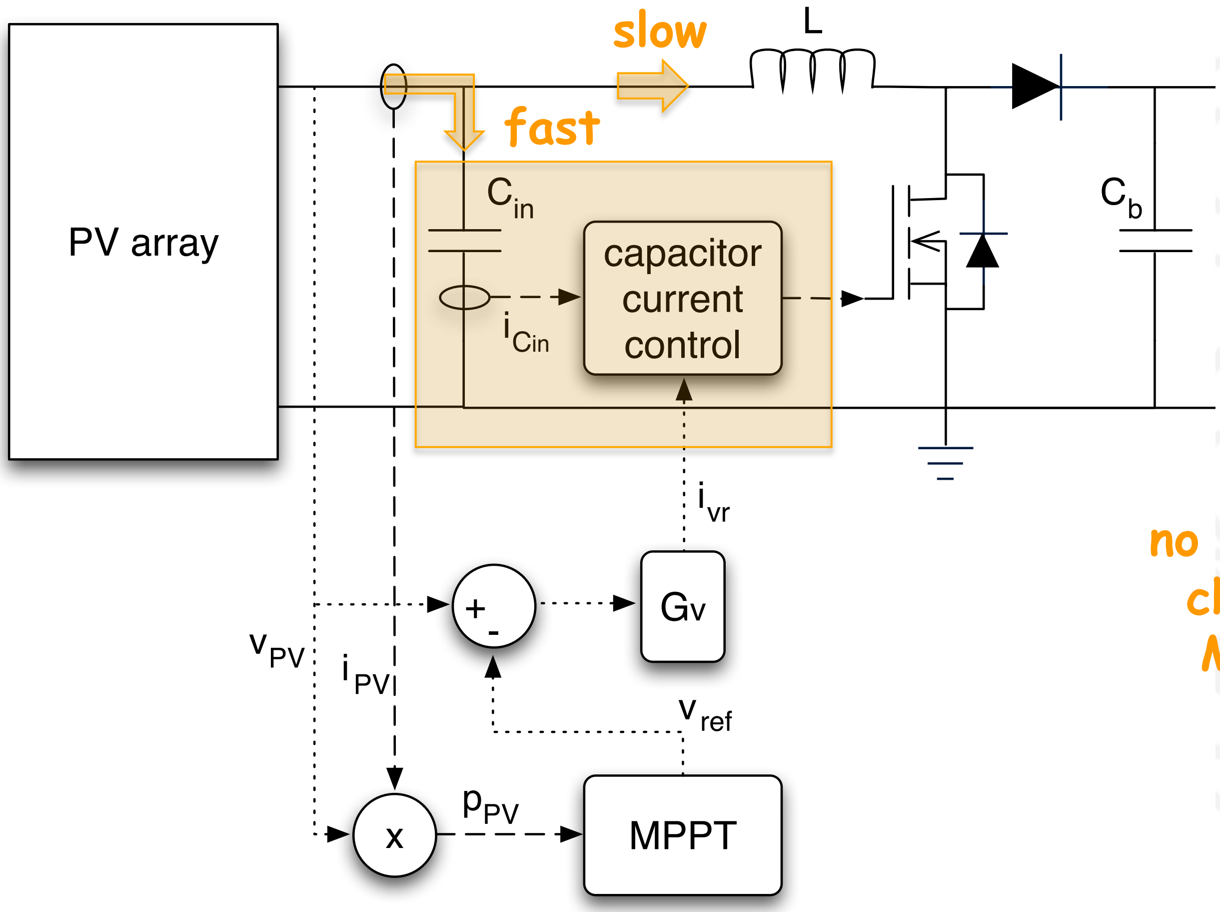
$$i_{ref} = i_{PV} + i_{vr}$$

$$e_i = i_{ref} - i_L = i_{Cin} + i_{vr}$$

$$e_i = 0 \Rightarrow i_{Cin} = -i_{vr}$$



An improved MPPT response



$$\frac{V_{pv}(s)}{I_{vr}(s)} = -\frac{1}{C_{in} \cdot s}$$

no dependency on the PV array characteristics, so that the MPPT performances do not depend on the PV array

no dependency on V_{bulk}, so that the 100Hz is rejected and the MPPT is achieved

G.Spagnuolo - gspagnuolo@unisa.it

Sliding mode conditions

$$SURF = 0$$

$$i_{Cin} + i_{vr} = 0$$

$$\frac{dv_{PV}}{dt} = -\frac{i_{vr}}{C_{in}}$$

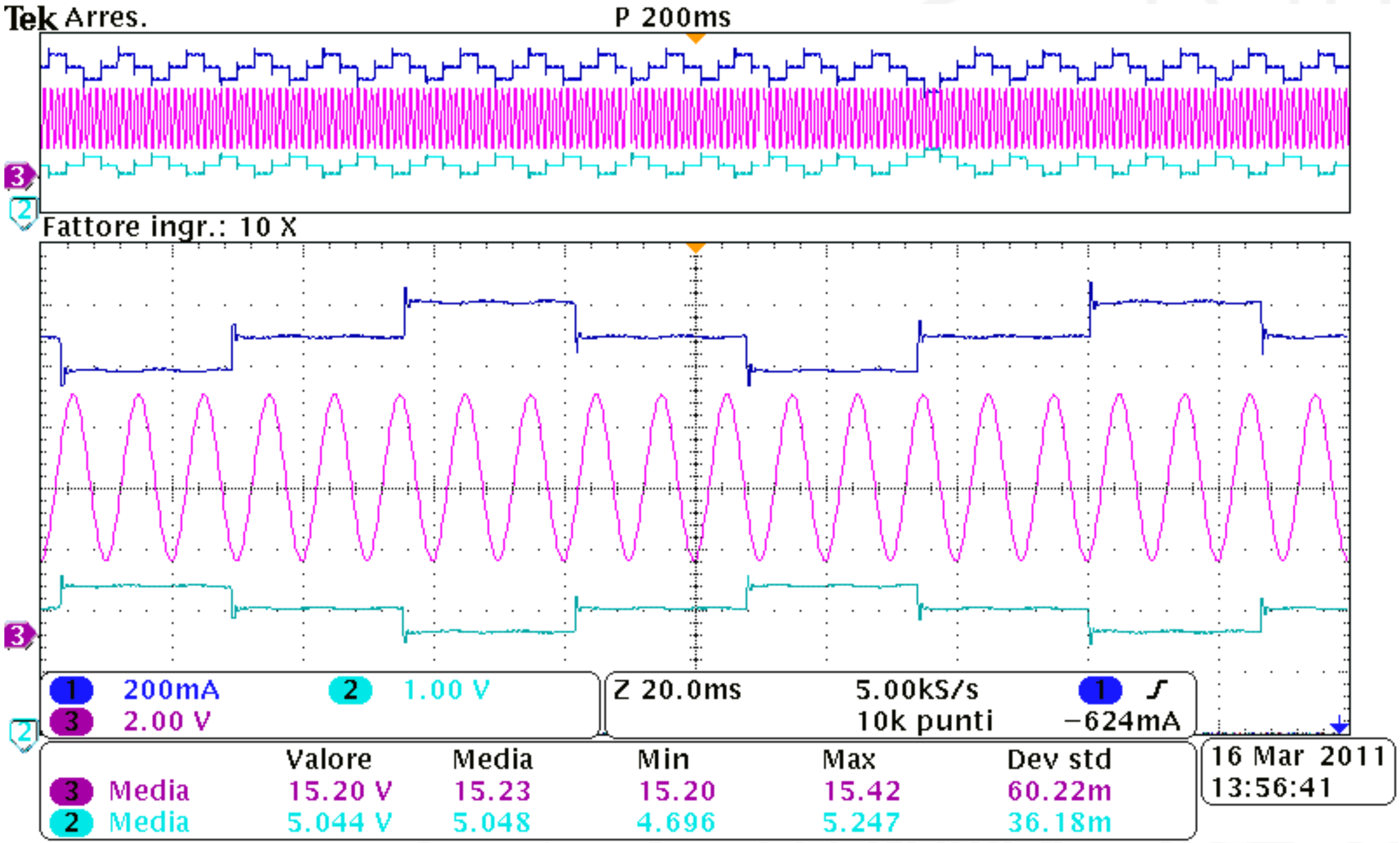
$$\frac{V_{pv}(s)}{I_{vr}(s)} = -\frac{1}{C_{in} \cdot s}$$

$$\frac{d(SURF)}{dt} = 0$$

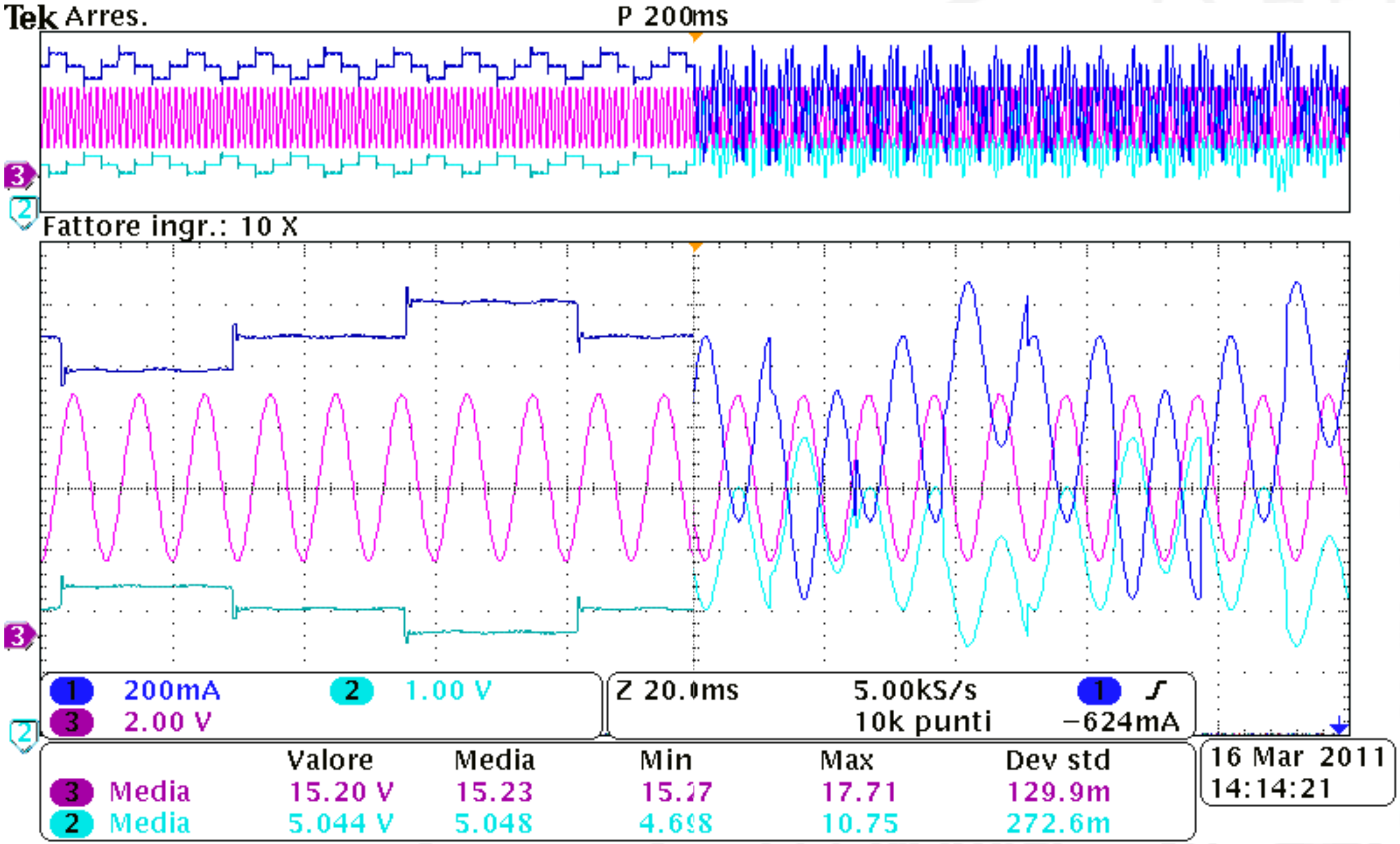
$$\frac{di_{Cin}}{dt} + \frac{di_{vr}}{dt} = \frac{di_{PV}}{dt} - \frac{di_L}{dt} + \frac{di_{vr}}{dt} = 0$$

maximum irradiation variation that can be tracked

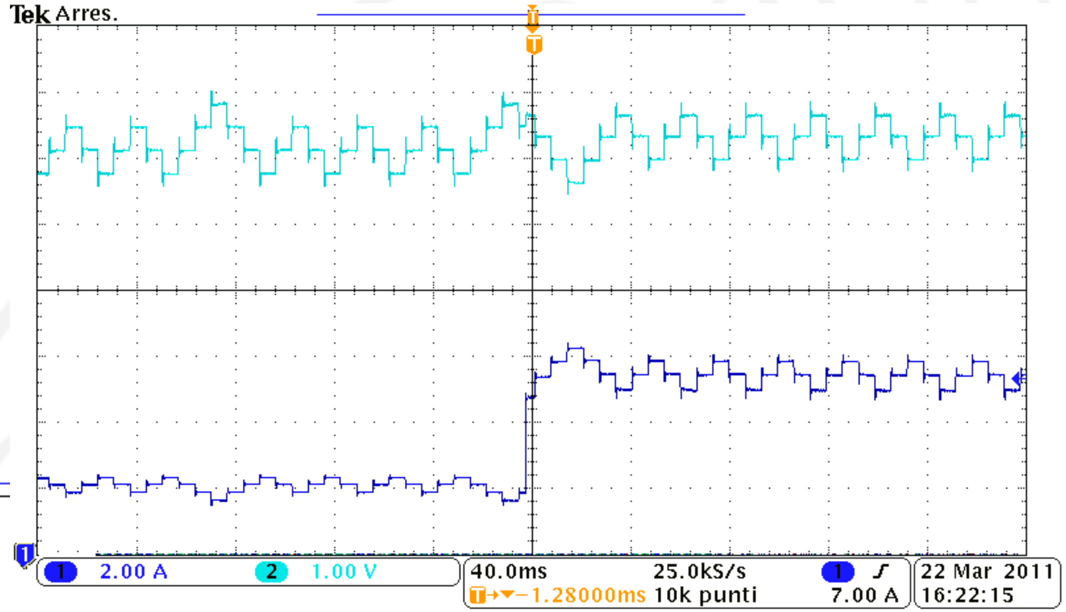
Experimental results: noise effect

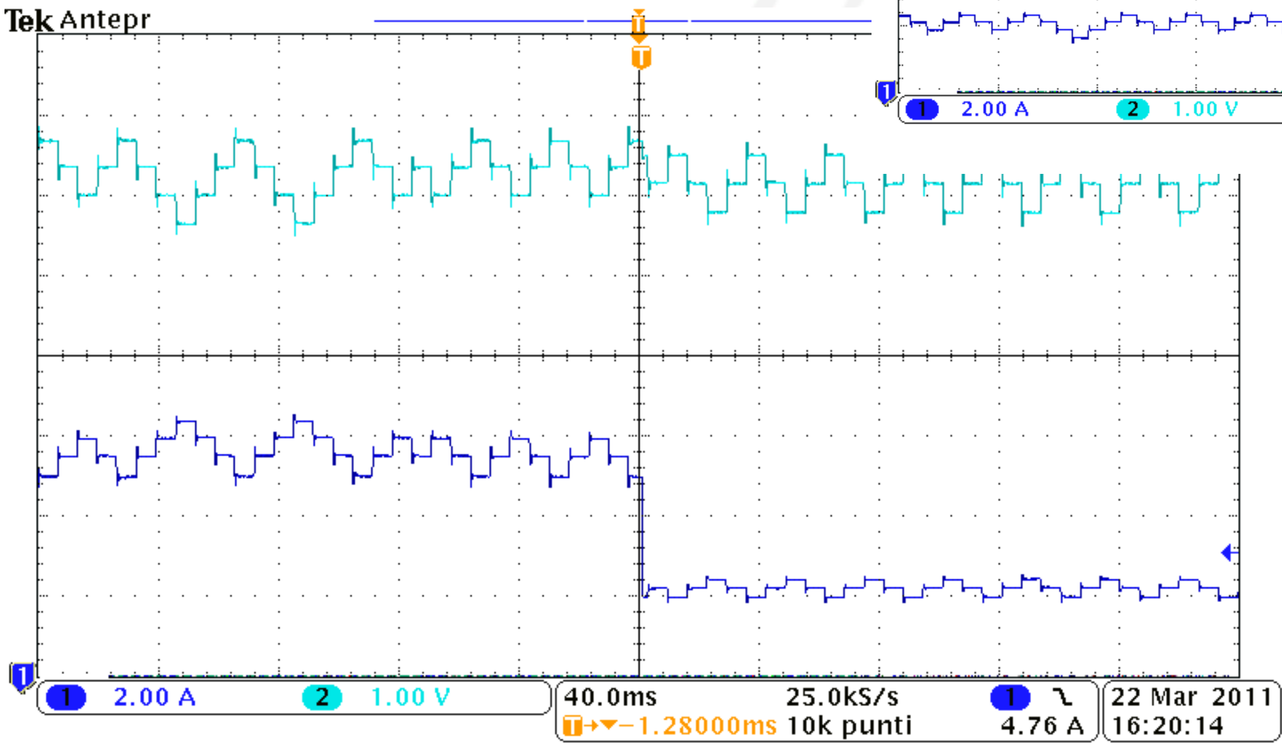


100Hz noise reduction benefit



Fast MPPT


Tek Arres.
2.00 A
1.00 V
40.0ms 25.0kS/s
-1.28000ms 10k punti
7.00 A
22 Mar 2011
16:22:15


Tek Antepr
2.00 A
1.00 V
40.0ms 25.0kS/s
-1.28000ms 10k punti
4.76 A
22 Mar 2011
16:20:14

Thank you for your attention

gspagnuolo@unisa.it