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Implementation of a maximum power point tracking (MPPT) Algorithm for photovoltaic (PV) system

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Abstract:
Solar energy is a clean and promising source of energy that can be adapted perfectly with multiple systems. The electrical characteristic of the Photovoltaic generator contains an optimal operating point generally called the maximum power point. For this, the implementation of a tracker of the maximum power point is necessary. They play a critical role in photovoltaic (PV) power system for maximize the power of the GPV under different irradiance conditions. This paper deals a strategy for optimizing the performance of a photovoltaic system under real climatic conditions. The maximum power point tracking "MPPT" used in this paper is the perturbation and observation (P&O) algorithm. A controlled Boost DC–DC converter was implemented and connected to a SunTech STP085B PV panel to verify the accuracy of the proposed method. Matlab/Simulink was used for the simulation studies. A digital signal processor (dSPACE ACE1104) based controller was constructed to implement the proposed MPPT control, and the experimental results are presented.

Keywords: Solar energy; Maximum Power Point Tracking; perturbation and observation algorithm;dSPACE controllerBoost converter

1. Introduction

The renewable energy plays a very important role in the production of electricity, mainly in developed countries. The sun is a clean, renewable and not polluting source to generate electricity. The electricity production in systems based on solar cells, where the solar photons are absorbed by a semiconductor is directly converted into electrical energy [1].

The characteristic of the photovoltaic generator (PVG) depends on the temperature, and the irradiation solar. The electrical characteristic voltage/power of the photovoltaic generator (PVG) represents the variation of the power according to the voltage across the photovoltaic generator. In this characteristic, the photovoltaic generator contains an optimal operating point generally called the maximum power point, located in a non-linear zone. To improve the efficiency of the photovoltaic system, the implementation of a tracker of the maximum power point (MPP) is necessary.

There are several methods to obtain the maximum power of the photovoltaic generator [2- 4] can be divided into two groups; offline methods and online methods[5]. These methods differ in terms of complexity, speed of response, amount of investment, the number and types of sensors required and the hardware implementation [5]. Offline methods commonly used the short circuit current and open circuit voltage of the GVP. Generally there are two well-known methods are; the open circuit method [6], and the short circuit current method [7], the authors [8] have been proposed the new offline method based in Artificial Neural Networks (ANN).

In online methods, the current and voltage of the solar panel are measured instantaneous; the most famous in this group are: Perturbation and Observation (P & O) [9], incremental conductance [2], the Ripple Correlation Control (RCC) [10], hill climbing, the three point's comparison and the feedback methods of power [11].

There are author used the methods based on «artificial intelligence» such as the authors [12 - 14] have proposed the maximum power point tracking (MPPT) algorithm based on artificial neural networks. The author [13] proposed genetic algorithms, and the author [15 - 17] have used fuzzy logic to obtain the optimum power point

In this paper, optimizing the performance of a photovoltaic system with Perturbation and Observation (P & O) algorithm, In Section 2 The solar panel modeland a Boost converter model are presented. Section 3 the photovoltaic system for tracking maximum power is introduced. Section 4 our method for tracking the maximum power is presented "the P and O algorithm" section 5 the experimental setup and results are presented to demonstrate the efficiency of the proposed system. Finally the conclusion are presented

2. Photovoltaic generator

There are several models mathematics used for simulate the photovoltaic generator. These models differ in the method of calculation and the number of parameters involved in the current - voltage characteristic.

In our case, we chose a simple model that requires the parameters given by the manufacturer.

We have implemented the five parameter model. The equation for the model of the photovoltaic cell involves the relationship between the output voltage and the current. To increase the output power of the system, solar cells are generally connected in series and/ or in parallel to form PV modules.

This model can be summarized as follows: [18 -20]

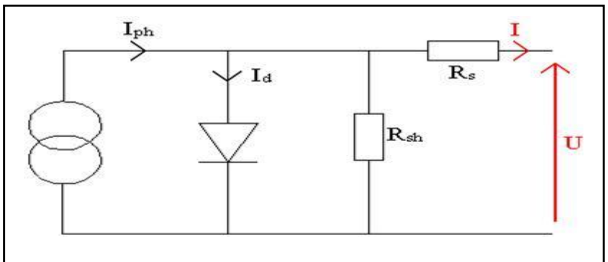

Figure 1. The solar cell

The output current of the solar cell is given by

$I = I_{ph} - I_d - I_{sh}$

By considering the electrical characteristics of a junction, this current can be given by

$$I = I_{ph} - I_0\left(e^{\frac{q(U+IR_S)}{AKT}} - 1\right) - \frac{U+IR_S}{R_{sh}} \qquad (1)$$

When one replaces the term VT = KT/q, one finds

$$I = I_{ph} - I_0\left(e^{\frac{(U+IR_S)}{AV_T}} - 1\right) \qquad (2)$$

The third term in equ (1) is neglected because R_{sh} is bigger than R_s

The output voltage of the cell becomes

$$U = -IR_s + \frac{AKT}{q}\ln\left(\frac{I_{ph} - I + I_0}{I_0}\right) \qquad (3)$$

Where:

R_s: series resistance

R_{sh}: shunt resistance

I_{ph}: short circuit current

I_d: current of the diode

I_{Rsh}: current of the parallel resistor Rp

I: output current and of the solar cell

U: output voltage of the solar cell

I_o: reverse saturation current of the diode

q: charge of the electron

A: diode ideality factor

K: Boltzmann constant

T: temperature in ºK

For the rest of our work, we have chosen a STP085B PV module. It consists of 54 polycrystalline silicon solar cells connected in series and provides a nominal power 85W. The electrical parameters are given in Table 1.

Table 1. Module STP085B

$I_{short-Circuit}$	$V_{Open-Circuit}$	$V_{Maximum}$	$I_{Maximum}$	$P_{Maximum}$
5.15 A	21.9V	17.8V	4.83 A	85W

The photovoltaic generator (PVG) is composed by cells solar connected serially and/or parallel. Voltage and current of PVG is proportional to the number of series and parallel cells respectively.

From the last equation, the characteristics of the solar module I = f (V), with a variable illumination, will have the following form (for a junction temperature of 25 ° C and a spectral distribution of said radiation of AM 1.5).

Note that the voltage Voc varies very little according to the illumination, unlike the current I_{sc} increases strongly with the illumination.

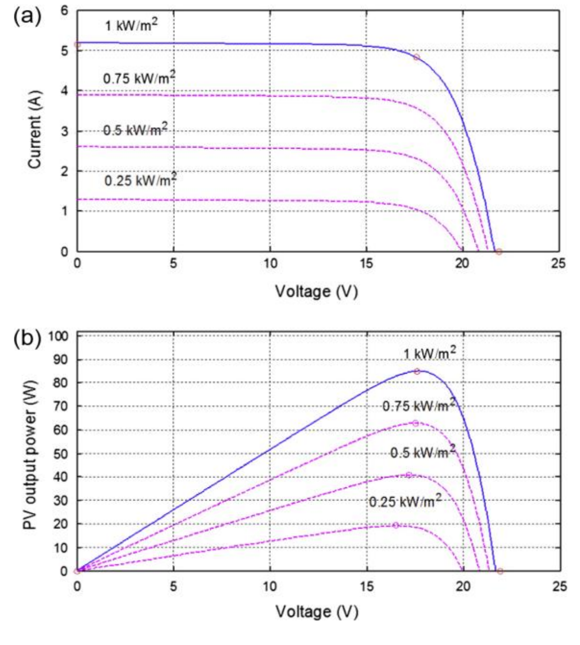

Figure 2. (a) I–V characteristics and (b) P–V characteristics with varying irradiation.

3. DC-DC Converter

The boost converter is a type DC-DC converter composed principally by Electronics components. It is used in several domains. In this case, the boost converter coupled with PVG. Maximum power point tracking "MPPT" controller generated the duty cycle will be controlled the MOSFET of Boost converter to maintain the power of PVG it near from the maximum power point, whatever of the variations of the illumination. The following figure shows circuit the boost converter: [20]

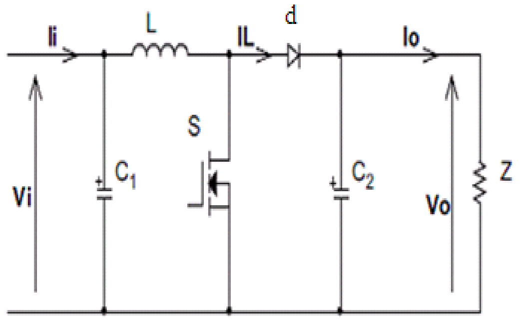

Figure 3. The Boost converter.

The mathematical model of the DC-DC converter expressed by the following equations: [20, 21]

$$\frac{V_0}{V_i} = \frac{1}{1-D} \quad (4)$$

$$\frac{I_i}{I_0} = \frac{1}{1-D} \quad (5)$$

$$I_L = I_i - C_1 \frac{DV_i}{dt} \quad (6)$$

$$I_0 = (1-D)I_L - C_2 \frac{DV_0}{dt} \quad (7)$$

$$V_i = (1-D)V_0 + R_L\, I_L\, L \frac{DI_L}{dt} \quad (8)$$

Where:

I_i: input current
Io: output current
V_i : input voltage
V_o: output voltage
d: diode
D:duty cycle
L: inductance
S: switch
C_1, C_2: capacitances
Z: output impedance

The critical values of the inductance and capacitance can be calculated using the following equations:

$$L = \frac{(1-D)^2.D.R}{2.f} \quad (9)$$

$$C = \frac{D}{2.f.R} \quad (10)$$

4. Maximum power point tracking

Maximum power point tracking "MPPT" controller play a critical role in photovoltaic (PV) power system for maximizes the power of the PVG. The role of maximum power point tracking "MPPT" controller is to search the maximum power point of the PV system. The control principle is based on the automatic variation of the duty cycle D to the appropriate value so as to maximize the power output of the PV panel. There are different type's algorithms of the MPPT controller [22].

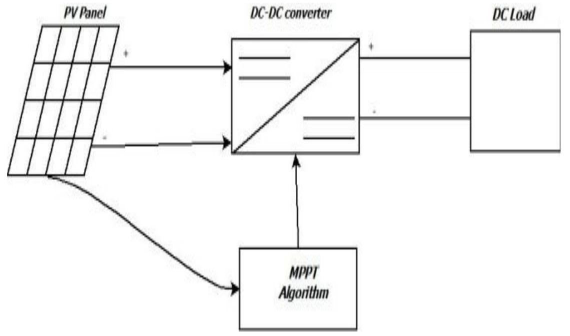

Figure 4. Maximum power point tracking MPPT controller of PV system

5. The P & O algorithm

The P & O algorithm is the most commonly exploited to search the point of maximum power, due to its simplicity and requires only voltage and current measurements of the PVG.

Operating principle based on perturbation of voltage and observing the impact of this change on the output power of the PV panel. At each cycle, and I_{pv}, $V_{pv}$are measured to calculate P_{pv} (k). The value P_{pv} (k) is compared with the value P_{pv} (k -1) calculated in the previous cycle.

If the output power has increased, Vpvis adjusted in the same direction as in the previous cycle. If the power output has decreased, Vpvis adjusted in the opposite direction as the previous cycle direction. It uses an iterative method. The table 2 bellow summarized the operation of the P&O-MPPT algorithm

Table 2
The principle operation of the P&O-MPPT algorithm

Case	ΔP	ΔV	Action
4	P(k) > P(k-1)	V(k) > V(k-1)	V++
3	P(k) > P(k-1)	V(k) < V(k-1)	V--
2	P(k) < P(k-1)	V(k) > V(k-1)	V--
1	P(k) < P(k-1)	V(k) < V(k-1)	V++

A scheme of the algorithm is shown in Figure 5.

If the step size is very small losses in states stable or slowly changing conditions will reduced, but the system has a slow response to rapid changes in temperature or exposure.

The ideal value for the width of the system cannot be determined experimentally or by simulation, thus meet a compromise between rapid response and loss power in stable state.

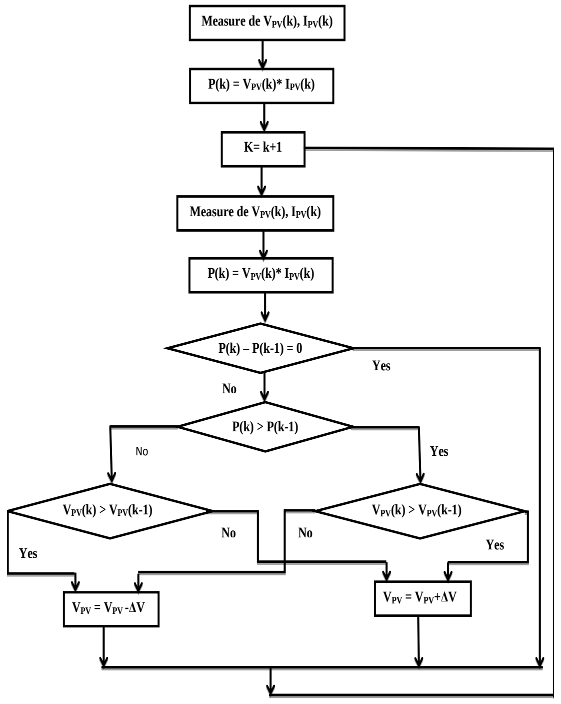

Figure 5 Organization of the disturbance and Observation (P and O) algorithm.

6. Experimental Setup

The proposed MPPT algorithm is implemented using a digital controller based on a dSPACE DSP unit. The DS1104 R&D Controller Board upgrades your PC to a development system for rapid control prototyping (RCP). The real-time hardware – based on the PowerPC 603e microprocessor – and its I/O interfaces make the board ideally suited for developing controllers in various fields – in both industry and university.

The dSPACE is a powerful tool to modify the MPPT controller parameters real time and to monitor real processes while an experiment is operated. The system components are:

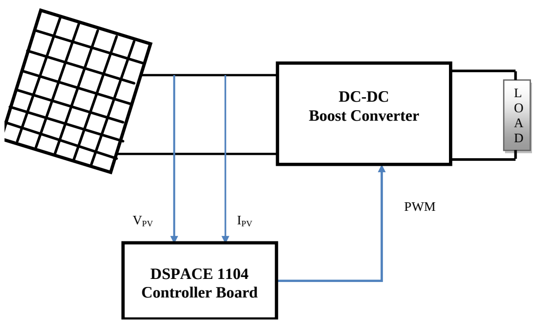

Figure 6.Configuration of a PV power Control system

The bench test was based on the following equipment: four real Suntech85 W panels (used in the LAS laboratory in Sétif, Algeria), a Semikron DC–DC Boost converter operating with a switching frequency of 10 kHz and a variable resistor as a load. A Hall Effect CT LEM (PR30) and a HAMEG HZ64 isolation amplifier were used to detect the PV output current and PV output voltage.

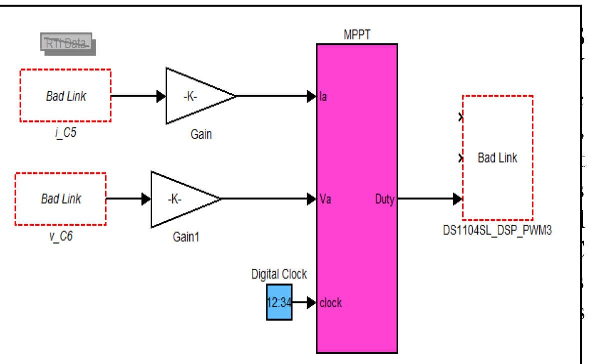

Figure 7. Simulink model of the MPPT algorithm for dSPACE implementation

7. Experimental Results

To test and verify the performance of the MPPT controller with perturbed and observe algorithm were performed on experimental prototypes designed and built in LAS laboratory in Setif "Algeria". A system of four PV solar panels was used as the resistance from 33 Ohm.

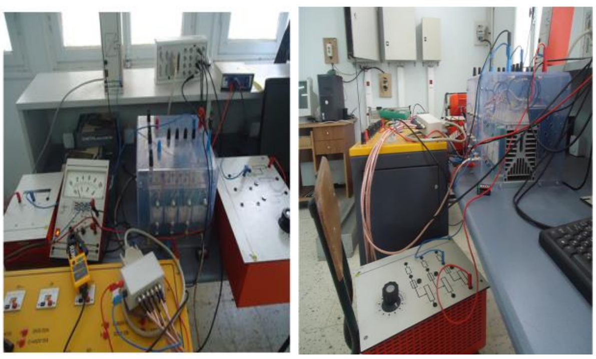

Figure 8. The bench test

The experimental results of the proposed system were implemented using DSPACE DS1104 is presented in figure 9, 10, 11and 12.

The experimental duty cycle is shown in Fig. 9. The experimental PV output voltage and current are shown in Fig. 11 and 10, respectively. The electrical characteristic of the photovoltaic generator (PVG), I = f(V) and P = f (V) are represents in Fig. 12.a and 12.b, respectively.

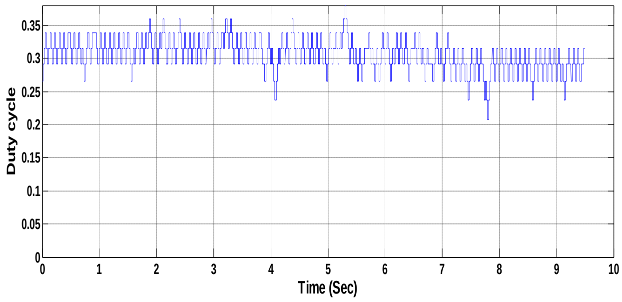

Figure 9. Duty cycle

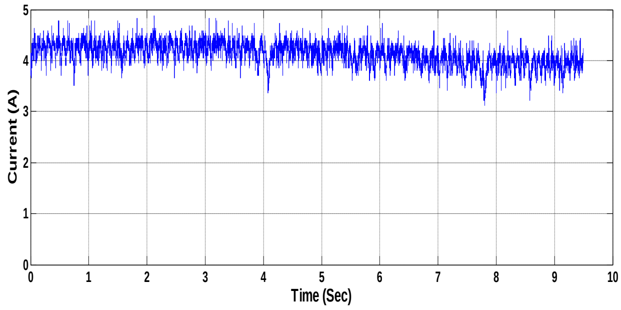

Figure 10. Experimental maximum PV current

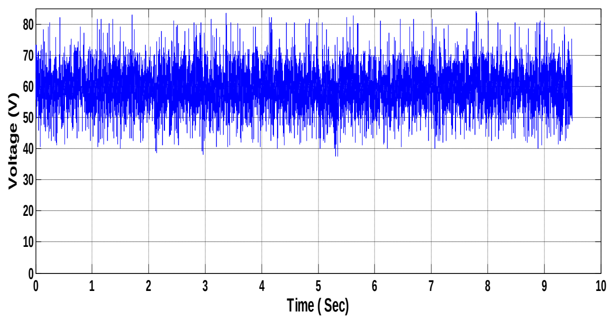

Figure11. Experimental maximum PV voltage

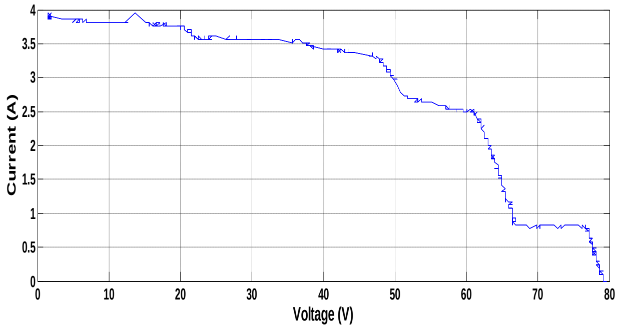

Figure 12 (a) Experimental I-V curve of a photovoltaic panel

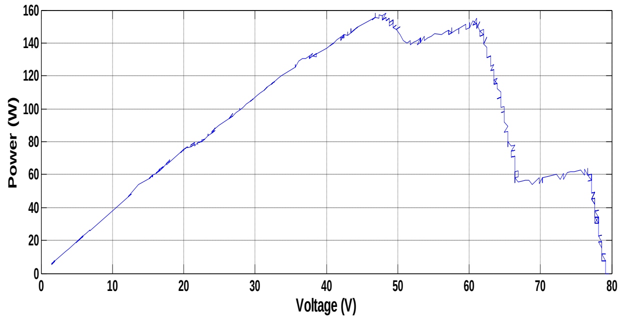

Figure 12 (b) Experimental P-V curve of a photovoltaic panel

8. Conclusion

The principal objective of this study is to improve the performances of a photovoltaic system under real climatic conditions. For this, we have used the MPPT control based on perturb and observe algorithm connected in boost converter. The system demonstrates acceptable response under real climatic conditions. A dSPACE ACE1104 based controller was used to implement the proposed MPPT and control algorithm. The experimental results are presented to verify the performance.

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