Photovoltaic Power Control Using MPPT and Boost Converter

A.Attou, A.Massoum and M.Saidi

***Abstract*—The studies on the photovoltaic system are extensively increasing because of a large, secure, essentially exhaustible and broadly available resource as a future energy supply. However, the output power induced in the photovoltaic modules is influenced by an intensity of solar cell radiation, temperature of the solar cells. Therefore, to maximize the efficiency of the renewable energy system, it is necessary to track the maximum power point of the input source. In this paper, a new maximum power point tracker (MPPT) using Perturb & Observe algorithm is proposed to improve energy conversion efficiency. Maximum power point tracking is an important function in all photovoltaic (PV) power systems. The simulation results show that the proposed MPPT control can avoid tracking deviation and result in improved performance in both dynamic response and steady-state.**

Index Terms— **Maximum power point tracking (MPPT), photovoltaic (PV) power system, maximum power point (MPP), switching mode DC-DC converter, switching duty cycle, Perturb & Observe control.**

I. INTRODUCTION

SOLAR energy is one of the most important renewable energy sources. Compared to conventional non renewable resources such as gasoline, coal, etc... , solar energy is clean, inexhaustible and free.

Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. The photovoltaic array is an unstable source of power since the peak power point depends on the temperature and the irradiation level. A maximum peak power point tracking is then necessary for maximum efficiency [3,5].

The V-I and V-P characteristic curves specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV operates at its highest efficiency. Therefore, many methods have been developed to determine MPPT [5].

In this work, a maximum power point tracker for photovoltaic panel is proposed. dP / dV and variation of duty cycle (ΔD), are used to generate the optimal MPP converter duty cycle, such that solar panel maximum power is generated under different operating conditions. A photovoltaic system including a solar panel, a DC-DC converter and a resistive load is modeled and simulated [3].

Amine ATTOU, is with the electrical engineering Department, Faculty of Technologie, Djillali Liabes University, Sidi-bel-Abbes, 22000, Algeria. (e-mail: attouamine@yahoo.fr).

Ahmed MASSOUM, is with the electrical engineering Department, Faculty of Technologie, Djillali Liabes University, Sidi-bel-Abbes, 22000, Algeria. (e-mail: ahmassoum@yahoo.fr).

Mossaab SAIDI, is with the electrical engineering Department, Faculty of Technologie, Djillali Liabes University, Sidi-bel-Abbes, 22000, Algeria. (e-mail: saidimoss@hotmail.fr).

II. MATHEMATICAL MODEL

The building block of PV arrays is the solar cell, which is basically a p-n semiconductor junction, shown in Fig.1. The V-I characteristic of a solar array is given by Eq. (1)

$$I = I_{sc} - I_0 \left\{ exp\left[\frac{q(V + R_s I)}{nkT_k} \right] - 1 \right\} - \frac{V + R_s I}{R_{sh}} \qquad (1)$$

Where:

- V and I represent the output voltage and current of the PV, respectively.
- R_s and R_{sh} are the series and shunt resistance of the cell.
- q is the electronic charge.
- I_{SC} is the light-generated current.
- I_o is the reverse saturation current.
- n is a dimensionless factor.
- k is the Boltzman constant, and T_k is the temperature in ^{o}K.

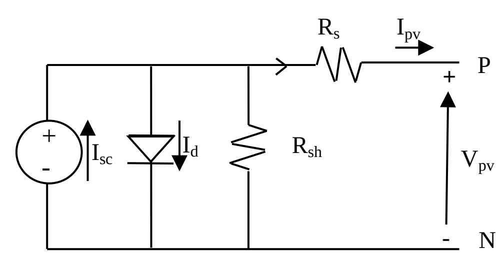

Fig.1 Equivalent circuit of PV array.

Equation (1) was used in computer simulations to obtain the output characteristics of a solar cell, as shown in Fig. 2.

This curve clearly shows that the output characteristics of a solar cell are non-linear and are crucially influenced by solar radiation, temperature and load condition [2,5]. Each curve has a MPP, at which the solar array operates most efficiently.

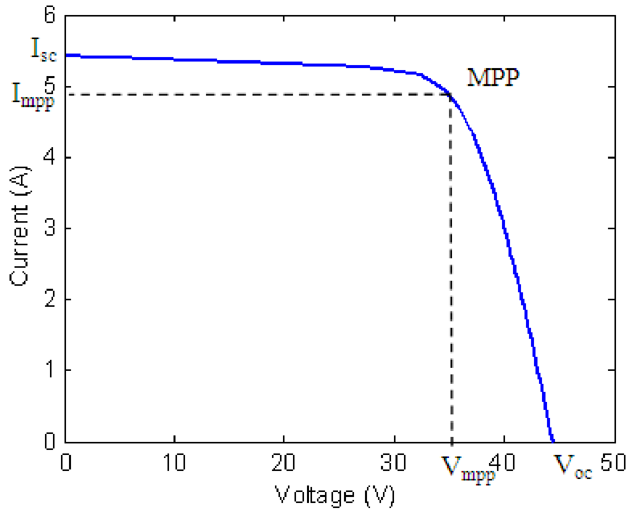

Fig. 2V-I characteristic of a solar cell.

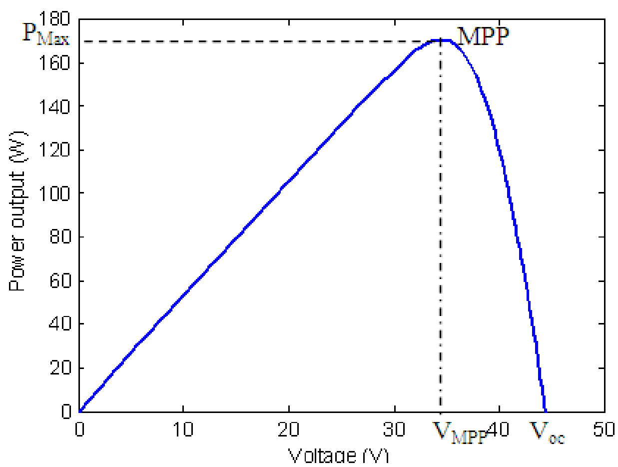

Fig. 3 V-P characteristic of a solar cell.

III. BOOST CONVERTER

Consider a boost type converter connected to a PV module with a resistive load as illustrated in Fig. 3.

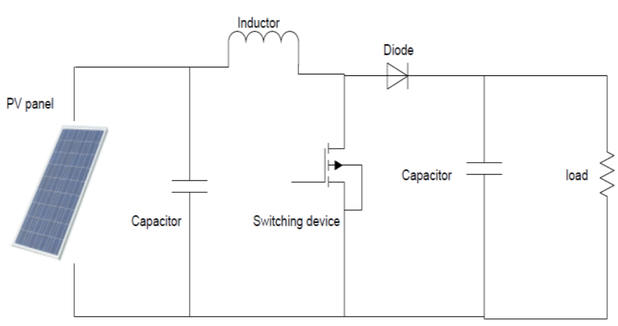

Fig. 4 Boost converter.

The power switch is responsible for modulating the energy transfer from the input source to the load by varying the duty cycle D [2-4].

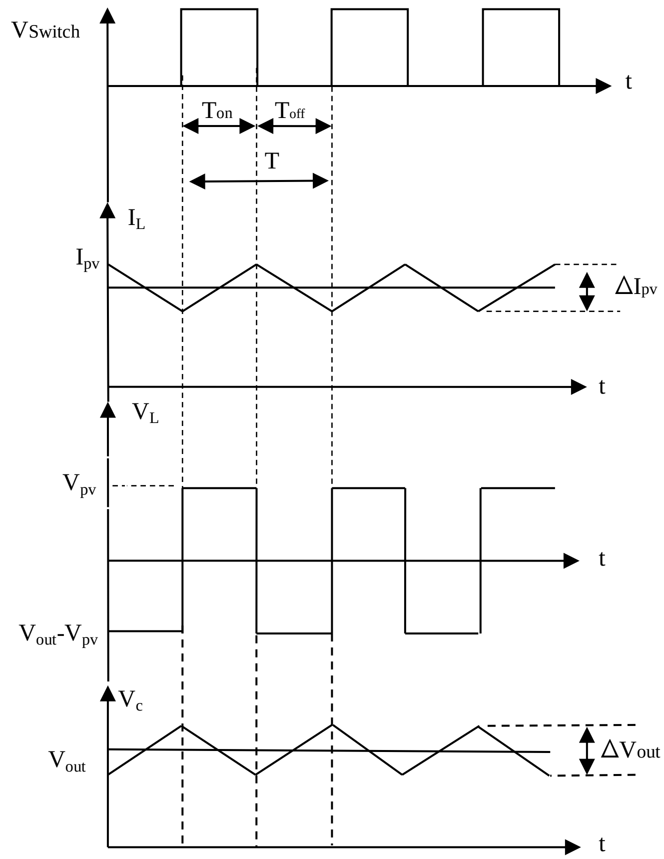

Fig. 5 Typical forms wave of boost converter.

$$V_{pv}\ t_{on} = (V_{out} - V_{pv}) \cdot t_{off} \quad (2)$$

And,

$$V_{out} = \frac{t_{on}+t_{off}}{t_{off}} V_{pv} \quad (3)$$

Where;

$$T = t_{on} + t_{off} \quad (4)$$

The report $\frac{t_{on}}{T}$ is called the duty cycle α and therefore

$$\alpha = \frac{t_{on}}{T} \quad (5)$$

From equation (3), the voltage release can be derived:

$$V_{out} = \frac{1}{1-\alpha} V_{pv} \quad (6)$$

where :

- V_{out} : isthe output voltage.
- V_{pv} : is thevoltageinput (solar cell).
- t_{on} : is the durationof time whenthe switch is closed.

IV. PROPOSED MPPT ALGORITHM

Maximum power point tracking, or MPPT, is the automatic adjustment of the load of a photovoltaic system to achieve the maximum possible power output. PV cells have a complex relationship between current, voltage, and output power, which produces a non-linear output. This output is expressed as the current-voltage characteristic of the PV cell.

Constant fluctuations in external variables such as temperature, irradiance, and shading cause constant shifts of the I-V curve upwards and downwards. A change in temperature will have an inversely proportional effect on output voltage, and a change in irradiance will have a proportional affect on output current [1].

The maximum power point tracking (MPPT) canbeaddressed by different ways, for example: fuzzy logic, neural networks and pilot cells. Nevertheless, the perturb and observe (P&O) and Incremental Conductance (INC) techniques are widely used, especially for low-cost implementations.

The P&O MPPT algorithm is mostly used, due to its ease of implementation. It is based on the following criterion: if the operating voltage of the PV array is perturbed in a given direction and if the power drawn from the PV array increases, this means that the operating point has moved toward the MPP and, therefore, the operating voltage must be further perturbed in the same direction. Otherwise, if the power drawn from the PV array decreases, the operating point has moved away from the MPP and, therefore, the direction of the operating voltage perturbationmust be reversed [6].

The MPP tracker operates by periodically incrementing or decrementing the solar array voltage. If a given perturbation leads to an increase (decrease) the output power of the PV, then the subsequent perturbation is generated in the same (opposite) direction. In Fig.6, set Duty out denotes the perturbation of the solar array voltage, and Duty+ and Duty_ represent the subsequent perturbation in the same or opposite direction, respectively[2,5].

In Fig. 6 it is given a flowchart witch describe the P & O technique:

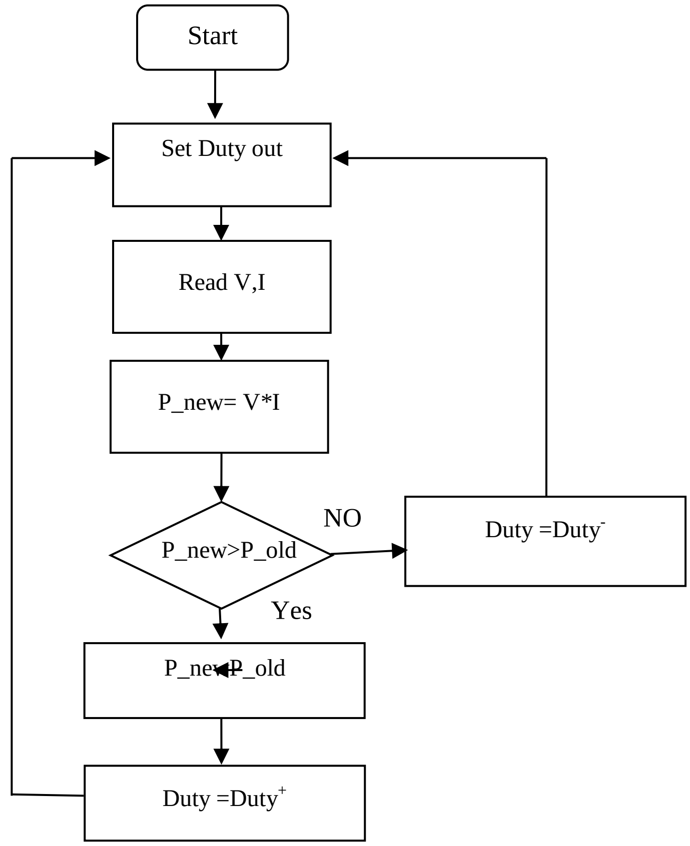

Fig. 6Flow chart of the P&O algorithm.

V. SIMULATION RESULTS

The modeling and simulation of the system (photovoltaic generator, boost converter and MPPT algorithm P&O) is then made with Matlab/Simulink software to validate the control strategy and evaluate the performance of the system. Fig. 7 represents the model used in the simulation.

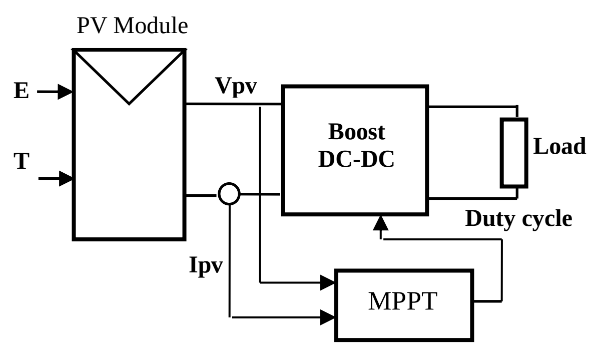

Fig. 7 System simulation model .

Fig.8 shows thesimulation results. We show that theMPPTcontrolforces the system to work optimally at all times around the maximum power point.

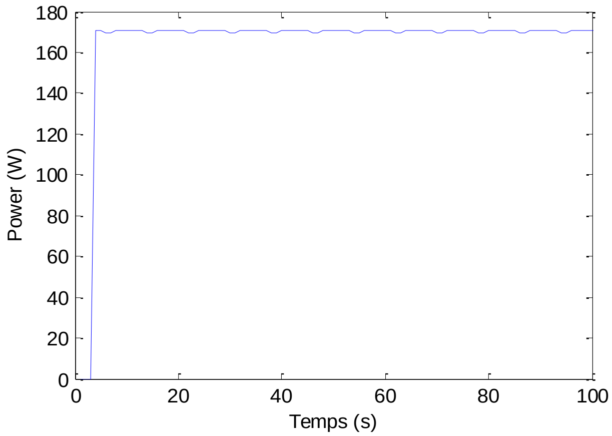

Fig. 8 PV-Output Power of with MPPT.

The change in level of irradiance and temperature are presented in order to show the robustness. First, the use of varied levels of irradiation is presented in the Fig. 9.

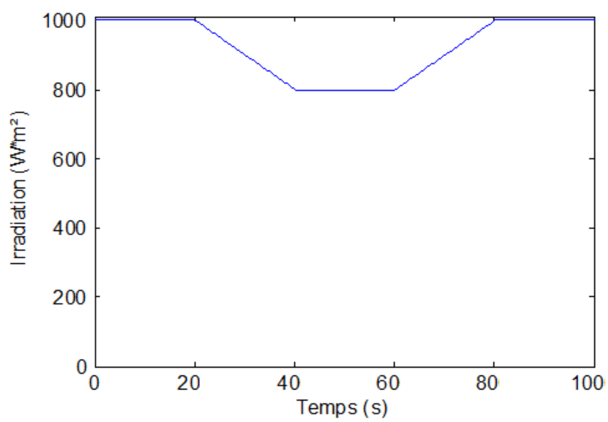

Fig. 9. The irradiation for many levels expressed in Wm^2.

For these levels of irradiation, the following figure represents the maximum power in the output of PV array.

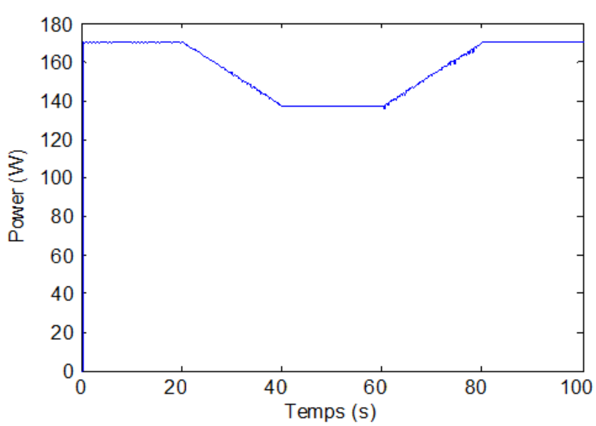

Fig. 10Power in the output of the PV array.

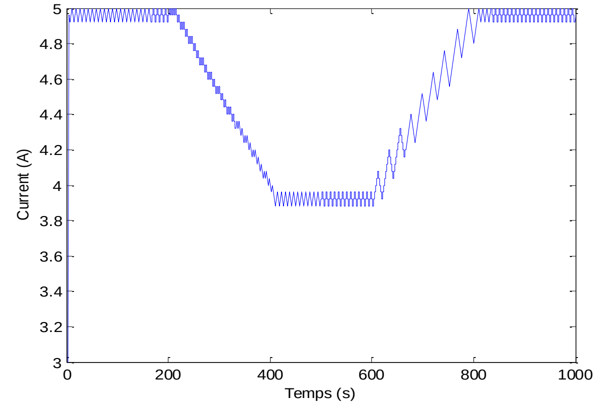

Fig. 11 Plot of Cuurent Output of PV panel.

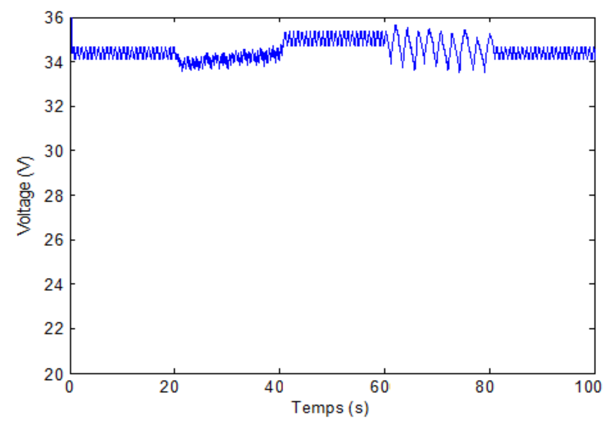

Fig. 12 Plot of Voltage Output of PV panel.

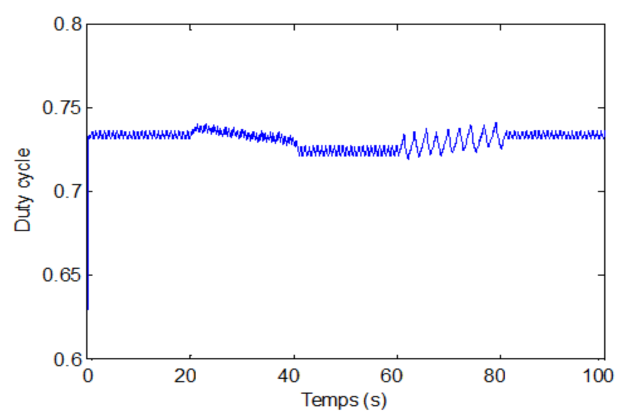

Fig. 13.Simulated duty ratio response of a PV system.

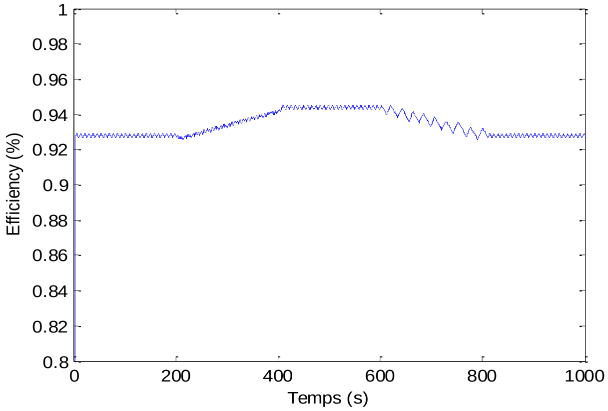

Fig. 14. Simulated the Efficiency response of a PV system.

In Fig.10, the simulation results of the output power of the PV panel using Perturb an Observe method controller is reported, so we can say it is shown that the P&O method, when properly optimized, leads to an efficiency which is equal to 94 % as shown in Fig. 13. We note that a method of P & O show converge to the value of MPP at steady sate. However, when the irradiation changes rapidly the P & O controller shows a better time response method.

IV. CONCLUSION

An energy-efficient fast-tracking MPPT circuit PV energy harvester is presented in this paper. Firstly the characteristics of PV system and vector mathematical model are presented.

The MPPT strategy based on Perturb & Observe method is proposed. The results obtained from simulation employing

P & O approach show the effectiveness of the proposed power tracking and control strategies with quick power tracking response and well direct current output.

ACKNOWLEDGMENT

The study is selected from *International Symposium on Sustainable Development*, ISSD 2013.

REFERENCES

[1] A. Barchowsky, J. P. Parvin, G.F. Reed, M. J. Korytowski, B.M. Grainger, "A Comparative Study of MPPT Methods for Distributed Photovoltaic Generation", Conference Publications, Innovative Smart Grid Technologies (ISGT), 2012 IEEE PES, 2012, pp.1-7.

[2] M.A.Elgendy, B. Zahawi, D.J. Atkinson, "Evaluation of perturb and observe MPPT algorithm implementation techniques", Power Electronics, Machines and Drives (PEMD 2012), 6th IET International Conference, IEEE Publication, March 2012, pp.1-6.

[3] A. Chouder, F. Guijoan, S. Silvestre, "Simulation of fuzzy-based MPP tracker and performance comparison with perturb & observe method", Revue des Energies Renouvelables, vol.11, no.4, 2008, pp.577-586.

[4] M. Arrouf, Optimization of Inverter, Motor and Pump Connected with a Photovoltaic Cell, Ph.D. thesis, University of constantine, Algeria, 2007.

[5] J.A. Jiang, T. H. Huang, Y.T. Hsiao and C.H. Chen, "Maximum Power Tracking for Photovoltaic Power Systems", Tamkang Journal of Science and Engineering, vol. 8, no 2, 2005, pp. 147-153.

[6] N. Femia, G. Petrone, Giovanni Spagnuolo, and M. Vitelli, "Optimization of Perturb and Observe Maximum Power Point Tracking Method", IEEE Transactions on Power Electronics, vol.20, no.4, 2005, pp.963-973.

BIOGRAPHY

Amine ATTOU, he was born in Sidi-bel-Abbes City, in 1987. He received the L.S. and M.S. degrees in electrical engineering from the University of Djillali Liabes, Sidi-bel-Abbes in 2011. He is a member in Intelligent Control Electrical Power System Laboratory (ICEPS).

Ahmed Massoum, he was born in M'sirda Fouaga, Tlemcen, Algeria, in 1959. He received his BS degree in electrical engineering from the Electrical Engineering Institute (INELEC) of Boumerdes 1985 and the MS degree from the Electrical Engineering Institute of Sidi-bel-Abbes University in 2004 where he is currently Professor of electrical engineering. He is a member in Intelligent Control Electrical Power System Laboratory (ICEPS).

Mossaab SAIDI, h**e** was born in SIDA City, in 1988. He received the L.S. and M.S. degrees in electrical engineering from the University of Djillali Liabes, Sidi-bel-Abbes in 2011. He is a member in Intelligent Control Electrical Power System Laboratory (ICEPS).