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Modeling and Simulation of A Solar Power Source for a Clean Energy without Pollution

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Article Info	ABSTRACT
	Photovoltaic cell generation is the technique which uses photovoltaic cell to convert solar energy into electrical energy. Now a days ,the photovoltaic generation is developing increasingly fast as a renewable energy source. The functioning of a photovoltaic cell as the power generator is equivalent to an electric circuit containing a current generator, diode, series and shunt resistance. This paper presents a modeling and simulation of a photovoltaic system constitutes of a generator photovoltaic (PVG), DC-DC converter (boost chopper) to transfer the maximum power to a base transmitter station. The temperature and irradiance effects on the PVG will be studied, particularly on the variables such as the short circuit current I_{cc}, the open circuit voltage V_{oc}. Depending on the load (BTS, I=60A, V=48V) profile and climatic factors influencing, we can find a highly gap between the maximum power supplied by the PVG and that actually transferred to the BTS. A maximum power point tracker (MPPT) based on a boost converter commanded by a Pulse Width Modulation (PWM) is used for extracting the maximum power from the PVG. Thus, a real time tracking of the optimal point of functioning is necessary to optimize the efficiency on the system. The modeling and simulation of the system (PVG, boost converter, PWM and MPPT algorithm of Perturbation and Observation P&O) is then made with Matlab/Simulink software.

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1. INTRODUCTION

For two centuries, the world has used its energy almost exclusively from the combustion of coal, oil and gas represent today 80% of global energy consumption marketed. But coal, oil and gas are fossil energy that are not renewed. This energy is the principal cause of global warming, is now a major environmental and economic problem affecting the perspectives of sustainable development. The use of solar energy to produce electricity by a photovoltaic panel requires no fuel. So there is no issue or producing toxic gases from the combustion of coal which has the effect of increasing the temperature of the earth by greenhouse gases. Solar energy is a clean and inexhaustible excellent alternative. In addition, there is no waste from this technique of energy production and not reject polluting and toxic substances in the soil. In this study, we model and optimize a system comprising a photovoltaic generator connected to a boost converter for a best transfer the power drawn from the sun and converted into electricity, without burning coal.

2. SYSTEM MODELING

The system studied is the association of a set of interconnected subsystems which are: the GPV, represents the solar module as a source of current in parallel with a diode, a resistor in series represents the contact resistance, and another so-called parallel bypass or shunt resistance, represents the currents of leaks, a quadrupole of adaptation, which is a power DC-DC converter. The DC-DC converter is controlled by a signal pulse width modulation with a research strategy of MPPT. The MPPT control follows the point of maximum power at each instant. This control, acts directly on the duty cycle of the converter.

2.1 Modeling of a Photovoltaic Cell

In the ideally a photovoltaic cell (PV) can be summarized by an ideal current source produces a current proportional to the Iph incident light power, in parallel with a diode. If we connect a resistive load to the terminals of the GPV, latter is delivers a portion of current I and the rest Id, current in the diode. For an ideal GPV, the voltage at the terminals of the resistance is equal to that at the terminals of the led: V=Vd and the nonlinear diode I-V characteristic is given by the relation.

$$I_d = I_s \left[e^{\frac{V_d}{nV_T}} - 1 \right]$$

(1)

The current supplied would be:

$$I = I_{ph} - I_d = I_{ph} - I_s \left(e^{\frac{V_d}{nV_T}} - 1 \right)$$

(2)

In the real case in models loss of voltage and leakage by two resistance in parallel Rp and Rs series. The model of the cell is shown in Figure 1:
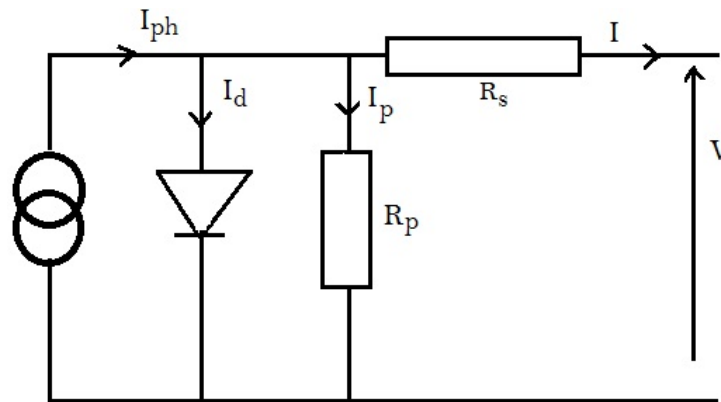

Figure 1. Model of PV cell with inclusion of voltage loss and leakage current

According the law of Kirchhofff, we have:

$$\mathbf{I = I_{ph} - I_d - I_p}$$

(3)

$$\mathbf{I_p = \frac{V_d}{R_p} = \frac{V + I.R_s}{R_p}}$$

(4)

$$\mathbf{I = I_{ph} - I_s \left(e^{\left(\frac{V + I.R_s}{n.V_T} \right)} - 1 \right) - \frac{V + I.R_s}{R_p}}$$

(5)

In the ideal, Rs tends towards 0 and Rp to infinity. And in the real, these resistors provide an assessment of the imperfections of the diode; considering that the resistance Rs has a low value. Using a numerical method (the method of Newton-Raphson for example) and under illumination, the slopes of the I-V characteristics are calculated at I=0 open circuit and short circuit V=0 and respectively give the inverse of series and shunt resistance values.

2.2 Influence of Light and Temperature on the Characteristic I(V)

The response of a PV cell at different light energy figure (2). Shows that irradiation has a significant effect on the current open-circuit. That is the curve of the I-V characteristic and relatively horizontal, while the effect on the voltage in open circuit, i.e. the slope of the I-V curve and relatively vertical, which is quite low. With regard to the maximum power of a photovoltaic cell, when the illumination is highest, the cell generates more power. The temperature has a very important effect on the open circuit voltage and a non-remarkable effect on the short circuit of cell figure (3).
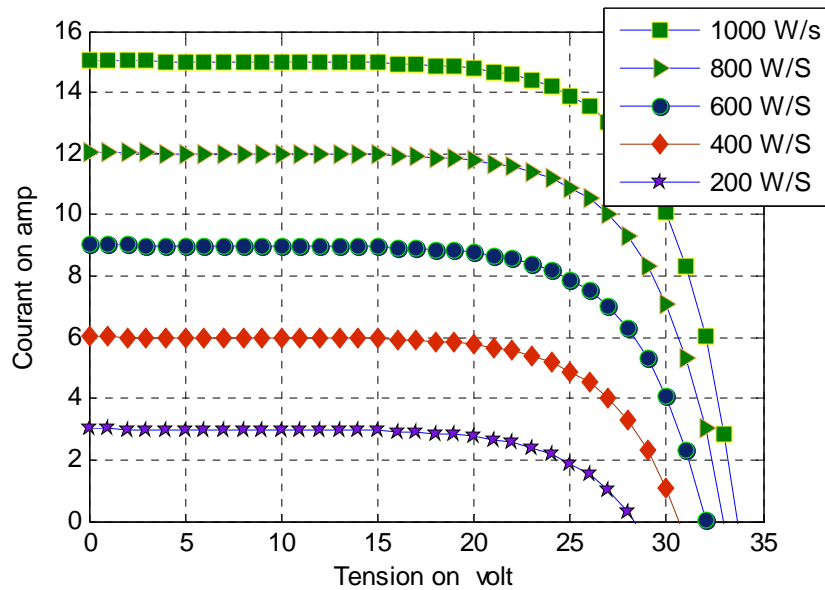

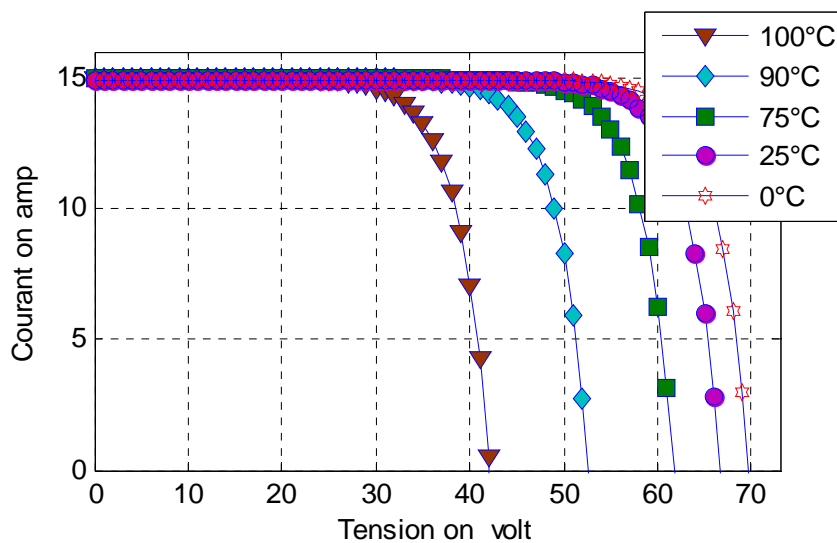Figure 2. Current-voltage characteristic for different values of radiation

Figure 3. Current-voltage characteristic in different temperature

2.3 Modeling of the Photovoltaic Generator

Because of its low thickness, a photovoltaic cell produces a very low electrical power of the order 1 to 3 W. So to increase the power, on assembles these cells either in series or in parallel for formed a photovoltaic module and achieve the desired power for supplying a BTS. An association of cells in series to increase the tension of the GPV, while an N_s connection in parallel allows increasing the output current of the generator. The equivalent circuit of the PV generator becomes:
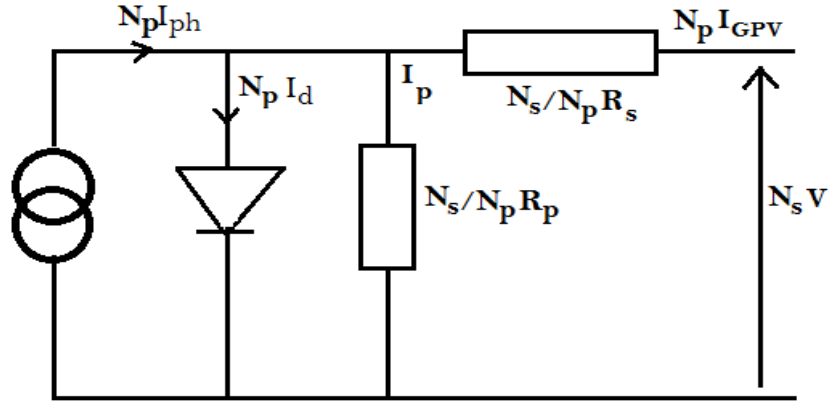

Figure 4. Model of the photovoltaic generator

The equation of the terminal for the current and the voltage is as follows:

$$I_{GPV} = N_p I_{ph} - N_p I_s \left(e^{\left(\frac{N_p.V_{GPV} + N_s.R_s.I_{GPV}}{N_s.N_P.V_T} \right)} - 1 \right) - \frac{N_p.V_{GPV} + N_s.R_s.I_{GPV}}{N_s.R_p} \qquad (6)$$

In fact, the photovoltaic efficiency is sensitive to small changes in resistance Rs, but insensitive to the variation of Rp for a PV module or a generator, the series resistance is apparently important and parallel resistance tends to infinity is replaced by an open circuit. The mathematical equation of the generalized model can be written as:

$$I_{GPV} = N_p I_{ph} - N_p I_s \left(e^{\left(\frac{N_p.V_{GPV} + N_s.R_s.I_{GPV}}{N_s.N_P.V_T} \right)} - 1 \right) \qquad (7)$$

$$V_{GPV} = N_s n V_t \ln \left(1 + \frac{N_p I_{ph} - I_{GPV}}{N_p I_s} \right) - \frac{N_s}{N_p} R_s I_{GPV} \qquad (8)$$

2.4 Modeling of Boost chopper

A DC/DC converter is a chopper transistor type parallel voltage booster used to increase the output voltage from the source, the schematic diagram is shown in figure (5).
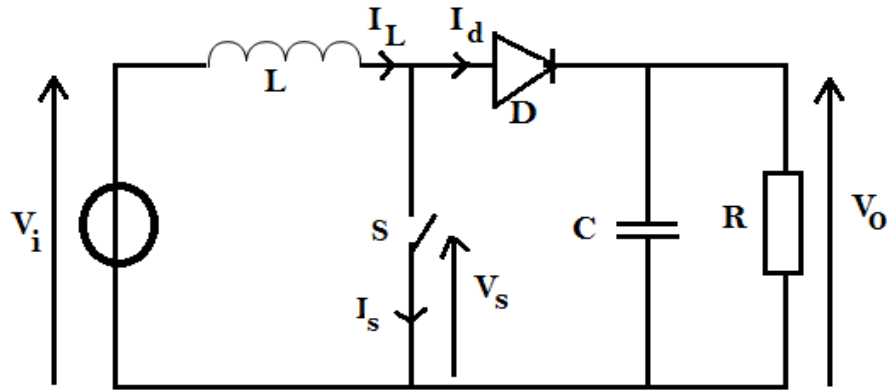
Figure 5. Model of a DC/DC chopper

It is sized for a 3 kW power that corresponds to the values nominal I=170, V=17.64 V, on the side of the generator, and Vs=50V, Is=60 A, load side. His transformation ratio is the duty cycle (ratio of time during which the transistor is closed, the period hash as $\alpha \ll 1$): and

$$\frac{V_S}{V} = \frac{1}{1-\alpha}$$

The chopper forces the GPV to operate at maximum power, whatever the illumination and transfer to the load for a duty cycle defined. This chopper has four components: An inductance L, a diode, a capacitor C and a switch that takes two states, S=1 and S=0. When the switch S is closed, the diode D is polarized in opposite the load is therefore isolated. The source provided energy to the inductance. If the switch S is open, the output stage receives energy from the source and inductor where an increase in the output voltage. Ideally, all components are ideal; the boost chopper can be modeled using the following ordinary differential equations:

$$C\frac{dV_c}{dt} = (1-s)i_L - \frac{V_c}{R} - i_0 \tag{9}$$

$$L\frac{di_L}{dt} = V_i - (1-s)V_c \tag{10}$$

And $V_0 = R.i$

We added to the previous model a resistance R_L internal inductance and resistance Rc internal capacity, so the (9) and (10) become:

$$C\frac{dV_c}{dt} = (1-s)i_L - \frac{V_0}{R} - i_0 \tag{11}$$

$$L\frac{di_L}{dt} = V_i - (1-s)V_0 - R_L i_L \tag{12}$$

$$V_0 = V_C + R_C.C.\frac{dV_C}{dt} \tag{13}$$

Inserting 13 in 11:

$$V_0 = V_C + \frac{RR_C}{R+R_C}(1-s)i_L - \frac{R_C}{R+R_C}V_C - \frac{RR_C}{R+R_C}i_0 \tag{14}$$

By developing the expression of V_0 in (15) becomes:

$$V_0 = V_C + \frac{RR_C}{R + R_C}(1-s)i_L - \frac{R_C}{R + R_C}V_C - \frac{RR_C}{R + R_C}i_0 \tag{15}$$

Developing the expression of V0 we get:

$$V_0 = \frac{R}{R + R_C}V_C + \frac{RR_C}{R + R_C}\left[(1-s)i_L - i_0\right] \tag{16}$$

The 11 expression becomes:

$$i_L = \frac{1}{L}\int\left[V_i - (1-s)V_0 - R_L i_L\right]dt \tag{17}$$

Using (16) and (17), it sets the pattern of the booster DC-DC real chopper, figure 6.
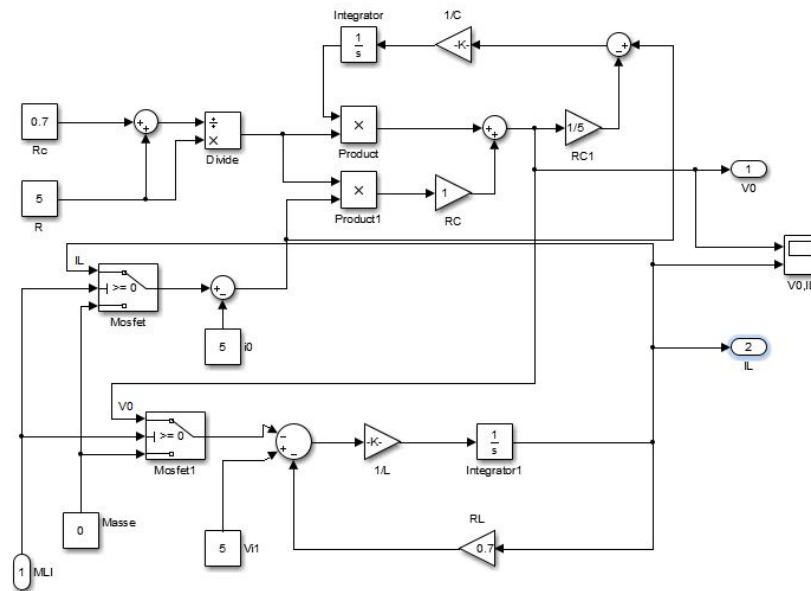

Figure 6. Real chopper Boost in Simulink

3.   MODELING OF THE COMMANDS

3.1. Control Algorithm "Disturbance and Observation"

The behavior of a GPV is nonlinear because its power depends on the temperature and illumination. Where the GPV feeds a network, it working at the point of maximum power MPPT to maximize performance. This MPPT always varies depending on the irradiation, the temperature…, We use an algorithm of Disturbance and Observation to find this item in real time. It is the algorithm based on disturbance of the system by the increase or decrease of Vi where by acting directly on the duty cycle of the DC - DC converter, then the observation of the effect on the output power of the Panel. If the value of power current P(k) of the Panel is larger than the previous P(k-1) value then we keep the same direction of previous disturbance otherwise you reverse the disruption of the previous cycle. Are model under Simulink is given by figure 7.
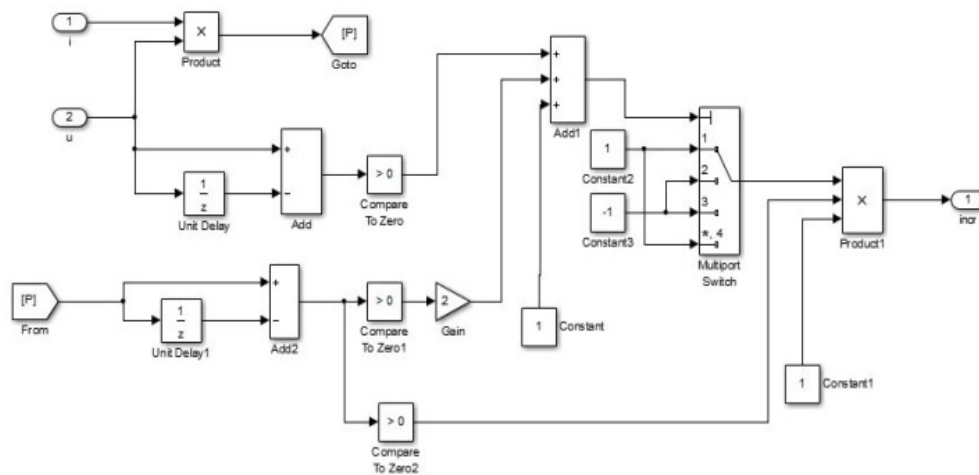
Figure 7. Simulink model of the P & O algorithm

3.2. Control by Pulse Width Modulation (PWM)

The PWM control is to cut the output voltage generated by the converter into a series of elementary patterns with low period, and variable duty cycle in time. The temporal change of the duty cycle of each switch is then determined by a modulating signal which is selected generally sinusoidal. The control commands of each cell are generated by the intersection between a triangular carrier and the modulating signal. According to the strategy, it can be sampled synchronously with the triangular carrier, or directly compared. Each switch is switched at a rate imposed by the carrier.

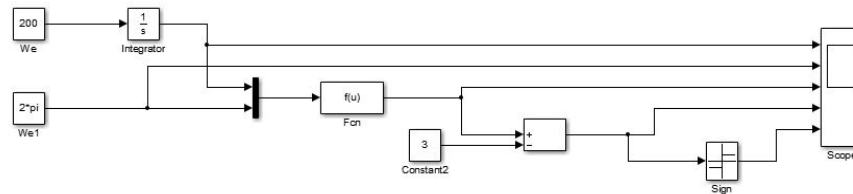The following figure illustrates the modeling of the PWM command in Matlab/Simulink.

Figure 8. Simulink model of the PWM control

4.   RESULTS

To realize the simulation considering the BTS as a resistive load. The figure (9) shows the evolution of the operating point on the power-voltage characteristic for different levels of sunlight and the figure (10) the power-voltage characteristic for different temperatures. For a duty cycle of 0.5, on at maximum power and figure (11) shows the relationship between the output power of the inverter and its duty cycle. Figure (12) shows that the power of the inverter output is equal to the load of the BTS.
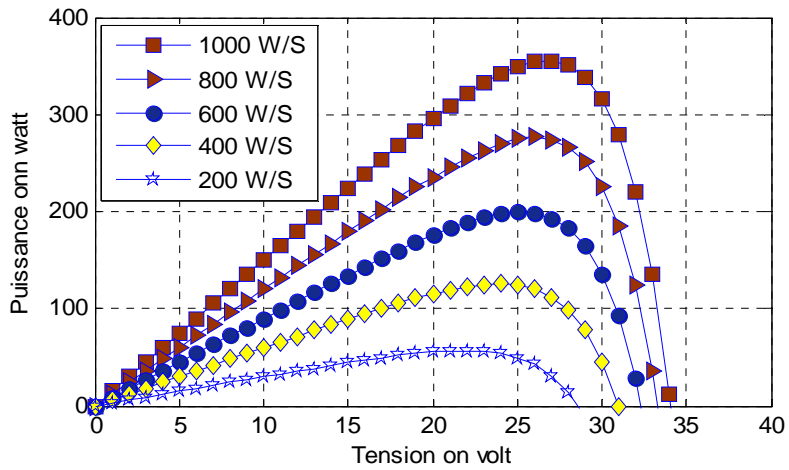
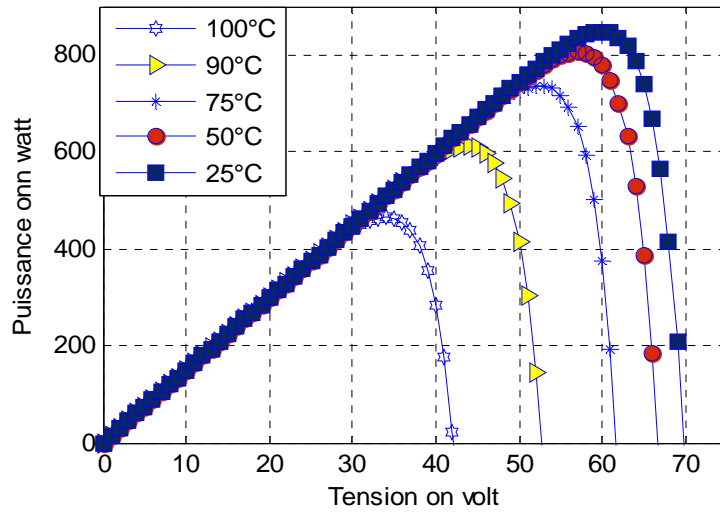Figure 9. Power-voltage characteristic for levels of sunshine

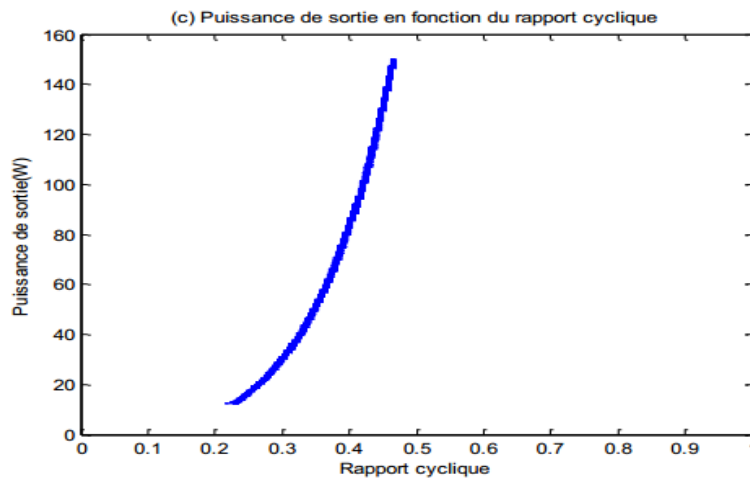Figure 10. Power-voltage characteristic for different temperatures

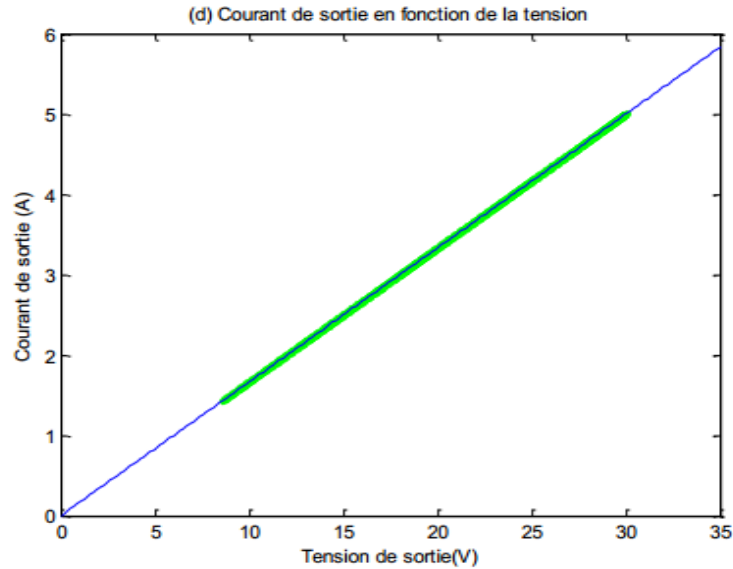Figure 11. Power curve depending on the ratio

Figure 12. I-V characteristic at the output of converter

5.   CONCLUSION

The consumption of fossil energy is a major source of environmental degradation. The Photovoltaic can be used in various applications. This type of application can be installed on the roof of private homes (an average of 3 kW). There are also systems of larger size, up to several megawatts. And to obtain the best power transfer between the PV generator GPV and the load, we modeled the entire conversion chain in Matlab and the search algorithm of maximum power point tracking (MPPT) has been designed and simulated. It forces the GPV to work at its Maximum Power Point (MPP), leading to an overall improvement of performance of electrical conversion system. Although satisfactory for direct GPV-BTS connection, improved P & O algorithm may be necessary in the case of sudden changes of temperature and insolation.

REFERENCES

[1]   D Saheb-Koussa, M Haddadi. "Modélisation d'un générateur photovoltaïque dans l'environnement". *4th International Conference on Computer Integrated Manufacturing CIP*, 03-04, 2007.
[2]   R Chenni, L Zarour, E Matagne T Kerbache. "Optimisation d'un système de pompage photovoltaïque". *Sciences & Technologie* B –No 26, décembre 2007.
[3]   A Meflah, T Allaoui. "Commande d'une chaîne de pompage photovoltaïque au fil du soleil". *Revue desEnergies Renouvelables*. 2012; 15(3).
[4]   J Surya Kumari and Ch Sai Babu. "Mathematical Modeling and Simulation of Photovoltaic Cell using Matlab-Simulink Environment". *International Journal of Electrical and Computer Engineering*. 2012; 2(1): 26~34.
[5]   R Chenni, M Makhlouf, T Kerbache, A Bouzid. *"A detailed modeling method for photovoltaic cells Energy"*. 2007; 32: 1724 – 1730.
[6]   Soltane BELAKEHAL. "Conception & commande des machines à aimants permanents dédié aux énergies renouvelables". *Thèse, Faculté des sciences de Constantine*, 2010.
[7]   C Boisvineau, M Nougaret et J Perard. "optimisation du fonctionnement d'un générateur photovoltaïque : Asservissement extrémal de la puissance". *Revue Phys*.1982; 17: 329-336.
[8]   Thi Minh Chau LE. "Couplage Onduleurs Photovoltaïques et Réseau, aspects contrôle/commande et rejet de perturbations". *Thèse université De Groneble*, 2012.
[9]   M.Hatti, IEEE Member. "Contrôleur Flou pour la Poursuite du Point de Puissance Maximum d'un Système Photovoltaïque". *JCGE'08 LYON*, 16 et 17 décembre 2008.
[10] Nur Mohammad, Md Asiful Islam, Tarequl Karim, Quazi Delwar Hossain. "Improved Solar Photovoltaic Array Model with FLC Based Maximum Power Point Tracking". *International Journal of Electrical and Computer Engineering*. 2012; 2(6): 717~730.
[11] Martin AIMÉ. "Évaluation et optimisation de la bande passante des convertisseurs statiques Applicationaux nouvelles structures multicellulaires". *Thèse Ecole Centrale de Lille*, 2003.