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Journée Ulg - FNRS - GREPES

Solar Array Maximum Power Point Tracking with Two Comparators

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SA MPPT with 2 Comparators

- Problem Statement
- MPPT Algorithm
  - Solar Array Dynamics
  - Control law
  - Convergence property
- Electronics Architecture
- Breadboard Validation
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  - Tracking precision
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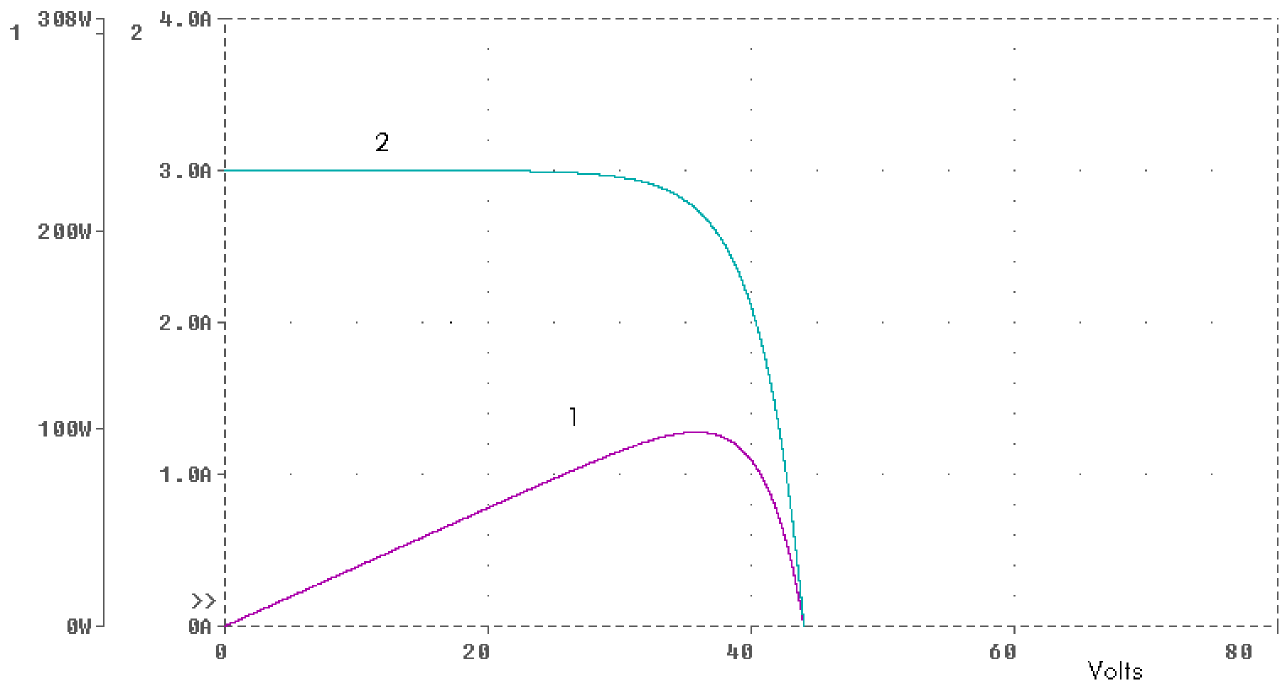
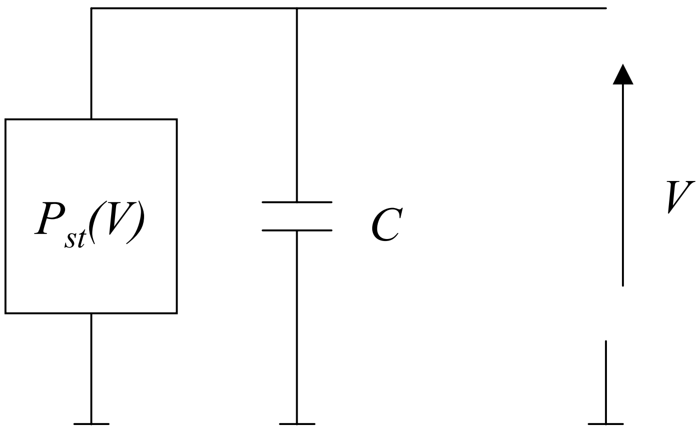
Problem Statement

- To operate the Solar Array at the Maximum Power Point,
- By insertion of a autonomous power switching converter in between the SA section and the voltage bus,
- With truly adaptive control with respect to changing SA MPP current and voltage conditions,
- Based on analogue and time continuous electronics (neither numeric components nor sampling circuits).



MPPT Algorithm (1/3)

- SA dynamics : a static power source and a parallel capacitor



$$P_{out} = P_{st}(V) - CV\frac{dV}{dt}$$

- the voltage collapses if $P_{out} > P_{st}(V)$
- the voltage shoots up if $P_{out} < P_{st}(V)$

MPPT Algorithm (2/3)

- Control law
  - If the voltage collapses too quickly (i.e. above a given threshold), then the output power is ordered to linearly decrease :

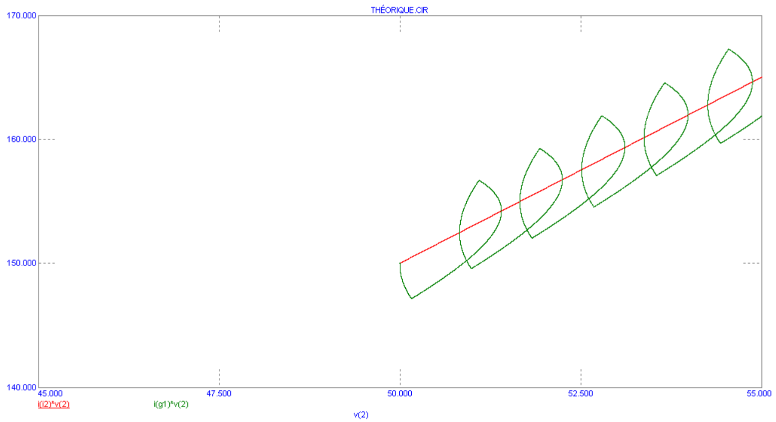
$$\frac{dV}{dt} < \left.\frac{dV}{dt}\right|_r (<0) \Rightarrow \frac{dP_{out}}{dt} = k_f (<0)$$

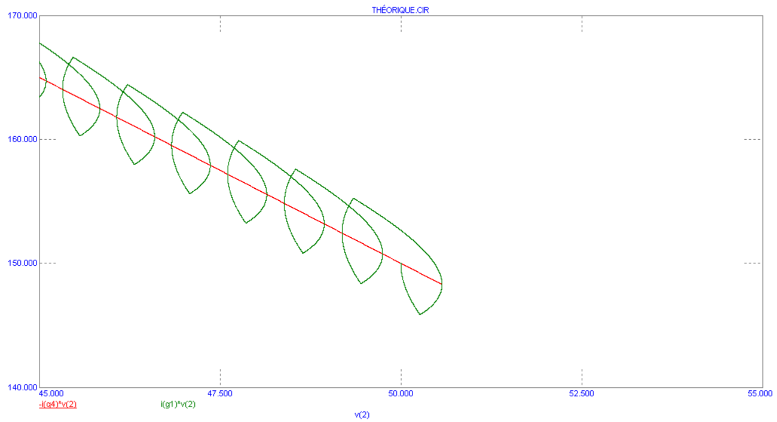
  - If the voltage shoots up too quickly (i.e. above a given threshold), then the output power is ordered to linearly increase

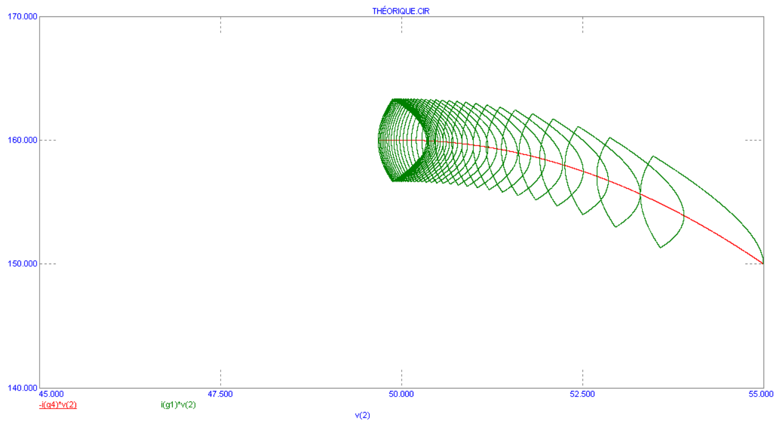
$$\frac{dV}{dt} > \left.\frac{dV}{dt}\right|_f (>0) \Rightarrow \frac{dP_{out}}{dt} = k_r (>0)$$

MPPT Algorithm (3/3)

- Convergence property
  - Conditions : $k_r < -k_f$ & $-\left.\frac{dV}{dt}\right|_r = \left.\frac{dV}{dt}\right|_f$



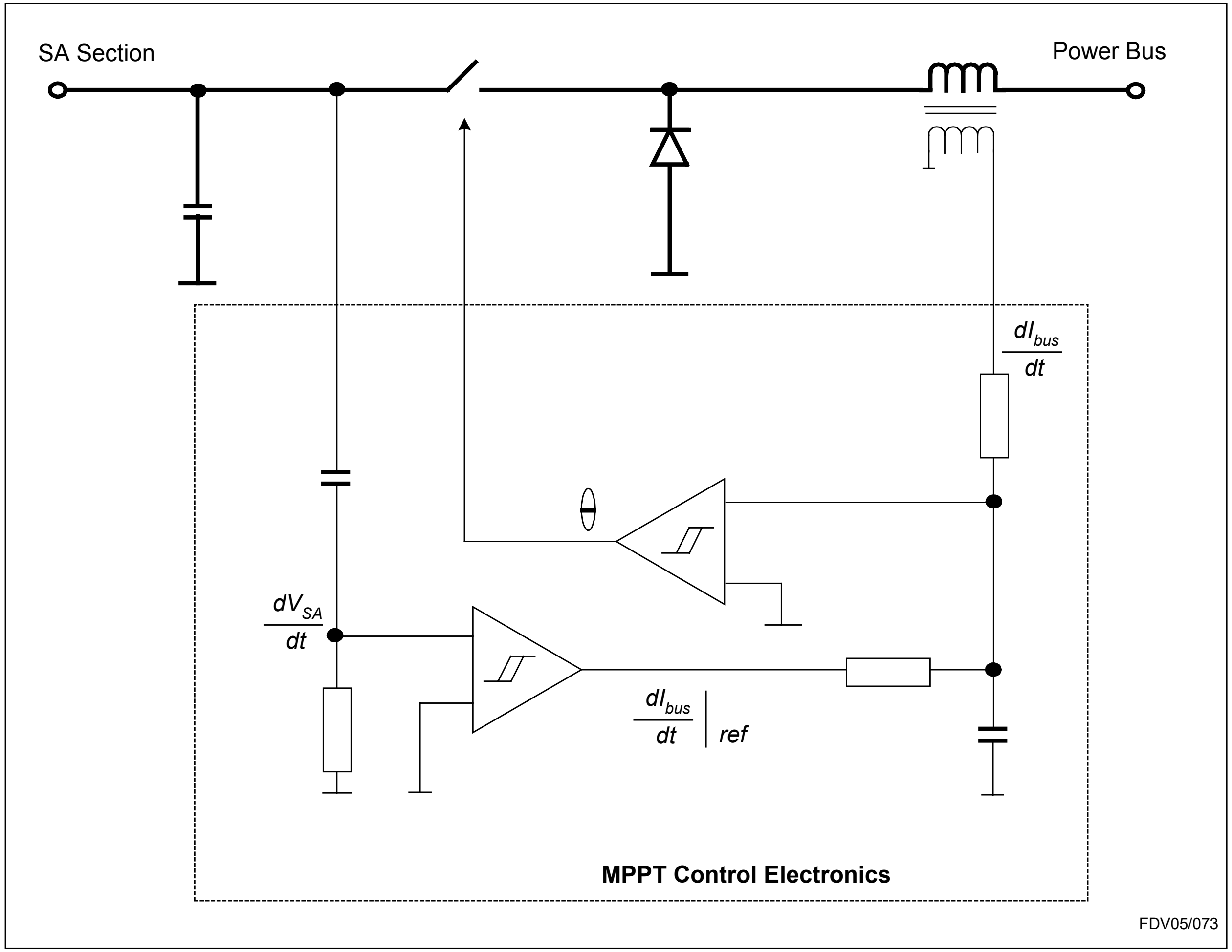




(P_{out}, V) diagrams

Electronics Architecture (1/2)

- MPPT power converter
  - Buck topology
  - Power control by output current control
  - First sliding control loop for current variation control (typ. 100 kHz)
  - Second sliding control loop for voltage time derivative criterion (typ. 1 kHz)

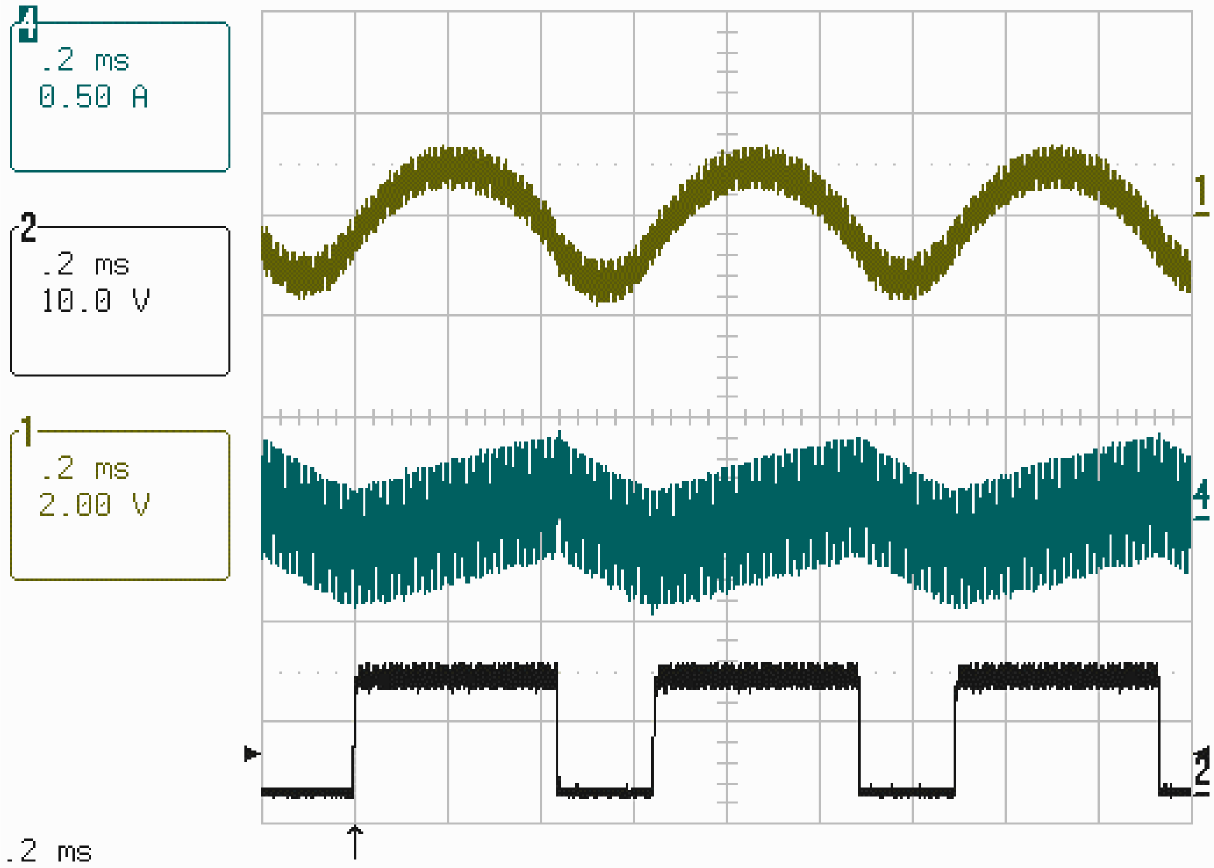


Electronics Architecture (2/2)

- Subsidiary functions
  - Main Error Amplifier control by digital clamping of the power (current) variation reference
  - Provision against ON or OFF switching device lock-up conditions by 0 % or 100 % duty cycle watch dog
  - Output power (current) limitation by current measurement shunt and associated electronics
  - Low level electronics referenced to ground and serially fed by the charges flowing from the FET gate control at SA positive terminal (no auxiliary supply)

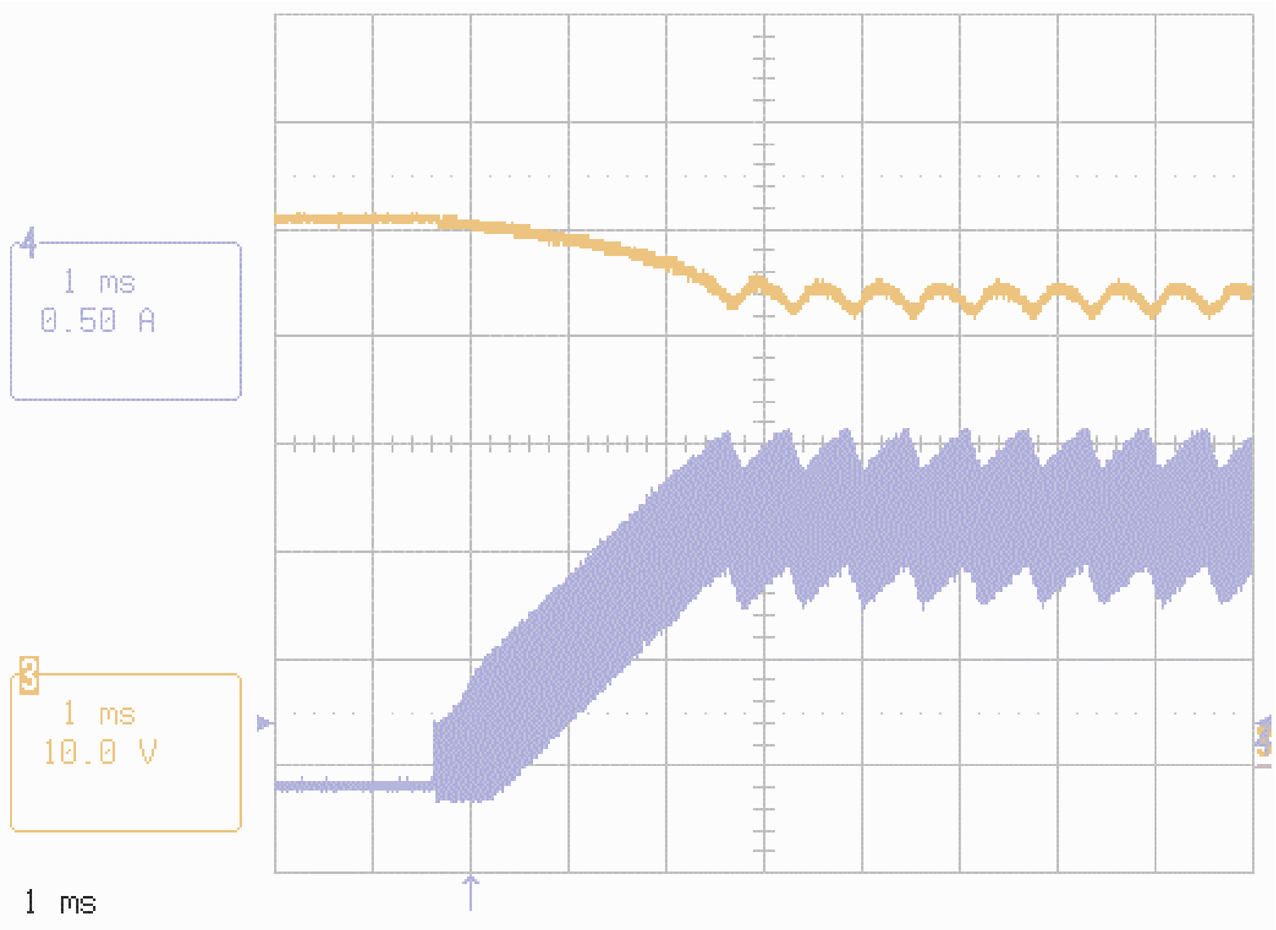
Breadboard Validation (1/3)

- Waveforms (CNES contract - Mars Sample Return Orbiter program)
  - (1) SA voltage
  - (4) Converter output current
  - (2) Power variation reference



Breadboard Validation (2/3)

- (3) SA voltage starting from open circuit condition
- (4) Converter output current starting from zero current



Breadboard Validation (3/3)

- Tracking precision
  - I_{SC} = 1,8 A, V_{OC} = 66,2 V, P_{MPP} = 95,6 W
  - For a 0 V_{pp} bus ripple :

    η_{MPPT} = 99,8 %
  - For a 1 V_{pp} bus ripple :

    η_{MPPT} = 99,5 %
- Low level consumption
  - Low level consumption (referenced to ground) :

    6 mA for a design based on 1 x LM139 IC
  - MOSFET gate control current (referenced to positive SA terminal) :

    6 mA = 60 nCb x 100 kHz for IRF9240 switching PMOS
  - Current consumption on SA section : 6 mA for IRF9240 switching PMOS

Qualification Status and IPR

- Qualification status
  - Alcatel MPPT design has been selected by the SmallSat program
  - SmallSat is a satellite platform dedicated to earth observation missions
  - Customer is the Canadian Space Agency
  - PCDU PFM to be delivered before mid 2006

- Intellectual Property Rights
  - Alcatel MPPT concept is protected by patent applications filed before the EU patent office, the US PTO and the Japanese office

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Conclusion

- A MPPT technique is proposed
  - Based on separate voltage and current processing (no power computation as a result of voltage time current multiplication)
  - Featuring an analogue and time continuous algorithm (no numeric component and no sampling circuits)
  - Driven by the time derivative of the power switching converter input voltage and output current (no current measurement shunt is necessary)
  - Requiring a single quad comparators IC (delivering the right PWM signal to the switching device)
- Serial supply from the SA is possible (no auxiliary supply)
- Quad configuration architecture is possible (reliable design)
- Making it a right candidate for segregated and fully autonomous SA MPPT control (LEO, GEO or deep space missions)