NA4.2 – Overview of methods for Maximum Power Point Tracking in PVs

Evangelos Rikos

Centre for Renewable Energy Sources and Saving

Dept. of Photovoltaics and Distributed Generation

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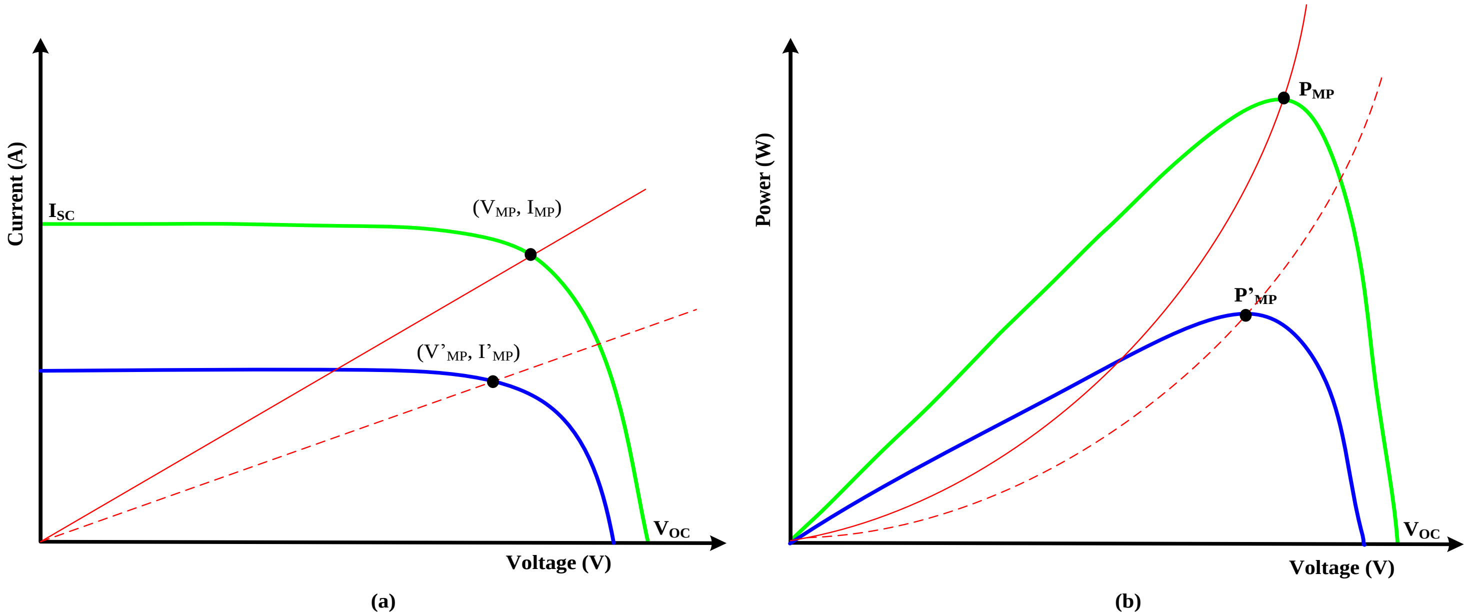
Why is it important to find the MPP?

I-V (a) and P-V (b) characteristics of a PV system



The above diagrams depict a qualitative behaviour of the PV current and power as a function of the DC voltage, for two different irradiation levels. In conjunction, different load curves (red lines) are depicted

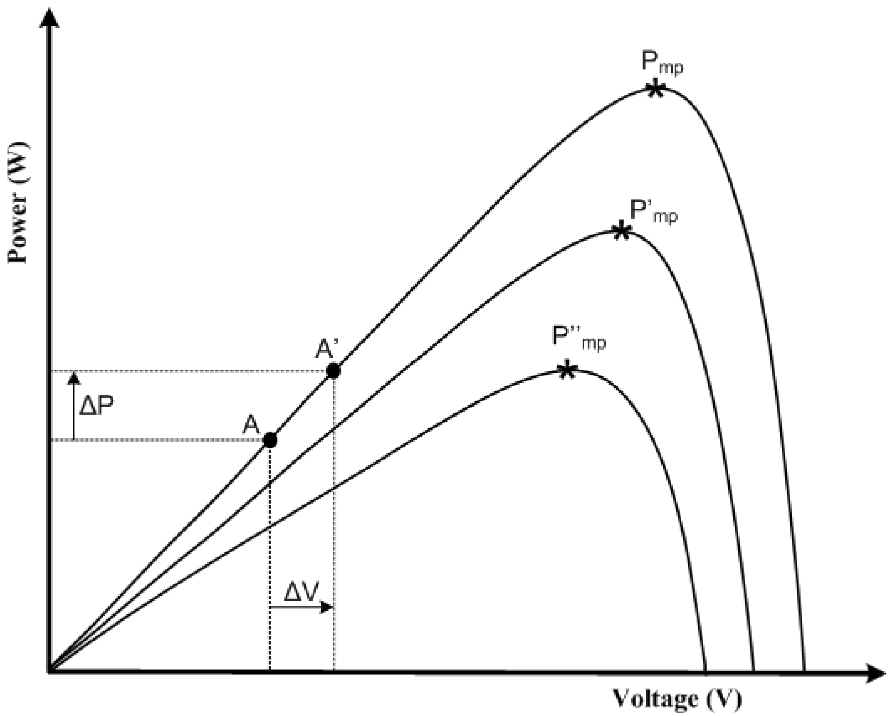
Methods of MPPT

- Symmetric PV modules' operation (i.e. same I-V characteristic):
  - Perturb & Observe, P&O
  - Constant voltage and current
  - Pilot Cell
  - Incremental conductance
  - Parasitic capacitance

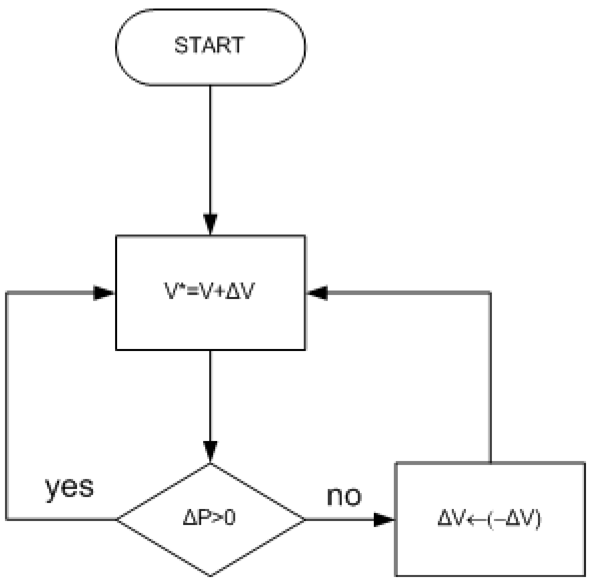
- Asymmetrical operation (i.e. partial shading)
  - Use of more sophisticated techniques based on mathematical algorithms

Method “Perturb and Observe-P&O”

Operation principle



P&O method’s flowchart



Method P&O (cont'd)

Advantages:

- Easy to implement $\Rightarrow$ most commonly used MPPT method

Disadvantages:

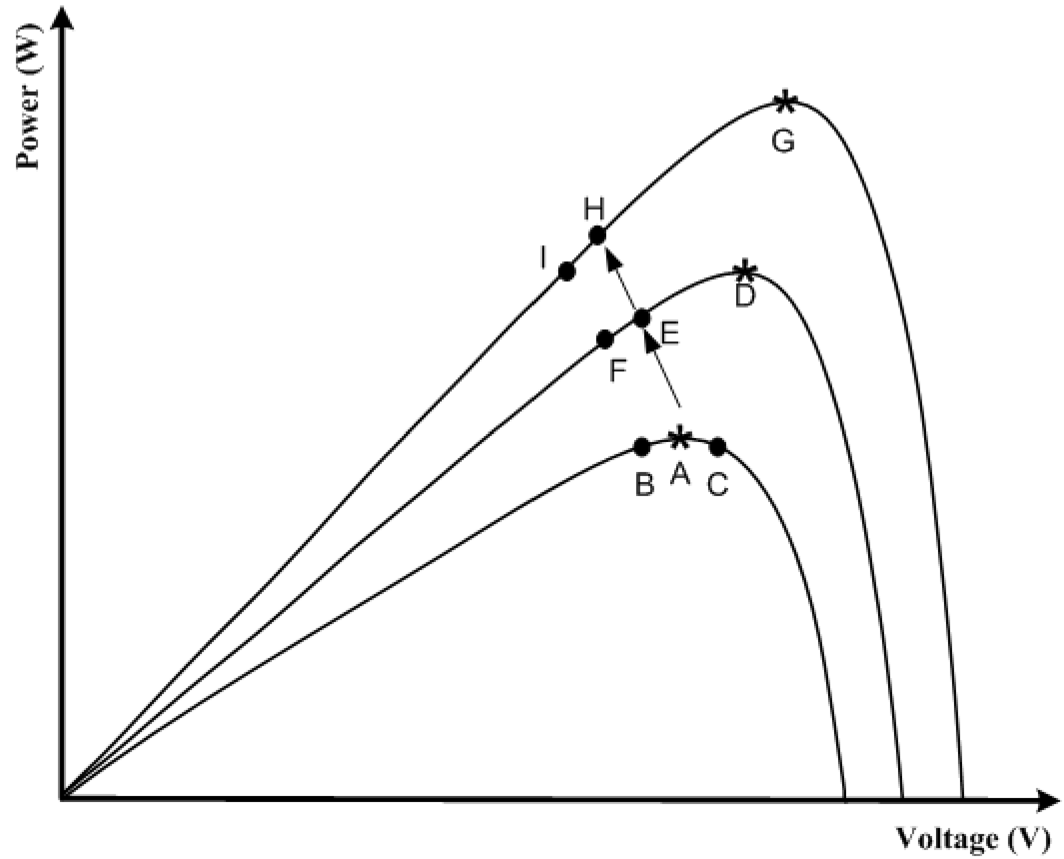
- Difficult or even impossible to track the MPP for reduced irradiance due to the almost flattened P-V curve
- Incapability of stabilising the operating point and appearance of some oscillations around the MPP
- Abnormal behaviour in very fast transients of the solar irradiance due to e.g. scattered clouds

Method P&O (cont'd)

Problem of fast changing solar irradiance

When the P-V curve changes rapidly, the MPPT algorithm misinterprets points E and H as MPPs because they are higher than A.

The inaccuracy is corrected when the curve is stabilised for enough time to allow the system to detect the true MPP, namely D or G

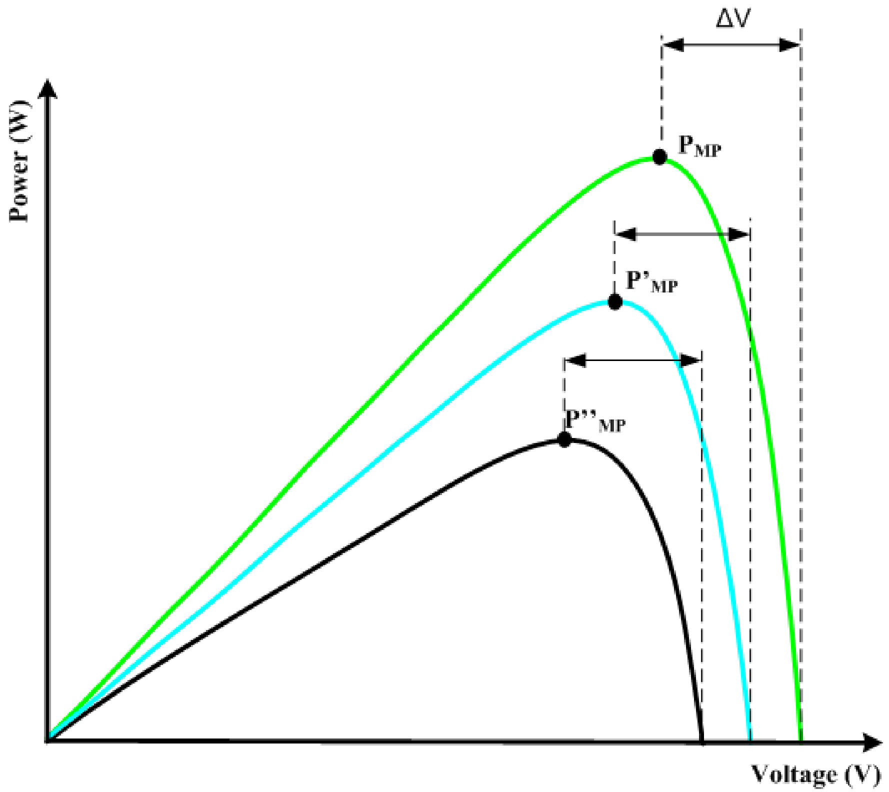


Improvements in the P&O technique

- Using a stand-by function: when the voltage deviation sign changes many times in a row, the controller assumes that the MPP has been reached and it temporarily stops perturbations. This reduces the oscillations around the MPP. However, the transient response of this variant worsens

- Measurement of power for a point P_1, V_1. Change to voltage V_2 measurement of P_2 . Restoration of voltage back to V_1 and measurement of P'_1. By comparing the power P'_1 to P_1 it can be inferred if there is an irradiance variation. The disadvantage is that the algorithm becomes slower

Method of constant current/voltage



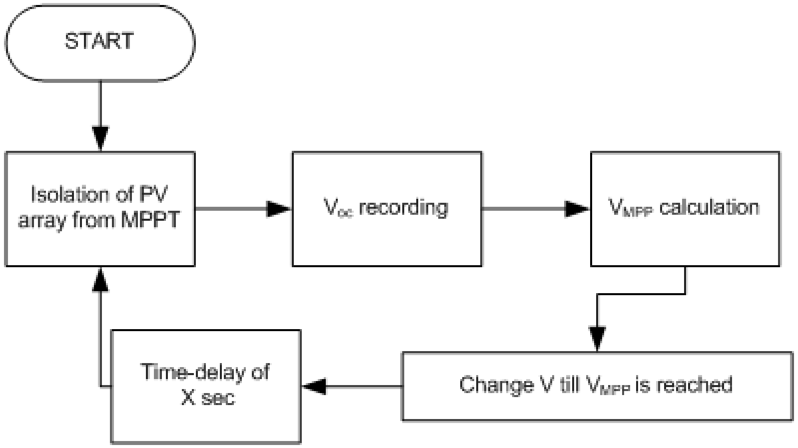
In practice the ratio of V_{mpp} over V_{oc} is almost constant or it follows a very predictable profile

$$\frac{V_{MPP}}{V_{OC}} \cong K < 1$$

K ranges between 0.7 and 0.8

Method of constant voltage

flowchart



Advantages-disadvantages

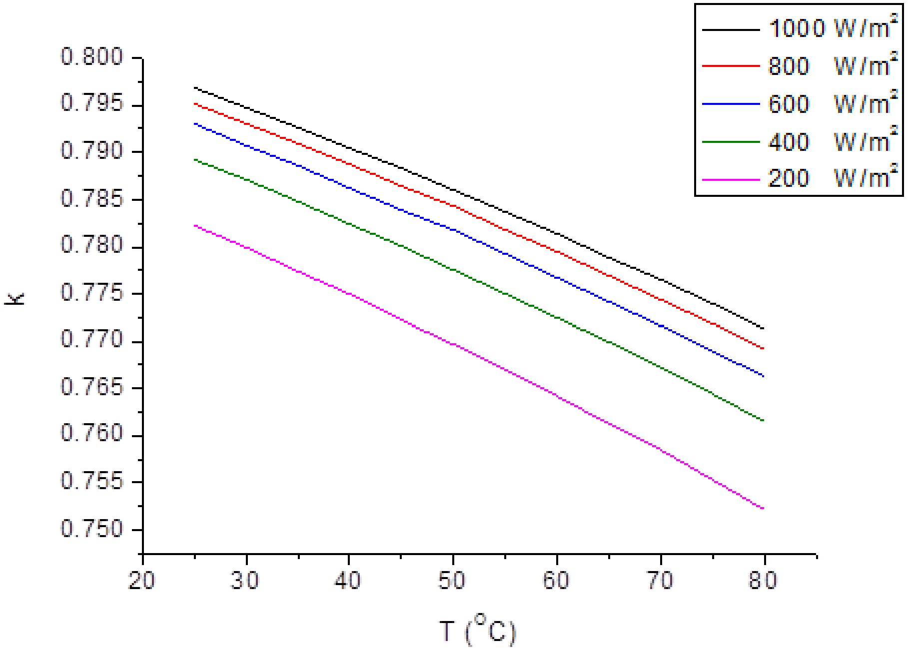
- 👍 Implementation simplicity
- 👎 Not easy to estimate the optimum K ratio

Variation of K with temperature and irradiance

PV module data

Manufacturer	Sharp
Model	NUS5E3E /NU185E1-185 W
Type	Mono-crystaline silicon
V_{mp}, V_{oc}	24.0 και 30.4V
I_{mp}, I_{sc}	7.76 και 8.54A

Diagram of k



Variant of constant voltage's technique

Constant current method:

- It calculates I_{mp} from the short-circuit current I_{sc}
- It uses a parallel switch to temporarily short circuit the panel in order to measure I_{sc}
- It is less advantageous compared to the constant voltage method because it is nearly impossible to obtain a perfect short-circuit due to resistances in cables, switch etc.

Use of reference cell

- Variation of the constant current/voltage method
- It makes use of a small reference cell for the calculation of the I_{mp} or V_{oc} value.
- Advantage: Reduction of energy loss in the main PV due to disconnection or short circuit actions
- Estimation of an accurate k value is still a problem
- The reference cell must have the exact same characteristics with the main PV
- Calibration of the reference cell increases the cost of the system

Method of incremental conductance (INC)

Operating principle:

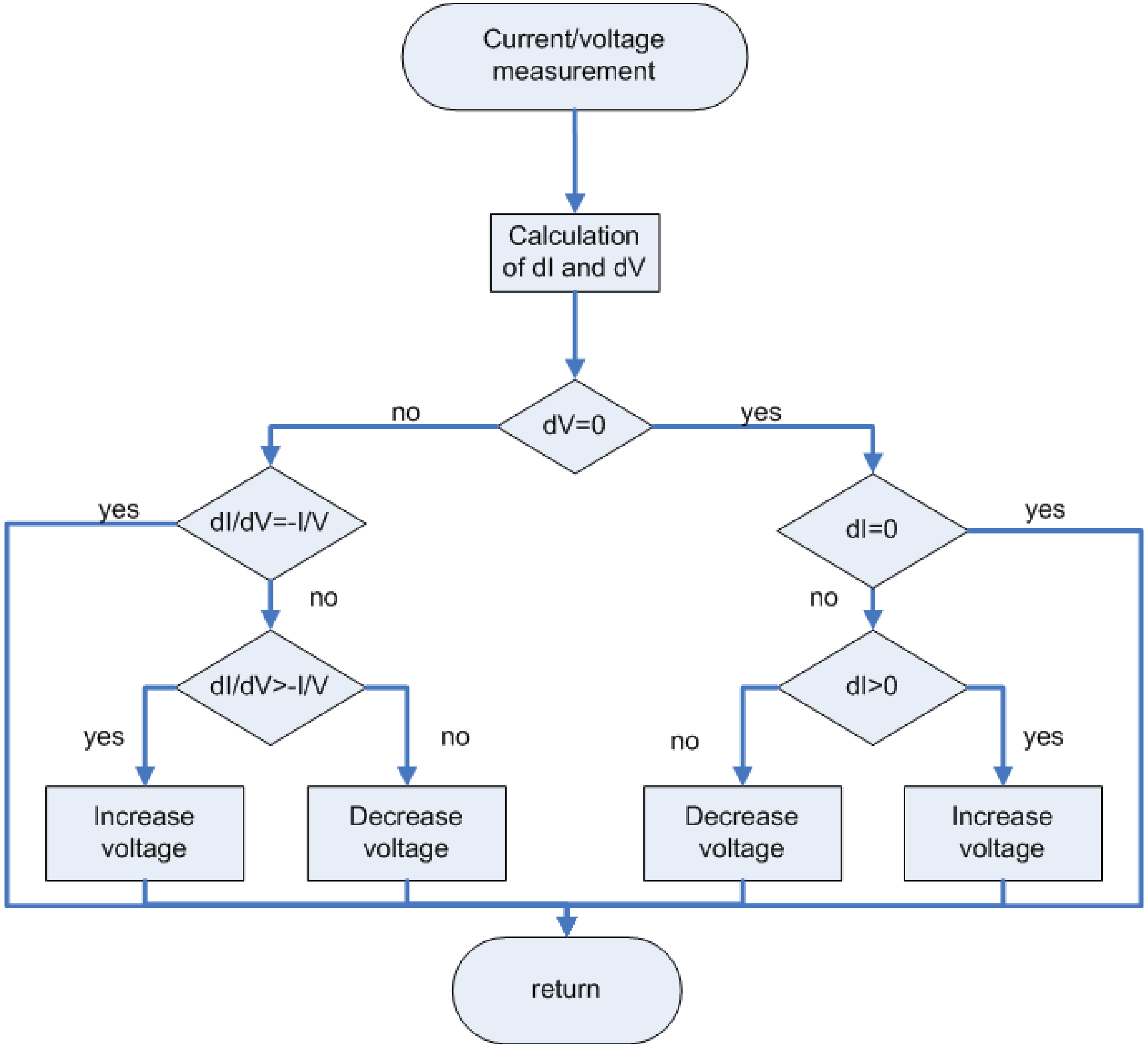
Calculation of power derivative as a function of voltage

$$\frac{dP}{dV} = 0 \Rightarrow -\frac{I}{V} = \frac{dI}{dV}$$

This is interpreted as follows:

Left of MPP	MPP	Right of MPP
$\frac{dI}{dV} > -\frac{I}{V}; \left(\frac{dP}{dV} > 0\right)$	$\frac{dI}{dV} = -\frac{I}{V}; \left(\frac{dP}{dV} = 0\right)$	$\frac{dI}{dV} < -\frac{I}{V}; \left(\frac{dP}{dV} < 0\right)$

INC flowchart



Comparison of INC with P&O

- INC is capable of detecting the direction of a disturbance. Hence, the method is more stable when solar irradiance varies rapidly.

- In addition, once it tracks the MPP it does not oscillate around it

Method of parasitic capacitance

- Variation of the INC method
- It takes into account the cell's parasitic capacitance
- Mathematical model:

$$I = I_L - I_O \left[\exp\left(\frac{V_P + R_S I}{a} \right) - 1 \right] + C_p \frac{dv_p}{dt}$$

$$\frac{dF(v_p)}{dv_p} + C_p \left(\frac{\dot{V}}{V} + \frac{\ddot{V}}{\dot{V}} \right) + \frac{F(v_p)}{v_p} = 0$$

Differential conductance

Method of parasitic capacitance (cont'd)

Calculation of differential conductance:

$$g_P = \frac{P_{GP}}{V_o^2} = \frac{\frac{1}{2}\sum_{n=1}^{\infty}\left[a_n^i \cdot a_n^\upsilon + b_n^i \cdot b_n^\upsilon\right]}{\frac{1}{2}\sum_{n=1}^{\infty}\left[\left(a_n^\upsilon\right)^2 + \left(b_n^\upsilon\right)^2\right]}$$

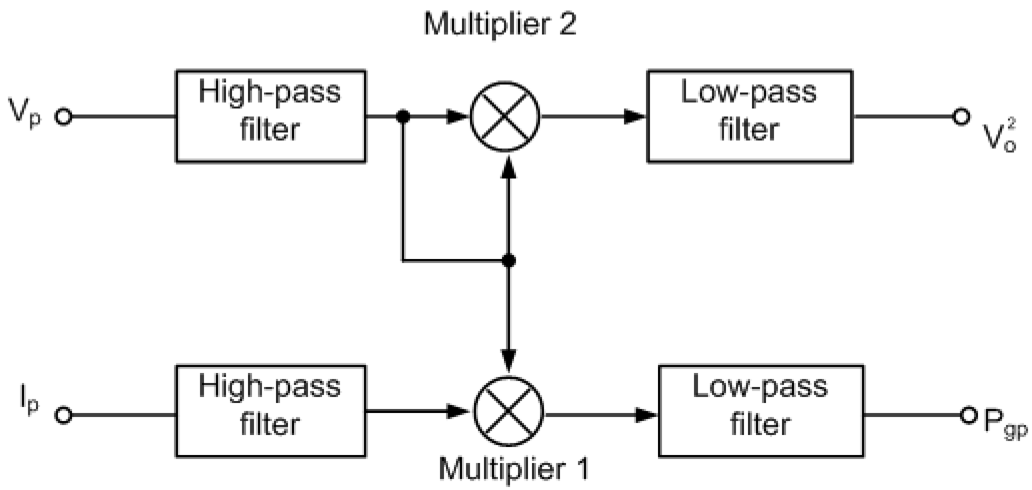
where: P_{GP} is the average ripple power

V_o is the amplitude of the ripple voltage

α_n^i, α_n^υ, b_n^i, b_n^υ Fourier coefficient for voltage and current

Method of parasitic capacitance (cont'd)

Block diagram for the implementation of the parasitic capacitance method:

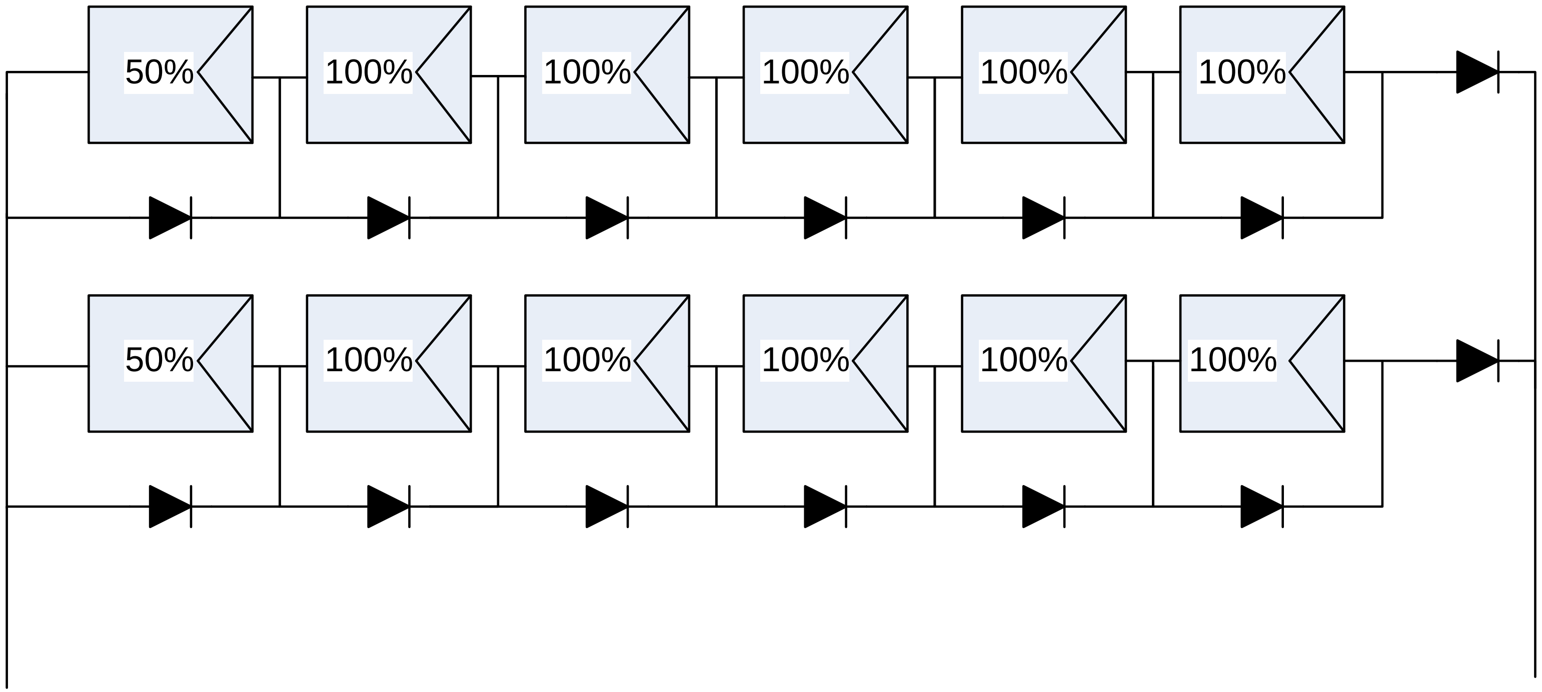


Algorithms based on the PV model

- Use of the current equation for a PV is more accurate
- Direct calculation of the MPP
- Comprehensive knowledge of the model's parameters is required
- Irradiance and temperature measurement
- Uncertainties in the parameters values and measured signals
- Large divergence in the parameters' values even for PV modules of the same type
- Increases the cost because of the sensors

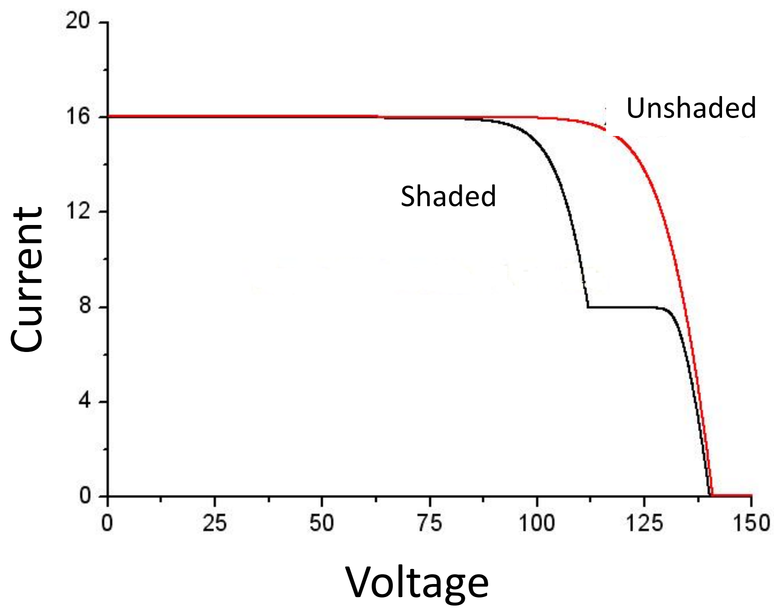
Asymmetrical operation-Partial shading

The system below consists of two parallel strings. Two of the modules (one in each string) are partially shaded to 50% of the maximum irradiance

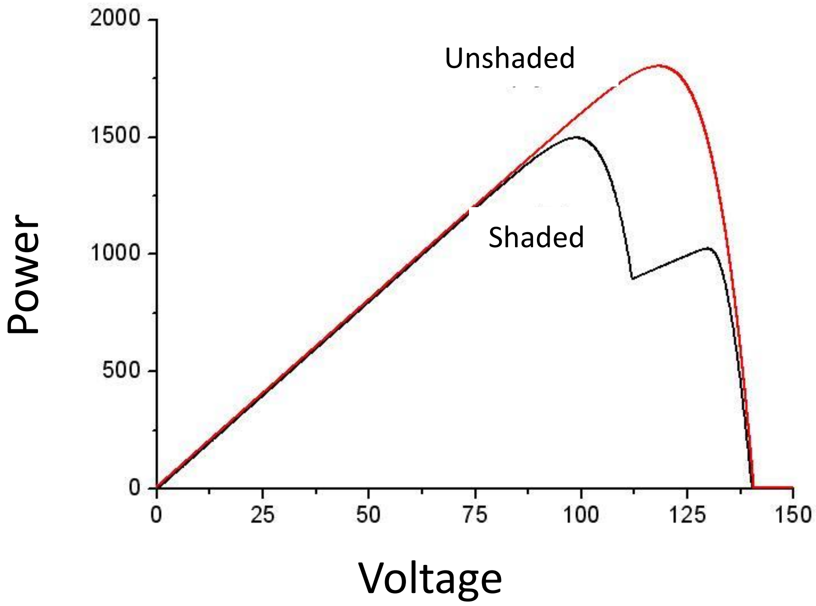


Asymmetrical operation-Partial shading (cont'd)

I-V characteristic

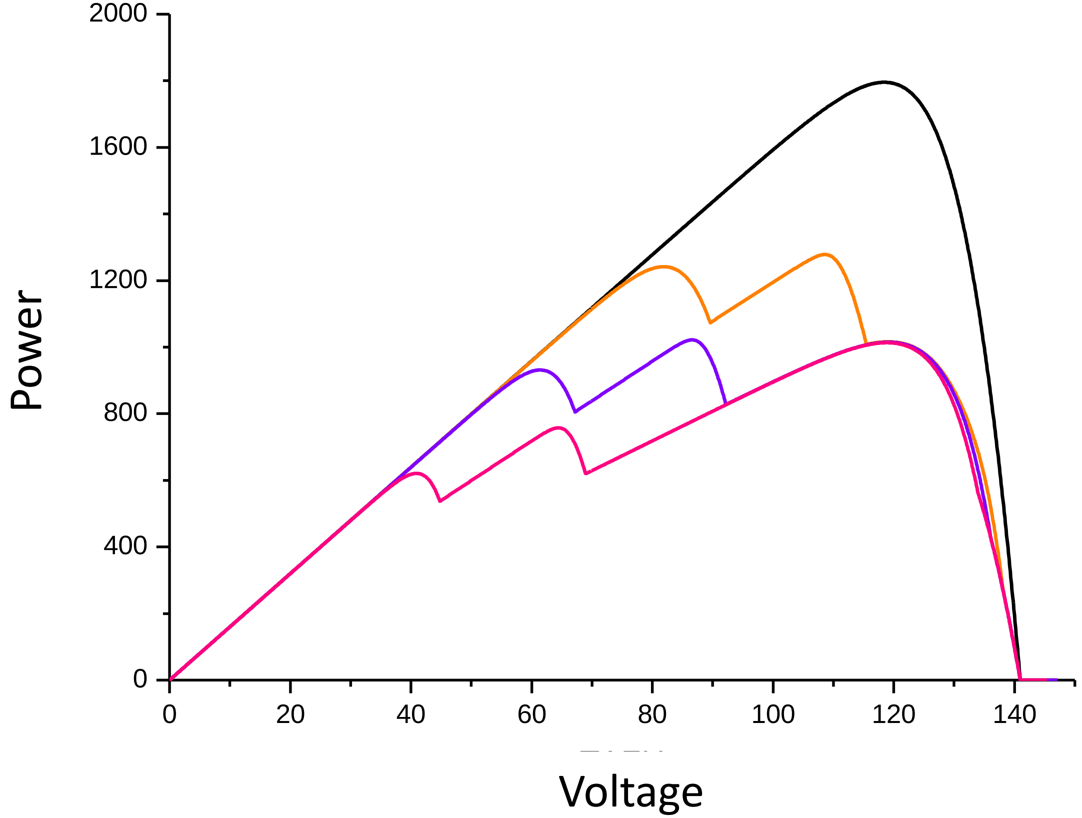


P-V characteristic



Asymmetrical operation-Partial shading (cont'd)

P-V characteristic for multiple shaded modules



Problems with using conventional MPPTs under partial shading

- Inability to detect global MPP
- The system stabilises at local MPPs
- Use of sophisticate mathematical algorithms to track the global MPP
- Drawback: Implementation complexity and power variation in a wide range → better for small systems

References

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