Control of a photovoltaic system by an analogical MPPT

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Abstract-*Renewable energies present the subject of current events, because the limited reserve of fossil energy will never provide for world growth need of energy which makes so important to develop means of exploitation of renewable energy sources, such as photovoltaic which takes an advanced place. Our work presented in this paper is considered as a step in this way, by presenting a model of an analogical MPPT, mounted on Simulink programme base, using principle of the famous Perturb an observe method. This MPPT is a means to control the power delivered by photovoltaic system. The work published in this paper is presented as following: At first we present à Simulink model of solar cell (Module) which make possible to simulate different solar cell characteristics in different meteorological conditions, after we expose different steps followed to verify our MPPT. Finally we expose different results of simulation.*

Key words: *Converter boost, analogical MPPT , Photovoltaic system, Inverter, Converter.*

I-Introduction.

The goal of this paper is to analyze the effect of the MPPT on the power delivered by a photovoltaic system.

II-Solar cell (module) model.

A solar module is constituted of a group of solar cells connected in series or in parallel. The number of cells in series corresponds to Ns multiplication of the cell tension, and the number of cells in parallel allows the multiplication Np time of current delivered by a cell.

The current delivered by a module can be expressed as following

$$I = N_p I_{ph} - N_p I_s \left[exp\left[\frac{q\left(\frac{V}{N_s} + \frac{IR_s}{N_p}\right)}{k_B T A} \right] - 1 \right] - \left[\frac{\frac{N_p V}{N_s} + R_s I}{R_{sh}} \right] [1] \qquad (1)$$

Such as:

$$I_{ph} = [I_{sc} + k_{sc}(T_c - T_{ref})] \frac{\phi'}{1000 Wm^{-2}} \qquad (2)$$

$$I_s = \propto_u T^3 \exp\left(-\frac{Eg}{K_B T_c}\right) [2] \qquad (3)$$

The injection of the mathematical model of the solar module in the simulink model fig (1) will allow to obtain a simulation base beforehand programmed that allow too to simulate the different characteristics of the solar module. Thus we have a model of a photovoltaic generator which presents one element of a whole photovoltaic system which will contain moreover: a DC/DC converter, an inverter, and a transformer**.**

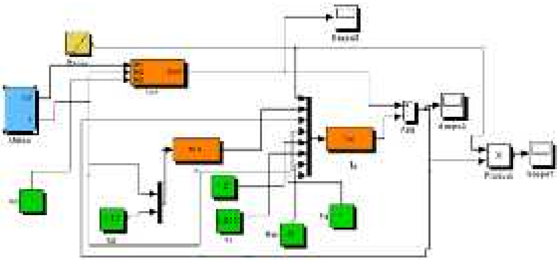

Figure1.Simulink Model of a solar module (cell)

III- Control of the maximum power delivered by a module.

The power extracted from a module is decided by the climatic conditions as well as by the load of which it feeds, in other words the power extracted from generator can be maximum only if the load has a very precise value known as optimal value, but the maximum power depends also on the irradiation; So for a given load the power which can deliver a generator statement is maximum only for one quite precise value of the irradiation, so what should be done? to force PV generator to deliver a maximum power, whatever the values of the load or the irradiation, the solution relies on the Maximum power point tracker indicated in summary by MPPT, it is a system which control the opening and the closing of the electronic switch of the converter between two times αT and 1 – αT successively, by the means of a PWM signal of period T.

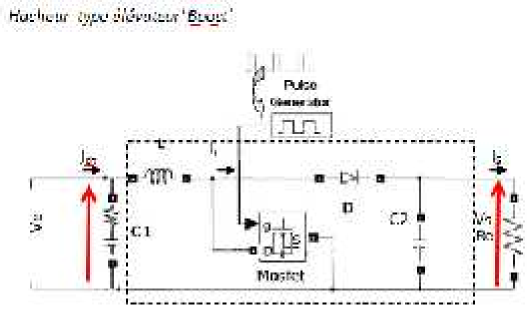

Figure2. DC/DC boost converter.

The device that we present in this paper is an analogical MPPT whose first idea was the principle of the MPPT of Z.Salameh [4]. It was verified according to the principle of the famous perturb and observes (P &O) method, it is one among a several methods proposed to build an MPPT.

Figure 3. Diagram principle of the MPPT which we developed under Simulink.

An MPPT generates a PWM signal fig (6), which orders closing and the opening of an electronic switch (MOSFET or a IGBT). For more detail we establish the mathematics relations between measures of entry and those of exit of the converter.
That is to say:

$$V_x = \frac{V_e}{(1-\alpha)} \tag{4}$$

α: the duty cycle , it is the ratio of the time of closing of the switch and the period of signal PWM.
Ve = V_{PV} the tension of entry of the converter is that provided from generator.

$$I_x = (1-\alpha) I_{pv} \tag{5}$$

I_x: current in the exit of DC/DC Converter

From(4), and (5), we deduce

$$R_{pv} = (1-\alpha)^2 R_x \tag{6}$$

Consequently

$$\alpha = 1 - \sqrt{\frac{R_{pv}}{R_x}} \tag{7}$$

Considering, $\alpha < 1$ there for $R_x > R_{PV}$

it is the condition which must be verified to say that we have a boost converter [5]

Under the optimal conditions, so
$R_{PV} = R_{optimale}$ we speaks about an optimal Duty cycle.

$$\alpha_{opt} = 1 - \sqrt{\frac{R_{opt}}{R_{sx}}} \tag{8}$$

From (4) and the (5), the power assessment is given by:

$$P_e = V_e I_e \approx V_x I_x = P_x \tag{9}$$

(If we neglect the power losses)

The Boost converter acts on its tension of entry (tension delivered by generator) in order to reach P_{max}; thus a change of the duty cycle of the ~ value to the~' value will enable us to write:

$$V_e = (1-\alpha) V_x \tag{10}$$
$$V_e' = (1-\alpha') V_x' \tag{11}$$
$$\alpha' = \alpha + at \tag{12}$$

Where a is a coefficient which could be positive or negative.

We substitute ~' in (11), so we have :

$$V_e' = (1-\alpha) V_x - at V_x \tag{13}$$

From where

$$V_e' = V_e - at V_x \tag{14}$$

According to the (14), one notes that an increase in the duty cycle (thus $a > 0$) lead to a reduction in the tension of entry of the converter (and conversely), which explains the role of the duty cycle in the pursuance of PPM.

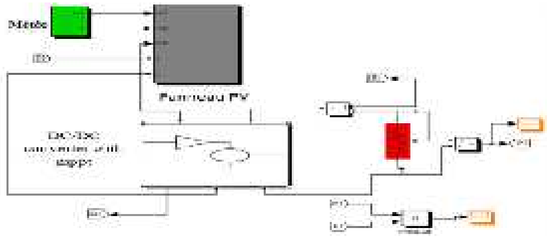

Figure 4. Model of PV system connected to a load.

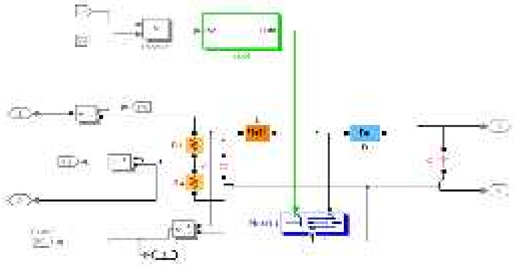

Figure 5.DC/DC Converter with MPPT.

In fig(6), on the right, figure the operation of creation of PWM signal by MPPT.

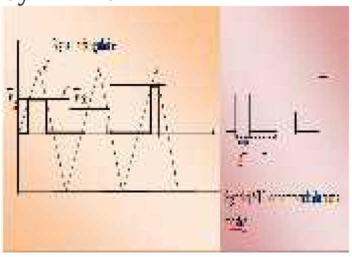

Figure 6. Production of a signal PWM.

IV. Simulation results

The simulated cell belongs to the solar panel Solarex MSX60. The model of the photovoltaic cell will enable us to obtain different characteristics of solar cell.

The figure 7 shows characteristic I-V and P-V of solar cell for the standard conditions.

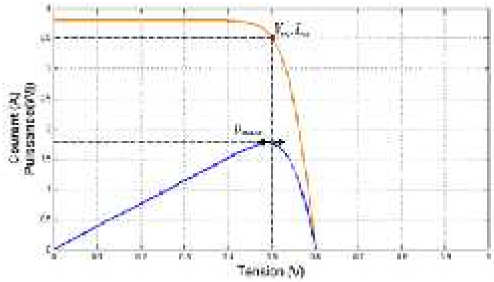

Figure 7. Characteristic I-V and P-V of a solar cell of crystalline silicon, under conditions standards ($\emptyset_{ref} = 1Kwm^{-2}, T25^{\circ}C$).

- Influence of the various agents (Irradiation, Temperature, series Resistance, shunt resistance) on characteristics I-V and P-V.

Figures 8 and 9 watch successively the influence of irradiation on the characteristics I-V and P-V.

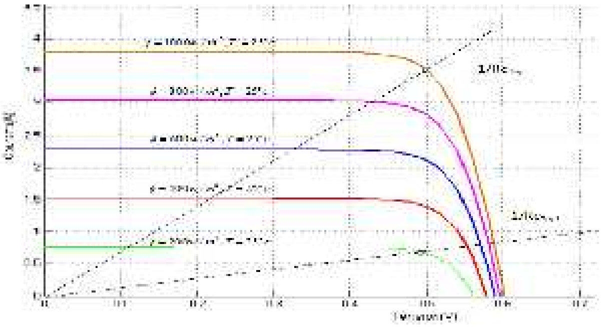

Figure 8.Characteristic I-V for different irradiations (solar cell).

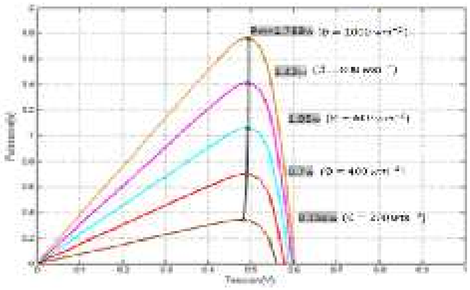

Figure 9. Characteristic P-V for different Irradiations (solar cell)

Table.1. Losses of power per contribution to optimal value following to changes of irradiation (without MPPT).

Irradiation(Wm^{-2})	Losses in irradiation	Maximum power	Delivered power(w)	Losses in power
$\emptyset$	$\frac{\emptyset_{ref}-\emptyset}{\emptyset_{ref}}$.	P_{opt}	P_d	$\frac{P_{opt}-P_d}{P_{opt}}$
1000	0	3.3834	3.3834	0
800	20%	2.7067	2.3729	12.8%
600	40%	2.03	1.3553	33.23%
500	50%	1.6917	0.9423	44.2%
00	60%	1.3534	0.6033	55.4%

200	80%	0.6767	0.1508	77**%**

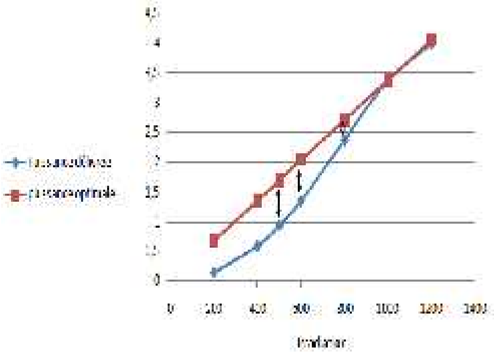

Figure 10. Influence I of irradiation on the power delivered by a solar cell connected to optimum load impedance corresponding to $\phi_{\text{réf}}$

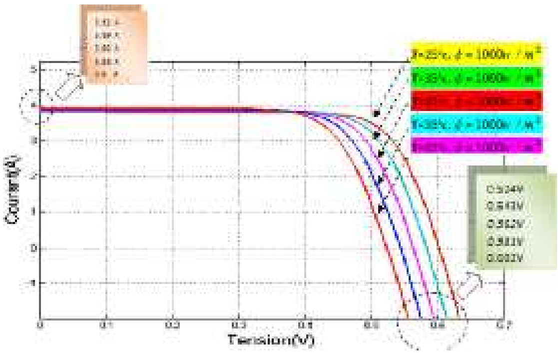

Figure11. Characteristic *I-V for different Temperatures.*

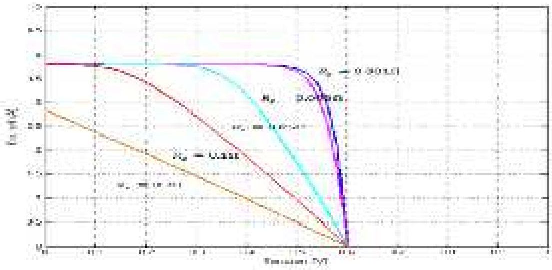

Figure12. Influence resistance series on characteristic I-V.

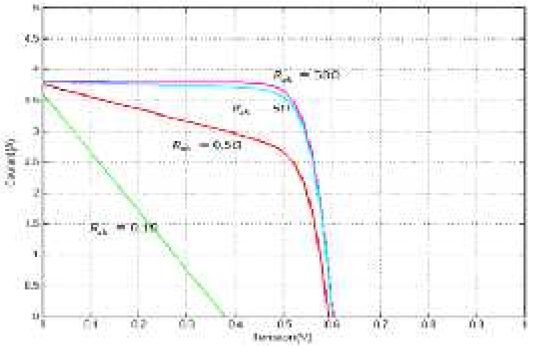

Figure13. Influence resistance shunt on characteristic I-V

The radial force influences the power delivered by a solar module.

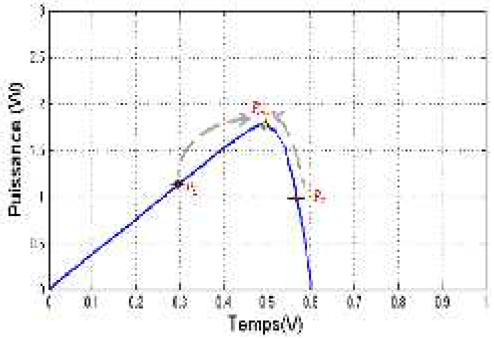

Figure 14.Characteristic of power. P1, P2 two powers correspond to two loads (R 1, R 2) such as R1<R_{opt}<R2
For a cell.

The results presented in the figures 15.a and 15.b are gathered in figure 15. In this figure it is visible that the MPPT remarkably improved the power extracted of the module in front of changing of load. Aspect of power graph delivered by a solar cell (module) without acting of MPPT, (on the right in above of the fig15).

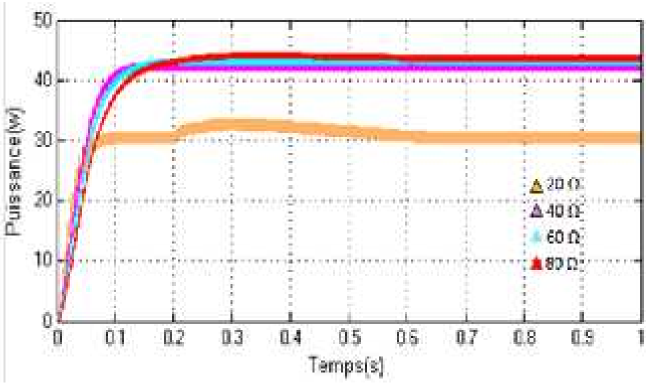

Figure15.a . Graphs of the maximum powers for four loads equal or lower than the optimum load impedance at the exit of the (DC/DC) converter.

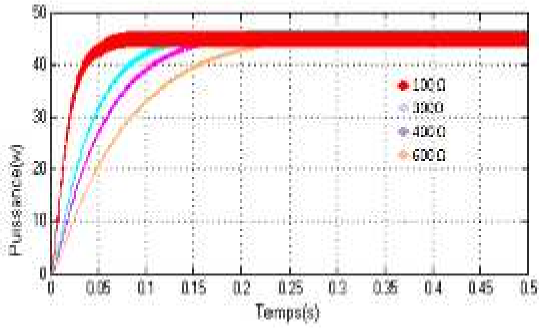

Figure15.b.Graphs of the maximum powers delivered by a module for loads equal or higher than the optimum load impedance at the exit of the converter.

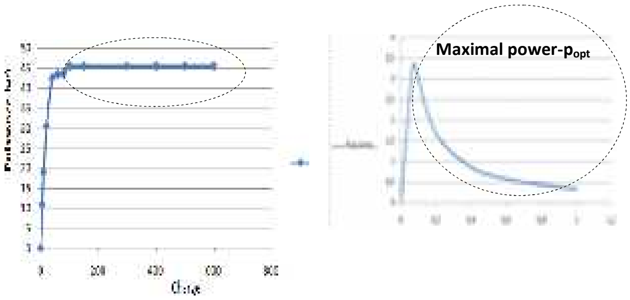

Figure 15.Maximum power delivered according to the value of the load at the exit of the converter.

According to the fig15 maximum power is magnificently reached for values of the load, higher than the optimum load impedance which is in this case equal to 100Ω.

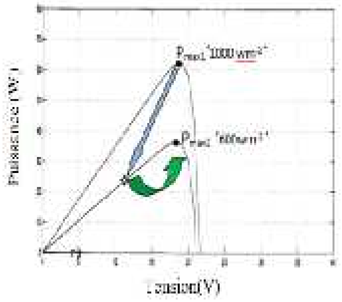

Figure 16.Action of the MPPT on the power with a changes of irradiation

We see in the tableau1 that the change of irradiation, reduces seriously the power delivered by the module compared to corresponding optimal value, this loss can reach 80% for an irradiation equal to 200wm^{-2} ; using of the MPPT reduces seriously these losses, see tab2.

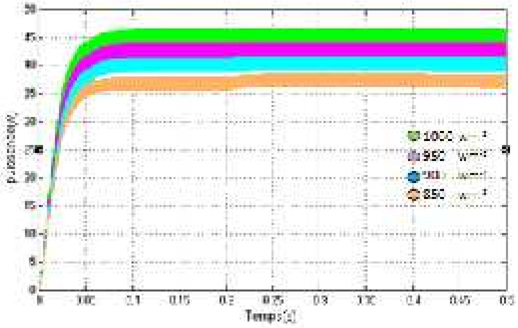

Figure17. Maximum powers delivered by a system statement with MPPT for different close irradiations.

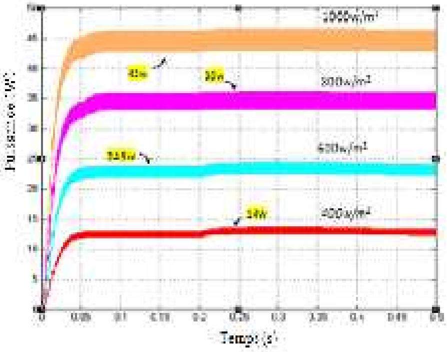

Figure18. Maximum powers delivered by a small system statement of MPPT for distant irradiations.

Table 2. Power delivered at the exit of the converter for various irradiations.

Irradiation(w/m^{-2})	1000	950	900	850	800	600	400
Maximal power(w)	45	42.75	40.5	38.25	36	27	18
Delivered power-p_d(w)	45	42.7	10.4	37.2.	35	24.5	14
$(p_{opt}p_d)*100/p_{opt}$	0	0.11%	0.24%	2.74%	2.77%	9.25	22.22

Figure 19, shows the speed of reaction of PV system equipped by an MPPT while an abrupt changing of irradiance.

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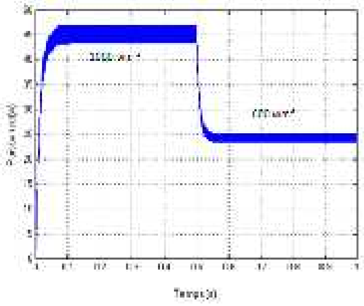

Figure 19.Reaction of a PV system equipped by an MPPT following an abrupt changing of the irradiation.

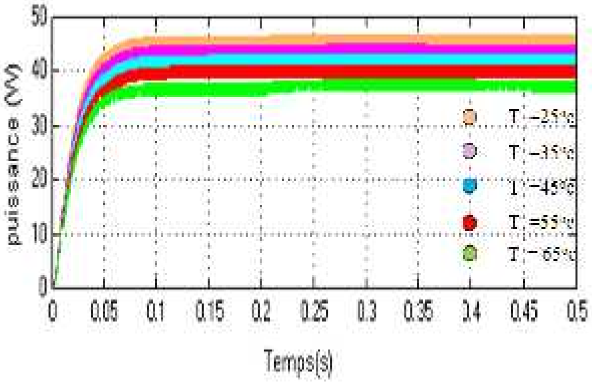

Figure 20.Power delivered by a PV system for various temperatures.

V.Conclusion

In this paper we showed at which point the use of the MPPT is necessary to make a photovoltaic system stable , effective and of a best efficiency. The results of simulation of the signals on the outlet side of the inverter did not appear in this paper.

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