Optimization of Photovoltaic Generator by Using P&O Algorithm Under Different Weather Conditions

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Abstract: The aim of this work is to apply the Maximum Power Point Tracking (MPPT) principle, to optimize the yield of the solar panel. For this, one used MatLab/Simulink software package to apply the Perturbed & Observer Algorithm of optimization on this panel which is supplied by a Boost converter. The results of the characterization of the modeling of the electrical characteristics of the photovoltaic (PV) panels have been presented in function of the illumination. The voltage and the power of the panel as well as the battery, and the duty cycle are well presented and analyzed to find the Maximal Power Point in function of luminosity and temperature, the results have been compared between a standard panel and a MPPT controlled panel.

Keywords: Solar cells, Photovoltaic, PV, MPPT, Converters, P&O, Optimization.

1. INTRODUCTION

The photovoltaic effect was discovered for the first time by Alexandre Edmond Becquerel in 1839. After this, many researches were launched in this area to explain more the photoconductivity, photoelectric effect, and the photovoltaic semi conductors, where the fabrication of the photovoltaic cells started to be developed in 1880.

The direct conversion of light into electrical energy is obtained through photovoltaic cells, the fact that can be called photovoltaic effect (Steven *et al.*, 2009). Photovoltaic solar cells are electronic devices that capture the sun's energy and convert it to an electrical energy. These cells can be made by different materials as Silicon (Si), Gallium Arsenide, thin film, Cadmium Telluride (CdTe) and Copper Indium Diselenide (CIS) (Adamo *et al.*, 2009; Chouder *et al.*, 2008).

Photovoltaic solar energy is among the renewable energy which has the widest potential development. To grasp the significance of renewable energy in Algeria, the solar field covers an exceptional area of 2381745 km^2. Our work is in the commitment of our country to exploit these renewable natural and non polluting resources and for the increased mobilization efforts of research/development control technologies to be implemented to facilitate the conversion of renewable energy power.

Algeria has decidedly chosen sustainable development as its energy strategy, the legal and regulatory framework adopted during the past years underscores our strong commitment (Hatti, 2008). The economic and social development in Algeria in the last years has been in need of continues increasing in demand of electricity, especially in the isolated countryside. Solar energy represents a significant potential in Algeria, the country receives more than 3,000 hour of sunshine per year with a high level of radiation. The average of daily solar irradiation is from 5 to 7 kW hour m^2 per day. In order to take full advantage of this natural resource, the Algerian government is conducting investments in solar energy and its applications. Large parts of electric demand are in the Sahara areas (-80% of the total surface). A dispersed population, a very hot climate of strong radiations (-7 kW hour m^2 per day) and a weak demand of energy characterise these regions. The use of the conventional energy sources is costing very high and extensions of electric networks find enormous problems. The solar energy is adapted for these areas, which have shown satisfactory results, this energy substitute conventional sources in soon future. Figure (1) shows the solar potential in Algeria (Steven *et al.*, 2009).

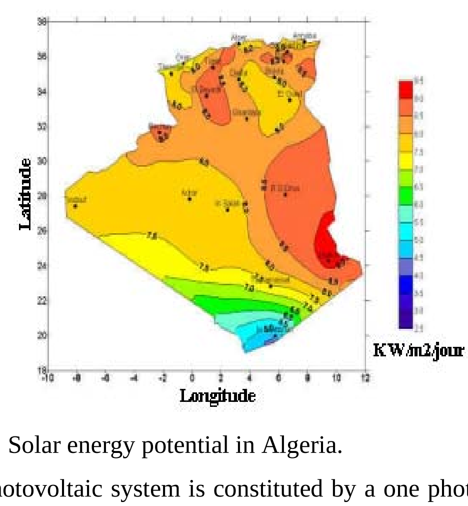


Fig. 1. Solar energy potential in Algeria.

The photovoltaic system is constituted by a one photovoltaic panel and a power interface charge. A simple circuit DC/DC converter (Boost) is used as an interface between the PV array and the load (here a battery). The wool system was developed using Matlab/Simulink and the model of a battery, the simulation of a DC/DC converter is initially controller by P&O (Perturbe and Observe), which presents oscillations around the MPP (Maximum Power Point) at Research of Maximum Power Point (Hatti, 2008).

2. PHOTOVOLTAIC GENERATOR

There are many electrical models that can characterize the effect of the photovoltaic cell, based on some electrical characteristics of the cell elements, but the simplest equivalent circuit of a solar cell is a current source in parallel with a single diode as shown in figure (2). This model describes well the solar cell characteristics (Francisco, 2005; Titouche, 2012).

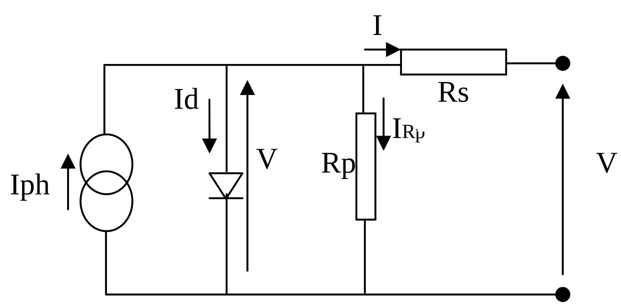


Fig. 2. Equivalent circuit of solar cell.

The output current of the solar cell is given by:

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

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

$$I=I_{ph}-I_0\left(e^{\frac{q(V+IR_s)}{AKT}}-1\right)-\frac{V+IR_s}{R_p}. \tag{2}$$

When one replaces the term V_T=KT/q, one finds:

$$I=I_{ph}-I_0\left[\left(e^{\frac{(V+IR_s)}{AV_T}}-1\right)\right]. \tag{3}$$

The output voltage of the cell becomes:

$$V=-IR_s+\frac{AKT}{q}\ln\left(\frac{I_{ph}-I+I_0}{I_0}\right). \tag{4}$$

The output power of the solar cell is calculated as:

$$P=I\ .V\ . \tag{5}$$

Where:
R_s: series resistance
R_p: parallel resistance
I_{ph} : short circuit current
I_d: current of the diode
I_{Rp}: current of the parallel resistor R_p
I: output current and of the solar cell
V: 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

The combination in series and/or in parallel of several solar cells composes a photovoltaic generator which has non-linear electrical characteristics with a maximum power point. In our case the proposed model of the PV generator has as input the illumination and the cell temperature and as outputs the I-V and P-V characteristics as shown in figure (3). Different curves of current and power were plotted in function of the voltage and in various values of illumination (Tsai *et al.*, 2008; Ould Mohamed *et al.*, 2008).

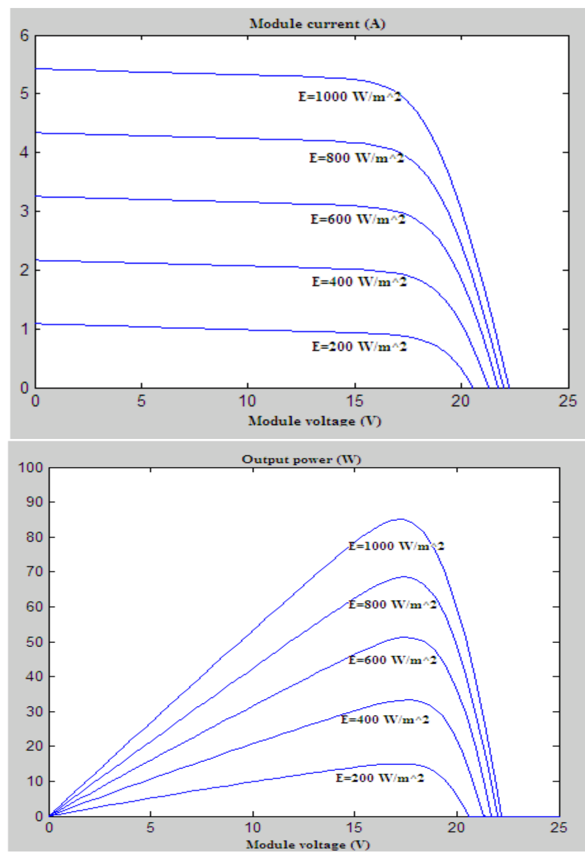


Fig. 3. Module current and power in function of its voltage in different values of illumination.

The module current depends on the illumination variation at constant temperature (T=25oC). The higher the illumination, the greater the current with a constant voltage final value. On the other hand, the major MPP will be obtained in the photovoltaic module (Femia *et., al* 2005; Hatti, 2008).

In fig. 4 the characteristic I-V/P-V PV of the PV generator is based on that of an elementary cell modelled by the equivalent circuit given previously. The curves have been taken for a generator 20 PVs cells, 36 cells and 50 cells VPs and VPs, which we can see that the output current, and therefore power, are proportional to the surface of the module.

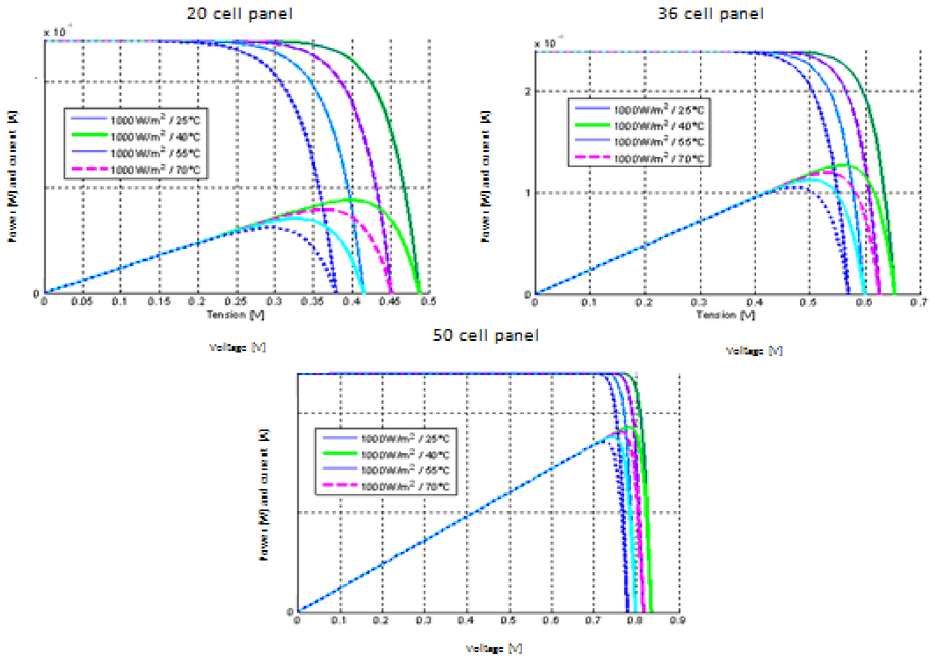


Fig. 4. Characteristics I-V / P-V generatosr based on the number of cells.

3. STORAGE SYSTEM

Unlike photovoltaic generators, the batteries are no longer simple electrical components in which the number of developed models is reduced, while it is not easy to model the electrochemical interactions of battery by simple electrical circuits as in the PV generator. Therefore, and for the wide variety of type of battery cells and the number of very varied parameters involved, a very empirical representation of the behaviour of battery can be established. Among many possible storage technologies, the lead-acid battery continues to be the workhorse of many PV systems because it is relatively inexpensive and widely available. In addition to energy storage, the battery also has ability to provide surges of current that are much higher than the instantaneous current available from the array, as well as the inherent and automatic property controlling the output voltage of the array so that loads receive voltages within their own range of acceptability (Akihiro, 2005).

4. BOOST CONVERTER

Owing to the variations of the temperature and the illumination, and to adjust the generated voltage in function of the used load, one must use a DC/DC converter which can help in increasing the efficiency of the photovoltaic system (Jiang *et al.*, 2005; Protin and Astier). The duty cycle of the MPPT controller will be introduced into the converter to maintain it near from the maximum power point, whatever of the external conditions. To attain the specified results for our project, the converter output voltage should be higher than its input voltage (Anita, 1999). This type of converter is called Boost converter, where its electronic circuit is illustrated in Fig. 5.

The most used DC/DC converter is Boost converter, this one can be explained by the following equations (Ayache *et al.*, 2010):

$$V_o = \frac{1}{1-D} V_i. \tag{6}$$

$$I_i = \frac{1}{1-D} I_o. \tag{7}$$

$$I_L = I_i - C_1 \frac{dV_i}{dt}. \tag{8}$$

$$I_o = (1-D) I_L - C_2 \frac{dV_o}{dt}. \tag{9}$$

$$V_i = (1-D) V_o + R_L I_L + L \frac{dI_L}{dt}. \tag{10}$$

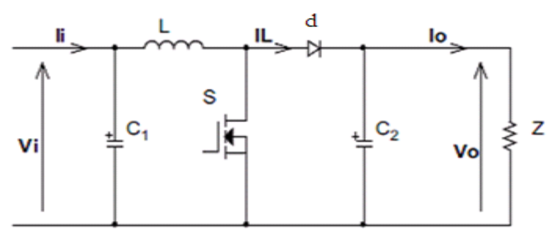


Fig. 5. Circuit of the Boost converter.

Where:
I_i: input current
I_o: 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

5. PERTURBE AND OBSEVE ALGORITHM

In Fig. 6, the load can be powered directly by the PV generator when the produced energy is sufficient for the operation of the load, but the problem here is that the PV generator cannot generate power However, if the sun was shining and the daily or seasonal weather influences the PV generator function. In such case the battery is used to store energy produced by photovoltaic generator (PVG), then the energy can be used anytime, even in the absence of sunlight (Ould Mohamed *et al.*, 2008; Knopf, 1999).

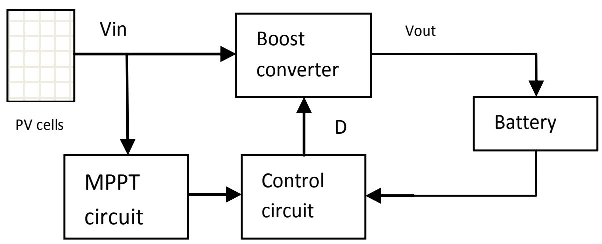


Fig. 6. Schematic PV generator with MPPT.

Many researches has been developed concerning the different algorithms for the maximum power tracking (MPPT) considering the variations of the system parameters and/or weather conditions such as the short circuit current or open circuit voltage techniques and perturbations methods (Pastor, 2006 ; Mrabti *et al.*, 2009) . The chart in Fig. 7 demonstrates the principle of the Pertube and Observe (P&O) algorithm. This algorithm has been largely used because it is easy to implement, it is based on the perturbation incrementing or decrementing the voltage Vref, or the current Iref with observing the result of this disturbance on the measured power (P = VI) (Femia *et., al* 2005; Ameur, 2009).

The algorithm of this command is shown in Fig.6.

• If dpv/dVpv>0, the voltage is increased, this induces an increase of the duty ratio D (k) = D (k-1) + C. C is a constant accrémentition

• If dpv/dVpv <0, the voltage is reduced that it reflects by reducing the duty ratio D (k) = D (k-1)-C

The load or the battery can be charged from a PV panel using a MPPT circuit with a specific controller to track the peak power generated by the PV panel. Other protection devices can be added. The control circuit takes voltage and current feedback from the battery, and generates the duty cycle D, This last defines the output voltage of the Boost converter (Ould Mohamed *et al.*, 2008; Jiang *et al.*, 2005).

If the step size is large, the MPPT algorithm responds quickly to sudden changes in operating conditions, but the power loss will be significant.

In other words, if the step size is small, the power losses in operating conditions stable or slowly changing will be lower but the system can not respond quickly to rapid changes in temperature or sunlight.

6. OPERATING UNDER STANDARD CONDITIONS

Fig. 8 and Fig. 9 allow us to visualize the variation of the duty cycle and the battery power, the voltage of the module and the battery are also illustrated with and without the MPPT control in standard atmospheric conditions ($1000 W/m^2$, 25°C). It is found that the use of a MPPT controller is necessary for maximum performance (Titouche, 2012).

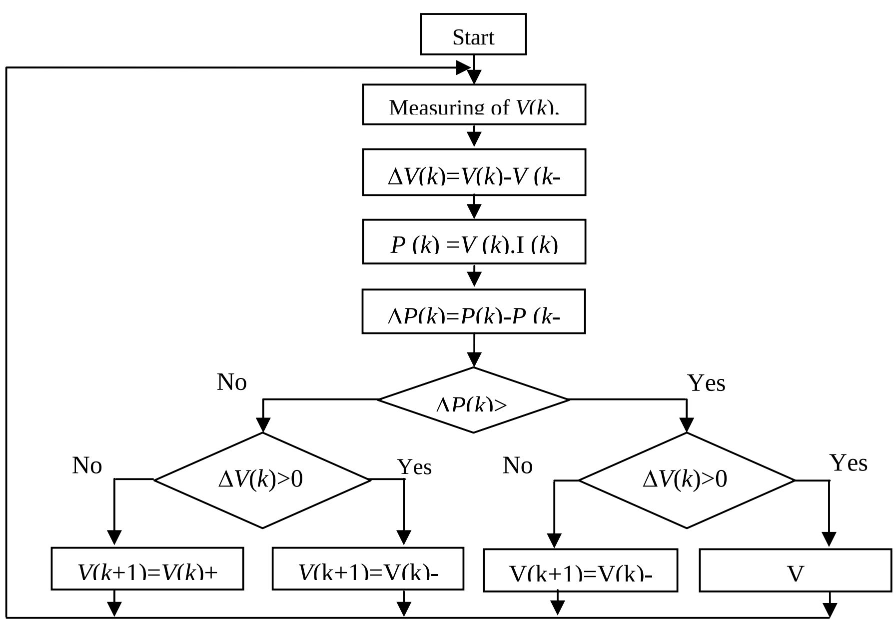


Fig. 7. Chart of the algorithm P&O (CP: step width of the disturbance).

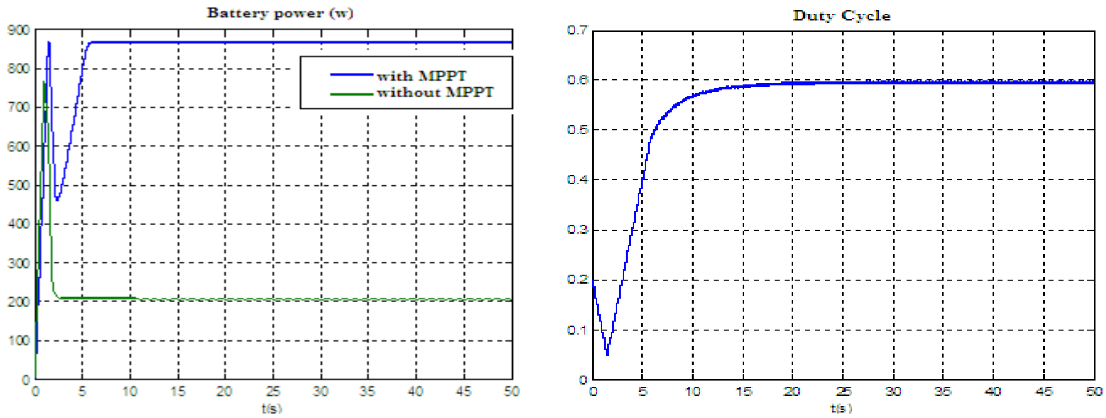


Fig. 8. Variation of the battery power, and the duty cycle D with MPPT P&O and without MPPT P&O in standard conditions (1000W/m^2, 25°C).

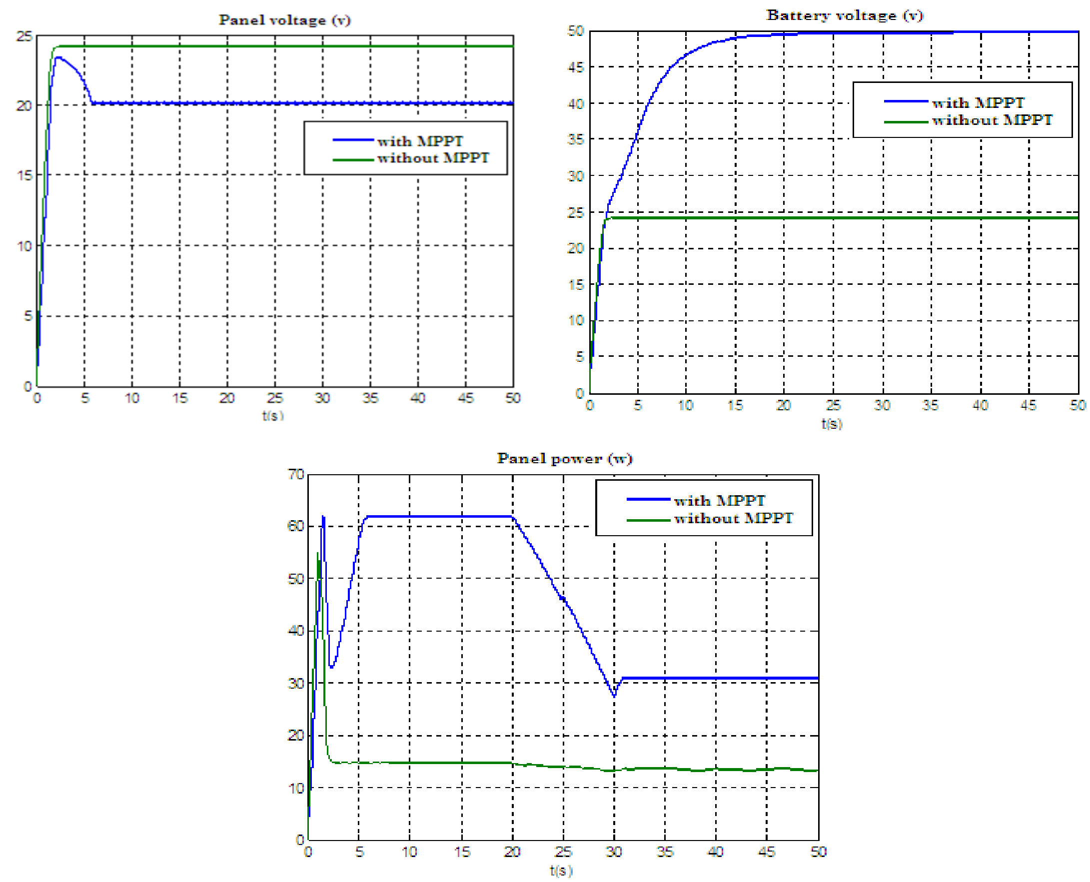


Fig. 9. Variation of voltages of the module and the battery with MPPT P&O and without MPPT P&O in standard conditions (1000W/m^2, 25°C).

7. OPERATION UNDER VARYING CONDITIONS

To visualize the behavior of our system in real conditions, one varies the illumination, the temperature, and the increment step. These variations allow us to study the robustness of our system.

7.1 Effect of variation in the illumination

The illumination varies from 1000W/m^2 to 500W/m^2 during a disruption of 10s. The temperature is kept constant at 298K (25 °C). The decrease of illumination affects the behaviour of MPP (Fig. 10), thus reducing the maximum power delivered by the PVG.

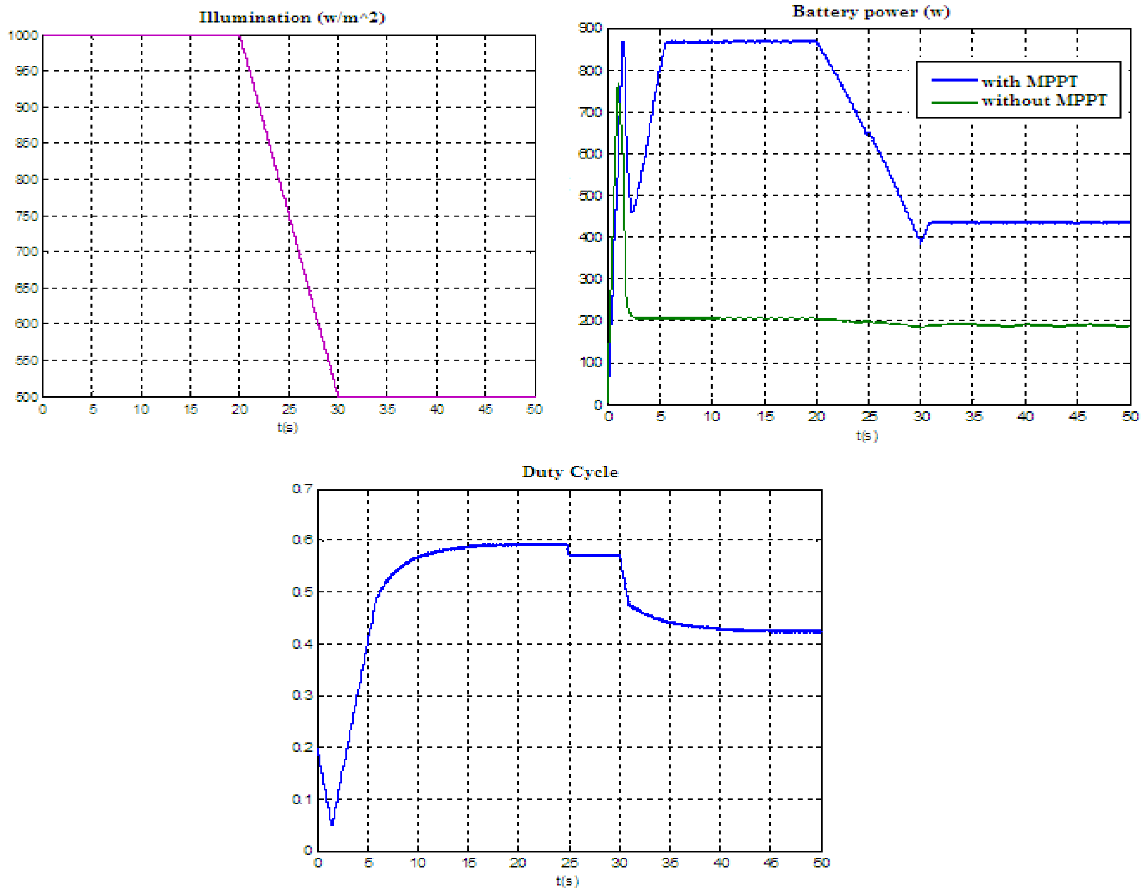


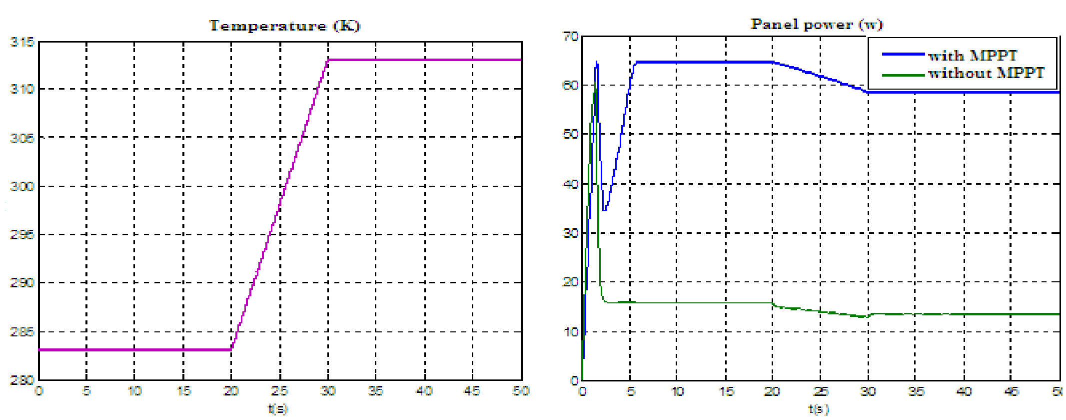
Fig. 10. Variation of the module power, battery power, and the duty cycle D in function of the illumination reduction with MPPT P&O and without MPPT P&O.

7.2 Effect of temperature variation

When the temperature varies from 283K (10°C) to 313K (40°C) during a disruption of 10s. The illumination was kept constant at 1000W/m2. Increasing the temperature slightly affect the output voltage of the generator and therefore the power transferred to the charge in the case of an MPPT controller (Fig. 12), but in the case "without MPPT," one doesn’t see the increase because of the presence of batteries which maintains the output voltage of the generator constant.

7.3 Effect of simultaneous variation of the illumination and temperature

The following figures show the simultaneous variation of the two atmospheric conditions. An increase of the illumination from 500W/m2 to 1000W/m2, and temperature from 283K (10°C) to 313K (40°C), can evidently influence the panel and the battery powers as well as the duty cycle.



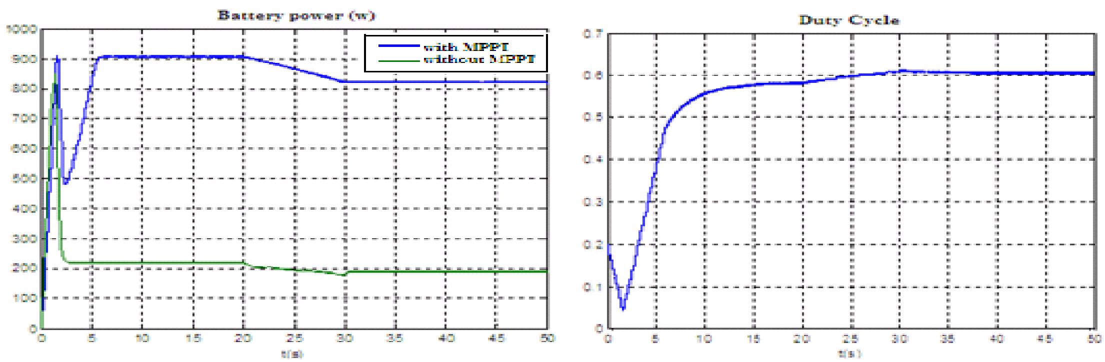


Fig. 11. Variation of the module power, battery power, and the duty cycle D in function of the temperature increase with MPPT P&O and without MPPT P&O.

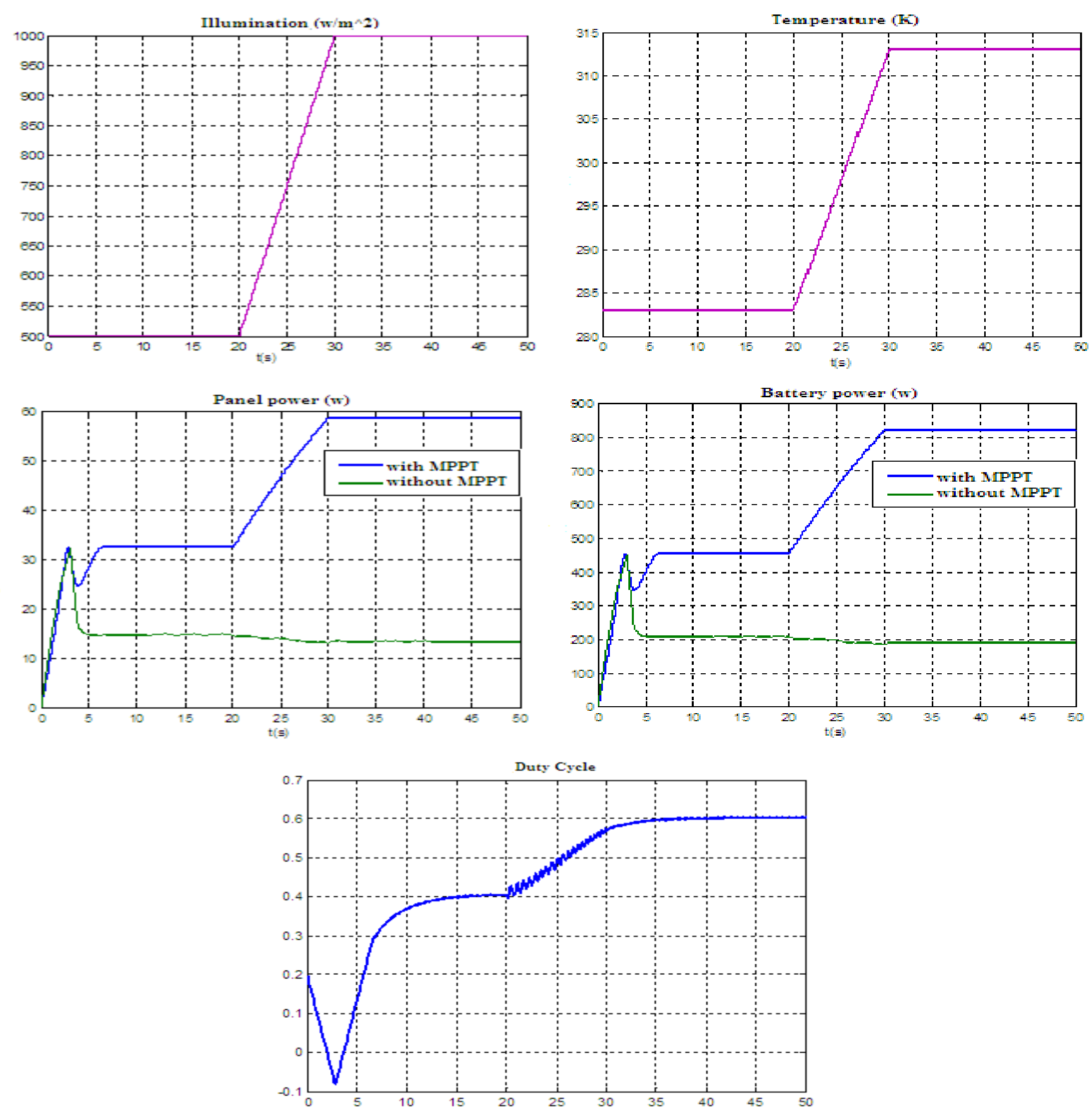


Fig. 12. Variation of the module power, battery power and the duty cycle D in function of simultaneous increase of the illumination and the temperature with MPPT P&O and without MPPT P&O.

One sees that the light has a dramatic effect on the power of PVG. By cons, the temperature has almost no influence on the output power due to the presence of batteries.

8. CONCLUSIONS

The work presented in paper deals with the optimization of the energy efficiency of a photovoltaic system. Therefore, numerical modeling of a photovoltaic cell has been developed. The model used for the silicon solar cell, is the model with single diode. One has established calculation programs under Matlab/Simulink to plot the IV characteristic. One has chosen a MPPT controller because it allows to have a yield higher than other controllers.

Firstly, one compared the simulation results obtained with and without using the P&O MPPT controller, by exposing the panel to the same environmental conditions. We observed through the results obtained that, with P&O MPPT controller, the PV generator under uniform illumination exhibits a current-voltage characteristic with a sole point, called the maximum power point (MPP), on the other side the electric power is sensitive to the duty cycle changes .

The disadvantage of the technique by P & O MPPT is that in the case of a rapid change in lighting conditions, such as an electric car enters a tunnel, this method can move the operating point in the wrong direction. To overcome this problem and as an extension of our work, another method will be used based on artificial intelligence techniques and the results can be compared to these ones.

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