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Design and simulation of shortcut current MPPTracking technique to control boost converter

Hassiba Serghine [*], Rachid Chenni [†] and Khalil Nebti

Laboratoire d'Electronique, Université des Frères Mentouri
Constantine 1, B.P. 325 Route de Ain El Bey, 25000 Constantine, Algérie

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Abstract - *This paper presents the control of boost converter using MPPT techniques in photovoltaic system. The short circuit current technique is characterized by its simplicity and easily realized. The technique is based on the measure of the short circuit current of panel considered as a reference, and the comparison with the real current is helpful to create the control pulse of the DC/DC converter. We realize the Boost converter using IGBT 'IRGPC60' transistor protected by RCD (Resistance, Capacitor and Diode) circuit. The galvanic isolation is achieved by photo coupler CNY18. Experimental results are measured using Dspace interface board to verify the validity of the presented technique.*

Résumé - *Cet article présente le contrôle du convertisseur boost en utilisant les techniques MPPT dans un système photovoltaïque. La technique du courant de court-circuit se caractérise par sa simplicité et sa réalisation aisée. La technique est basée sur la mesure du courant de court-circuit considéré comme référence, et la comparaison avec le courant réel est utile pour créer l'impulsion de commande du convertisseur DC / DC. Nous réalisons le convertisseur Boost en utilisant le transistor IGBT 'IRGPC60K' protégé par le circuit RCD (Résistance, Condensateur et Diode). L'isolation galvanique est réalisée par photo coupleur CNY18. Les résultats expérimentaux sont mesurés en utilisant la carte d'interface Dspace pour vérifier la validité de la technique présentée.*

Keywords*:* Short circuit current - MPPT - Boost converter - PV system - Dspace interface.

1. INTRODUCTION

The demand for electric energy has been increasing in last years as well as the constraints linked to its production, such as the effect of pollution and global reheating, lead research towards the development of renewable energy source [6]. Among these photovoltaic energy which is currently a strong development in the word.

This development is boosted by international and national policies aimed at reducing the use of fossil energy. The maximum output power of PV module depends on temperature, solar insolation and load, so it is necessary to track MPP of PV array all the time for deferent's techniques.

The most used techniques disturb and observe (P&O) method, in the first case; this means that the reference changes in the positive direction, and the continuous step of voltage to be added to the reference with the same sign.

In the second, the algorithm evolves in the negative direction, and the step is changed sign to regain increasing power.

This method used widely due to its simplicity and efficiency, however there is serious power oscillation around MPP which decreases the efficiency of PV system [8]. To reduce the power oscillation, perturbation step should be adjusted according to work point of PV module [9].

[*] Hassiba-serghine@outlook.com - idor2003@yahoo.fr
[†] rachidchenni@yahoo.fr

This last has been largely used because it is easy to implement, it is based on the perturbation incrementing or decrementing the voltage V_{ref}, or the current I_{ref} with observing the result of this disturbance on the measured power.

The second algorithm is the "Hill-Climbing". According to the same principle, it is this time directly the cyclic ratio of the chopper controlling the panels is incremented or decremented.

After a reminder about the different methods used to find the maximum power point of a photovoltaic generator, we will present the objective of this work.

This work consists of the verification by simulation of short circuit current fraction control technique (FSCC) and also validates this algorithm by experimental result.

The design of any PV system depends mainly on specific parameters such as solar irradiance, number of sunshine hours and the temperature variation [1]

2. MODELING OF PV SYSTEM

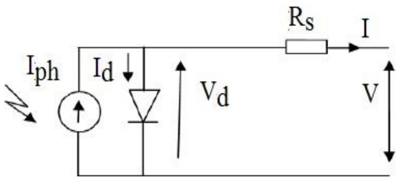


Fig. 1: Equivalent circuit of PV solar cell

The voltage is susceptible to change depending on the temperature. Reheating of the module shows a decrease in voltage. This is why it's important to ventilate the modules so that they do not lose too much voltage.

When the variation of the voltage is due to the temperature is unavoidable, so the number of panels in series can be changed in order to compensate voltage drop.

According to the law of Kirchhoff:

$$I = I_{ph} - I_d \tag{1}$$

I, is the harvested current of the cell. I_{ph}, is the solar-generated current.

The harvested current I_{ph}, depends on the solar irradiance linearly and it is given by [4].

$$I_{ph} = I_{ph}(T_1) \times (1 + K_0 \times (T - T_1)) \tag{2}$$

$$I_{ph}(T_1) = I_{cc}(T_1) \times (G / G_0) \tag{3}$$

$$K_0 = \left(I_{cc}(T_2) - I_{cc}(T_1)\right) / \left(T_2 - T_1\right) \tag{4}$$

K_0, is the short circuit current / temperature coefficient. T, is the temperature of the cell. T_1, the temperature of the cell and the nominal cell temperature (T_1 = 25°C = 298 K). G_0, the reference irradiance (G_n = 1000 W/m^2). I_{cc}, short circuit current {the current that circulate through the junction under illumination when the cell is in short-circuit).

From the equation (2) the PV junction current intensity changes according to the illumination. The more light is strong, the intensity is higher. Indeed, it is the photons of light that transmit their energy to the electrons and release them during the day. At noon, when the irradiance is at maximum, the production of cells increases to the maximum. The ideal conditions for the operation of a cell are the maximum irradiation at a minimum temperature.

I_d, Current crossing to the diode, it's given by:

$$I_d = I_s\left(e^{(V_d / V_T)} - 1\right) \tag{5}$$

V_T, Thermodynamic voltage defined by:

$$V_T = n \times K \times T / q \tag{6}$$

n, is the ideality factor of the diode. K, is the Boltzmann constant. V_d, Voltage across the diode.

$$V_d = V + R_s \times I \tag{7}$$

V, is the harvested voltage of the cell. R_s, is the series resistance.

$$R_s = -\left(dV / dI_{V_{oc}}\right) - \left(1 / X_V\right) \tag{8}$$

$$X_v = \left(I_s(T_1) / V_T(T_1)\right) \times \left(e^{\left(V_{oc}(T_1) / V_T(T_1)\right)}\right) \tag{9}$$

V_{oc}, The open circuit voltage {measured voltage when current don't circulate in the photovoltaic device}. I_s, is the saturation current of the diode and it is defined by:

$$I_s = \left[I_s(T_1) \times (T / T_1)^{3/n}\right] e^{(-q \times V_g / n \times k)(1/T - 1/T_1)} \tag{10}$$

$$I_s(T_1) = I_{cc}(T_1) \ / \left(e^{\left(V_{oc}(T_1) / V_T(T_1)\right)} - 1\right) \tag{11}$$

The harvested current from the cell is given by [3]

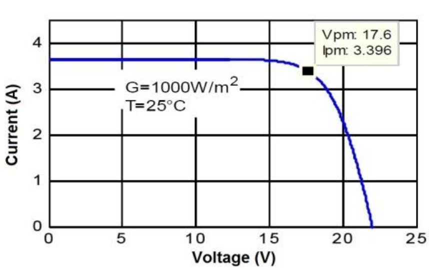
$$I = I_{ph} - I_s\left(e^{(-q \times V_g / n \times k)} - 1\right) \tag{12}$$

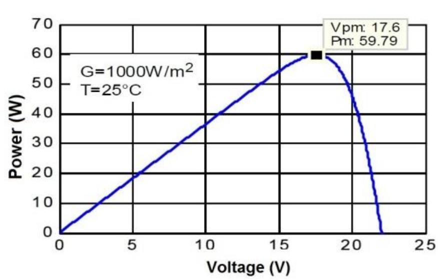
2.1 PV panel validation

We chose the photovoltaic model TE 600, which contains 36 series cells $(n\_s = 36)$.

Table 1: Electrical specification of the solar module

Maximum power, P_m	60 W
Voltage at maximum power, V_{mp}	17.6 V
Current at maximum power, I_{mp}	3.47 A
Short circuit current, I_{cc}	3.65 A
Open circuit voltage, V_{oc}	22.0 V
Temperature coefficient, K_0	0.065±0.015)%/°C





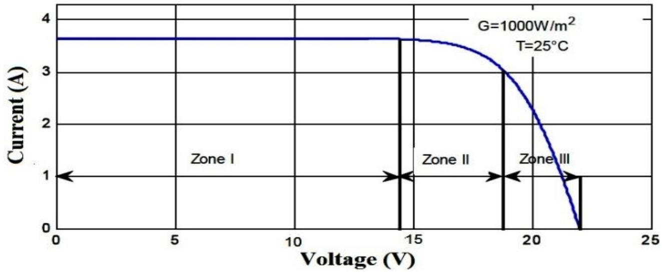


Fig. 2: MPP determination

- Zone (I): the current remains constant whatever the voltage, in this area, the photovoltaic generator functions as a current generator.
- Zone (II): corresponding of the curve of the characteristic, the intermediate region between the two zones (I and III), represents the preferred region for the operation of the generator, where the optimal point (characterized by maximum power) can be determined.
- Zone (III): which is characterized by a current variation corresponding to a nearly constant voltage, in this case the generator is comparable to a voltage generator.

2.2 Temperature influent

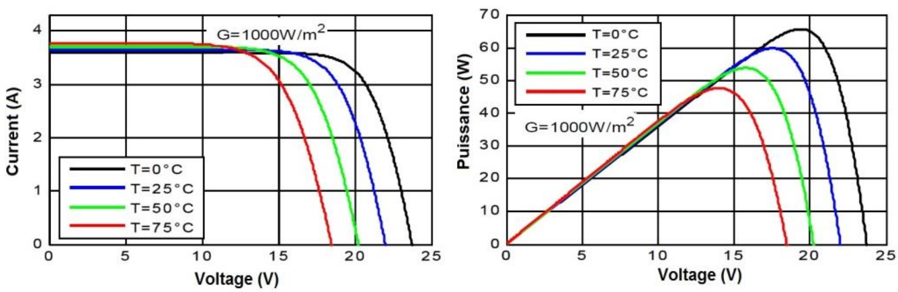


Fig. 3: Temperature influence on PV panel

Decreasing the temperature causes the decrease of the series resistance, which reduce the voltage drop and increase the current.

2.3 Irradiation influent

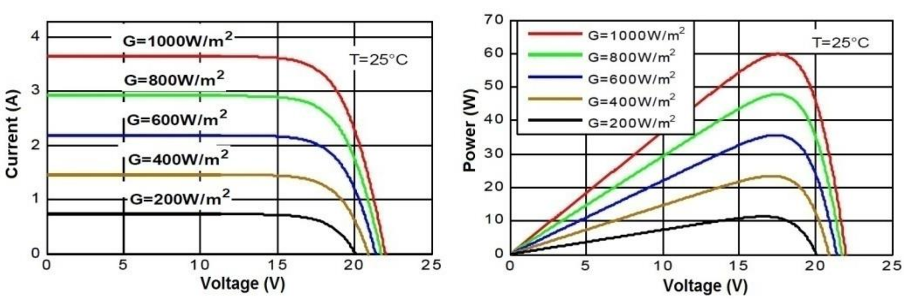


Fig. 4: Irradiation influence on PV panel

The current is directly proportional to the irradiation at these levels of illumination {Eq. (3)}, which justifies the increase of the current when the illumination increase.

2.4 Panel association

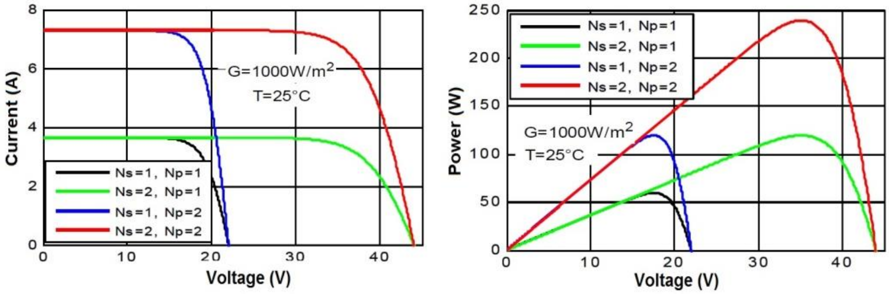


Fig. 5: Series and parallel association PV panel

To obtain an increase of the generator voltage, we associate $'N_s'$ modules in series and to increase the current we associate $'N_p'$ modules in parallel as shown in figure 5.

3. THE DC-DC CONVERTER

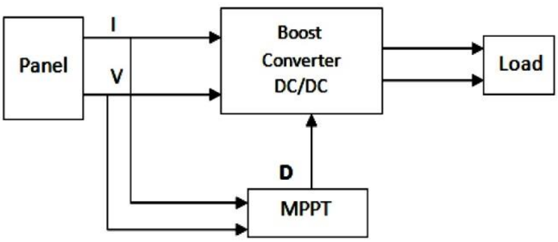


Fig. 6: Photovoltaic conversion elementary chain

Choppers are DC-DC converters for generating a variable DC voltage source from a fixed DC voltage source. We can model the boost converter with ordinary differential equations [5, 7]:

$$C.dV_c / dt = (1-k).I_L V_c / R - I_{co} \tag{13}$$

$$L.dV_L / dt = E - (1-k).V_c \tag{14}$$

$$V_s = R.I \tag{15}$$

L and C are electrical parameters of boost converter. V_c, Voltage of capacity C. K, State of the interceptor (IGBT: 1 ou 0). I_{co}, Initial capacitor current. I_L, the current across the inductor. E, Input voltage. V_s, Output voltage {all these devices in the ideal case cannot consume power, this is the reason of very good efficiency of converters}.

The average output voltage V_s is described by this equation:

$$V_s = V_{pv} / (1-\alpha) \tag{16}$$

Where V_{dc} and V_{pv} are the output and input voltage of the converter and α is the duty cycle of the switch T.

3.1 Realization of boost converter

The power circuit contains:

a) An electronic switch IGBT 'IRGPC60K";

b) By pass diode (D) 'BYW29';

c) An R C D circuit: Resistance, Capacitor and Diode { R_1 = 100 W, C = 0.1 mF, D (IN 54018)} is used as a protection of the main switch (IGBT).

d) Storage Indicator (L).

e) Filter capacitor (C).

The control circuit:

a) DSPACE interface: gives the control pulse of the IGBT (MLI) from MPPT program in Matlab software. The maximum output voltage of the DSPACE is 5 V.

b) NPN transistor 2N2222: it is used to increase the amplitude of the pulse coming from the dSPACE interface from 5 V to 15 V {voltage needed by the IGBT switch in order to commutate}.

c) An photo coupler HCPL-3100: it provides perfect galvanic isolation between input and output using a quick LED, a photodiode, an amplifier and 2 transistors.

d) A Driver IR2112: it provides sufficient pulse amplitude to control the gate of IGBT.

e) Alimentation supply cards: to alimented the components by 5V, 0V and 15V.

4. FSCC MPPT CONTROL METHOD

Many studies have shown that the ratio between optimal current {for which the output power is maximum} and short circuit current is approximately constant. This is the basis of constant current operation which can be interpreted by the following equation:

$$I_{opt} / I_{cc} = K_{cc} < 1 \tag{17}$$

In this technique, we used two identical panels. The first is short circuited on a current sensor which is characterized by low resistance, its role is to measure the short circuit current of the first panel and deduct the optimal (reference) current.

The second panel supplies the load via a parallel chopper and its control is determined as follows:

The input current of the converter is compared with the reference current. The error between two currents goes through a regulator hysterisis to build the control pulse of the main switch of the DC/DC converter Boost.

Among the disadvantages of this method is that it requires an additional panel to measure the short-circuit current at any time, and also to have a limited yield, because the coefficient of proportionality depends on the temperature of the cells, which can be very variable.

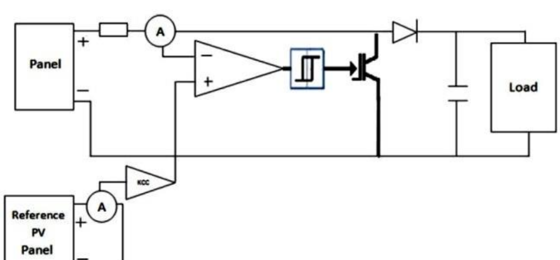


Fig. 7: MPPT control technique FSCC

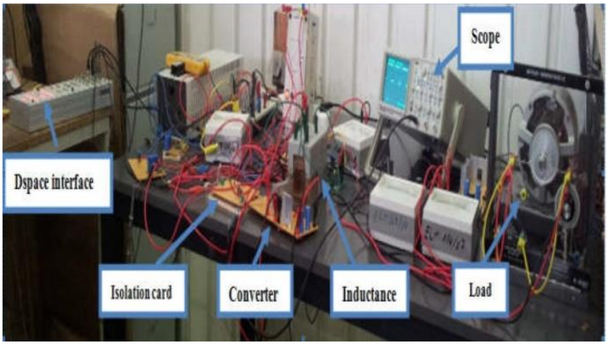


Fig. 8: The complet system with MPPT

4.1 Simulation of FSCC MPPT method

For simulation results the value of the irradiation is about 320 W/m^2.

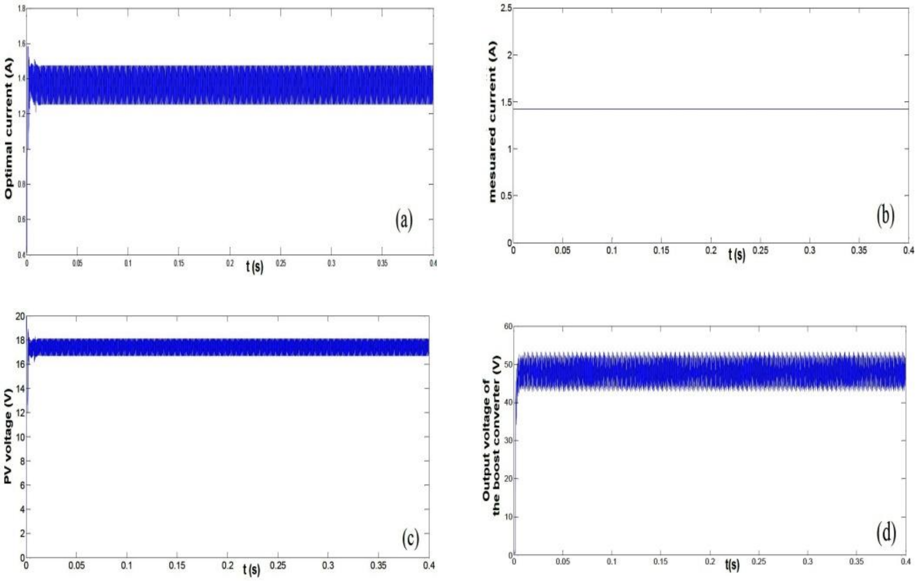


Fig. 9: **(a)** Optimal current, **(b)** Mesuared current, (c) PV voltage (d) Output voltage of the boost converter

4.2 Experimental results

The experimental and simulation results of the value of the irradiation are about 320 W/m^2.

Experimental results verify the validity of our simulation.

For simulation results, input and output voltages contain a lot of noise because of the lack of information about the IGBT's parameters. In our simulation, we use simpower system IGBT and diode model.

The error between the measured and optimal current is nearly zero. The measured current follows with precision of the optimal current (reference current) in simulation and also in experimental results.

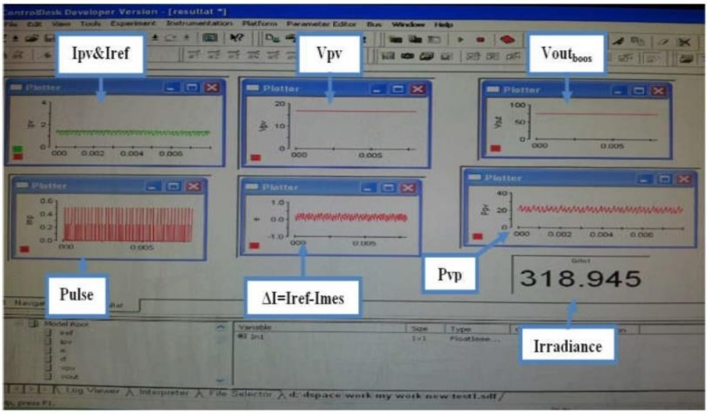


Fig. 10: Experimental results

5. CONCLUSION

In this article we presented the MPPT technique by short circuit current. The proper operation of the maximum power point tracking method of a photovoltaic system. Although it is efficient in terms of PPM tracking, the short circuit current MPPT method has simplicity of construction and acceptable accuracy. At the ripples at the level of the error are due to the oscillatory characteristics of the hysteresis regulators.

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