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A Generalized Method MPPT Controller for a Photovoltaic System

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ABSTRACT : Currently, renewable energies become alternative solutions to replace fossil energies. Solar energy is one of these solutions. It uses the PV power system. To improve the PV panels efficiency, influenced by the temperature and solar radiation, several technics of the Maximum Power Point Tracking are now used. This paper presents a new topology of Photovoltaic power generation system with simple Maximum Power Point Tracking (MPPT) approach named Generalized Method (GM-MPPT). The GM is simple to be implemented. Simulation results show that the GM-MPPT presents better performances as, tracking, robustness and stability by comparison with the P&O method.

KEYWORDS – Generalized Method (GM), P&O, MPPT, photovoltaic system.

I. INTRODUCTION

Renewable energy sources become more important and necessary to contribute at the total energy consumed in the world. Currently, their utilization increases considerably to reduce pollution. The generator photovoltaic system (GPV) is one of these sources which is widely used. Besides, it does not need much maintenance and does not generate noise. The GPV uses solar panel to convert sun irradiation to electric energy using photovoltaic effect. It is well-known that the output voltage of a solar panel is varying according to the sun irradiation and temperature [1], [2]. In order to get the maximum of power from solar panels and enhance the PV system's efficiency, using a maximum power point tracker (MPPT) algorithm is necessary. Various MPPT methods have been developed and implemented. The perturbation and observation (P&O) method is the most popular because of the simplicity of its control structure and few measured parameters for the power tracking. The name of algorithm itself reveals that it operates by periodically perturbing the control variable and comparing the instantaneous PV output power after perturbation with that before. Therefore, continuous perturbation or oscillation occurs around the MPP in steady state [3]. This method cannot readily track immediate and rapid changes in environmental conditions or partial shading of the PV modules. Indeed, tracking the maximum power point is difficult when a PV array is partially shaded or is installed in a rapidly changeable insolation conditions, because two or more local maximum power points may appear [3]. In this paper, a novel strategy of MPPT is proposed for photovoltaic power generation systems based on generalized method controller to realize simple control system to track the real maximum power point even under non-uniform insolation conditions or for rapidly changing insolation. First, a generality of a system PV and its modelling with the boost converter are given. Then, P&O and the GM methods are presented. Finally, simulation results are showed to do comparison between the two methods. A conclusion resumes the present study.

II. PV SYSTEM DESCRIPTION

Figure 1 presents the electrical power circuit employed to test the performances of the MPPT approach. A photovoltaic module constitutes the energy source of the PV system, the boost converter acts as interface between the solar panel and the load and the MPPT controller allows reaching the available maximum power. Notice that the current IPV and the voltage VPV provided by the PV module are used as inputs to the Boost converter and to the MPPT controller. The average control signal u generated by the MPPT controller is sent to the converter [4].

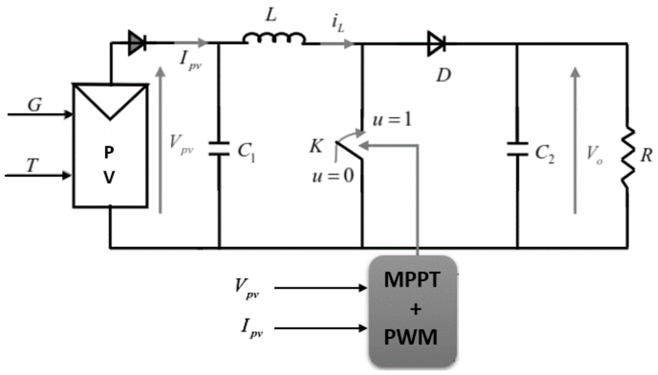

Figure 1. Photovoltaic system with MPPT controller

A. *PV cell Model:* *In this paper, the single-diode PV cell modeling was adopted, as shown in Fig.2 [11].*

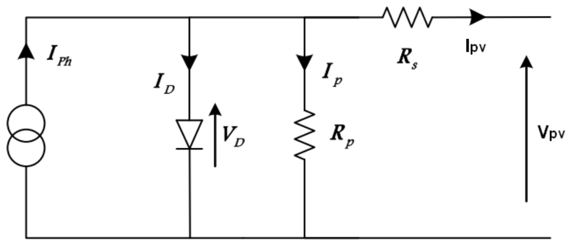

Figure 2.Equivalent circuit of a PV cell

It can be noted that the PV cell is modelled by a current source (Iph) with an anti-parallel diode associated with series (Rs) and parallel (Rp) resistances. The model of a PV issues from this schema, defined by the following equations [5], [11], [12]:

$$I_{pv} = I_{ph} - I_d - I_p \tag{1}$$

Where, Iph is a photo current, Id is a diode current and Ip a shunt current.

The PV cell equation is given by relation (2):

$$I_{pv} = I_{ph} - I_s\left[\exp\left(\frac{q(V_{pv} + R_s I_{pv})}{nkT}\right) - 1\right] - \frac{(V_{pv} + R_s I_{pv})}{R_p} \tag{2}$$

Where **Vpv** is the panel voltage, **Ipv** the panel current, **n** the ideality factor, **k** , the Boltzmann constant, **q**, the electron charge, **T**, the temperature in Kelvin, and **Is**, the saturation current

B. PV cell characteristics: Figure 3 and Figure 4 show the I-V and P-V characteristics of PV cell under different temperature levels (fixed irradiance). Figures 5 and 6 show the I-V and P-V characteristics of PV cell under different solar radiation levels (fixed temperature).

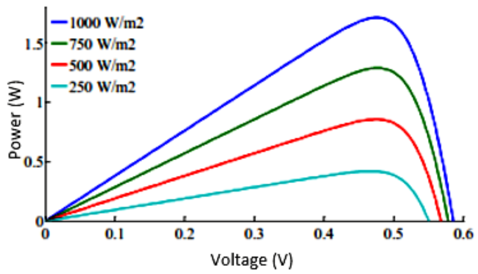

Fig.3 P-V curves under different solar irradiance (T=25°C)

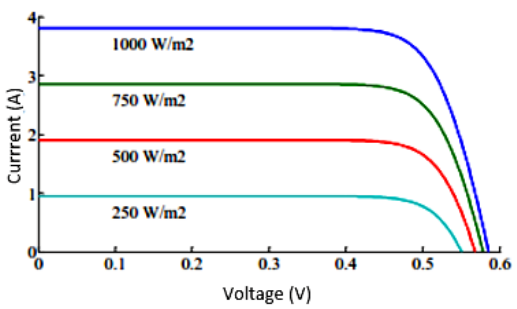

Fig. 4 I-V curves under different solar irradiance (T=25°C)

From Fig.3, it is noted that the power of the PV cell increases as the solar radiation value increased. Besides that, Fig.5 shows that the voltage of the PV cell decreases as the ambient temperature value decreased. From

Fig.4, it is clear that the current of the PV cell increased linearly by increasing the solar energy, while the voltage of the PV cell increased in a logarithmic pattern as the solar radiation increases. Figures 5 and 6 give the characteristics when the irradiance solar is taken constant (here G = 1000 Wh/m²) and the temperature is varying.

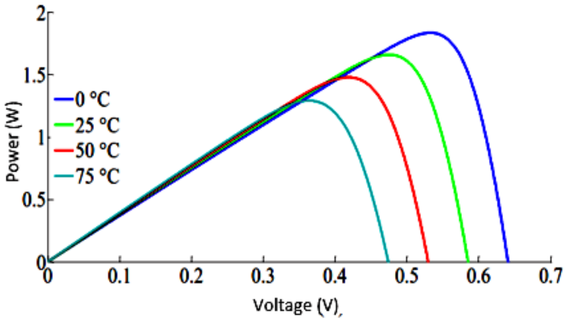

Figure 6. P-V curves under different temperatures and constant solar irradiance (G = 1000 Wh/m²)

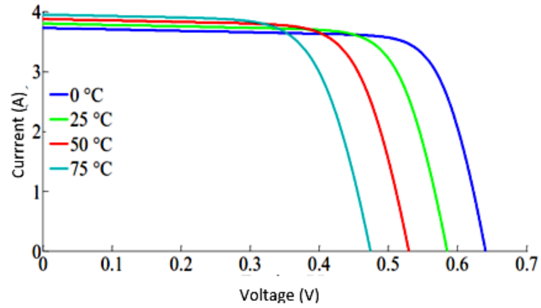

Figure 7. I-V curves under different temperatures and constant solar irradiance (G = 1000 Wh/m²)

From Figures 6 and 7, the voltage of the PV cell decreases as far as the ambient temperature value increases, while the current of the PV increases in logarithmic pattern by the decrease in the ambient temperature [13].

As for the model of a PV module, it can be described by the following equation:

$$I_{pv} = N_p I_{ph} - N_p I_s \left[\exp\left(\frac{q(V_{pv} + R_s I_{pv})}{N_s nkT}\right) - 1\right] - N_p \frac{(V_{pv} + R_s I_{pv})}{R_p} \quad (3)$$

Here, **Ns** and **Np** are the number of PV cells in series and parallel respectively.

C. DC-DC Boost Converter: DC-DC converter is used to transfer power of solar panel to load side ensuring that maximum power has been transferred [10]. The regulation is normally achieved by pulse within modulation (PWM) and the switching device is normally MOSFET or IGBT. Boost DC-DC converter's function is to step up DC voltage [11]. Fig.7 shows configuration of DC-DC boost converter. Maximum power is reached when the MPPT algorithm changes and adjusts the duty cycle of the boost converter.
The voltage output V_o is given by:

$$V_o = \frac{V_{PV}}{1-D}, \quad (4)$$

Where D denotes the duty cycle.

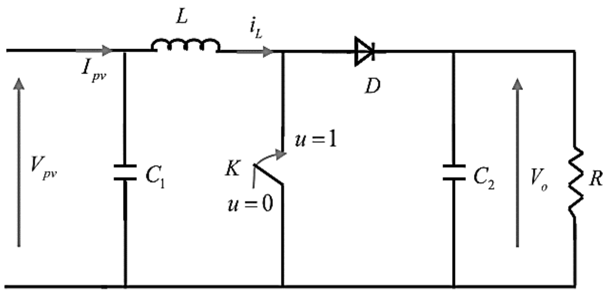

Figure 7. DC-DC boost converter

In (4), it can be noticed that if D increases, the output Vo increases and when D decreases, the output Vo decreases.

D. P&O MPPT Controller: Due to its simplicity, P&O algorithm presented in Fig.8 is the most widely used method of the conventional MPPT [6. 28]. In this algorithm a small perturbation is introduce to the system. This perturbation causes the power of the solar module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached, the algorithm oscillates around the peak point. In order to keep a small power variation, the perturbation size is kept very small [7], [8]. This method works well in the steady state condition (the radiation and temperature conditions change slowly). However, the P&O method fails to track MPP when the atmospheric condition is rapidly changed. Flowchart of the P&O method is described in Figure 8 [7]-[10].

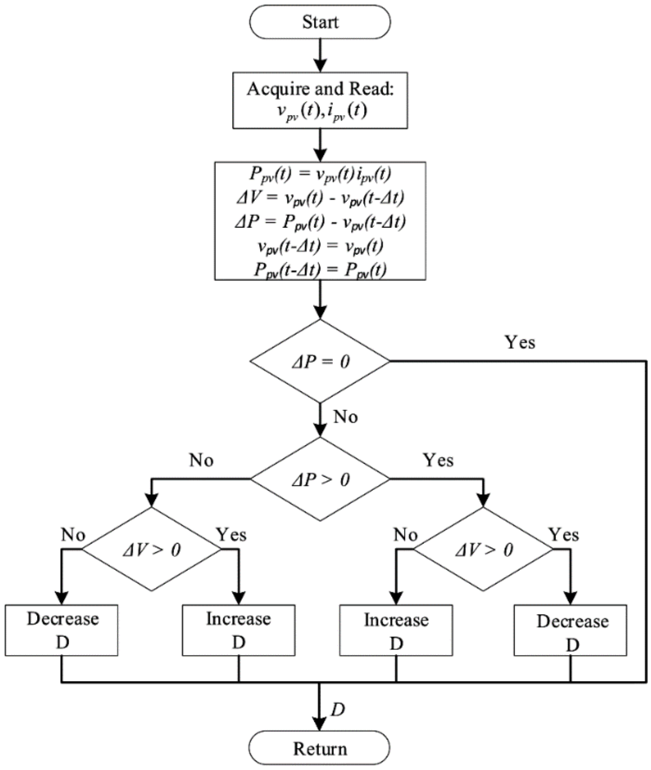

Fig.8 P&O allgorithm

E. Generalized Method (GM): The MPPT control is generally based on the adjustment of the DC-DC converter duty cycle in manner automatic to bring the generator to its optimal operating point regardless of weather conditions or brutal variations of loads, which can occur constantly. Several MPPT algorithms have been proposed in the literature. Among all these strategies, the maximum power point of a PV module will reach a maximum value when ΔP/ΔV equals to zero. In this part, a new method is proposed and the reasoning is the same: maintaining □P/□V equal to zero but by using a traditional P controller with a gain **g**. The reasoning rests in Figure 9.

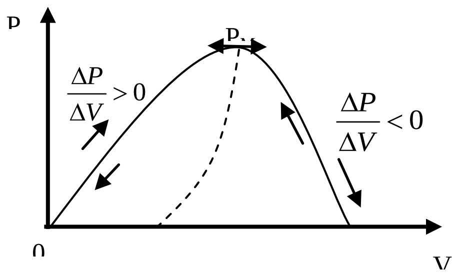

Figure 9. Reasoning using P-V characteristic

The characteristic is devised in two regions: the left region where $\Delta P / \Delta V$ is positive and the right one where $\Delta P / \Delta V$ is negative.

When $(\Delta P / \Delta V) > 0$, V must be increased so D must be increased and when $(\Delta P / \Delta V)$ is < 0, V must be decreased and the duty cycle D decreased too.

The error is given by,

$$e = \text{reference} - (\Delta P / \Delta V) \quad (5)$$

Here, the setpoint or the reference is assumed to be null. Since this reference is equal to zero, the sign of the error is the opposite to ($\Delta P/\Delta V$).
Thus,

$$\begin{cases} e > 0 \Rightarrow \Delta P/\Delta V < 0 \Rightarrow D\downarrow \\ e < 0 \Rightarrow \Delta P/\Delta V > 0 \Rightarrow D\uparrow \end{cases} \quad (6)$$

So, in anytime when using a gain ***g*** of a P controller,

$$\begin{cases} e \neq 0 \Rightarrow D(k) = D(k-1)) - g.e(k) \\ e = 0 \Rightarrow D(k) = D(k-1) \end{cases} \quad (7)$$

If the error ***e*** ≠ 0, the relation (4) permits automatically if the duty cycle D must be decreased or increased. The gain ***g*** accelerates the convergence to the point of maximum power point P_M. Figures 10 and 11 show the implementation and the algorithm of the proposed method.

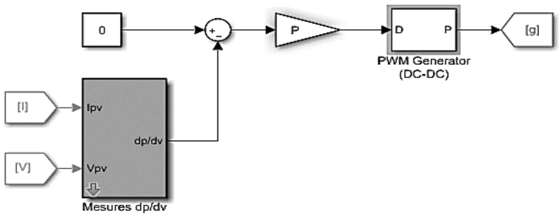

Figure 10. GM MPPT implementation

In Fig.10, P denotes a Proportional controller with a gain ***g***. Fig.11 shows the GM-MPPT algorithm

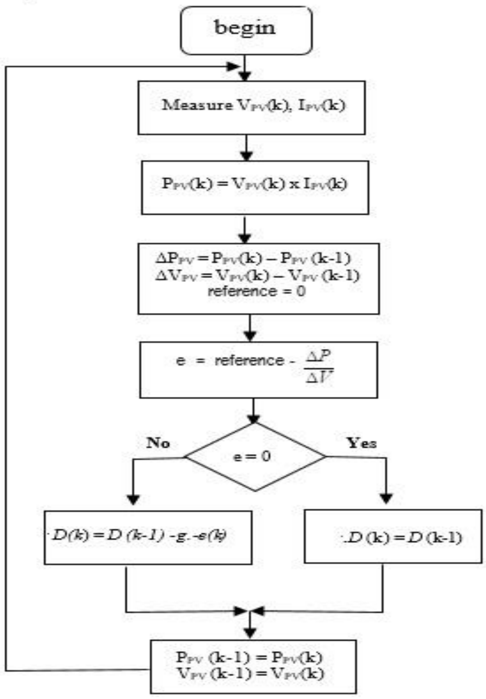

Fig.11 GM-MPPT algorithm

II. SIMULATION RESULTS AND DISCUSSIONS

The photovoltaic system illustrated in Fig.1 is modelled in MATLAB/Simulink. A boost converter is used as an interface of the PV array and a resistive load. The characteristics of the simulated PV panels and the boost parameters are shown in table-I and table-II, respectively. To perform the maximum power point tracking, both P&O and generalized method have been implemented with all consideration of the optimization techniques. The simulation allows verification of the feasibility and relative performance of both algorithms under correctly the same conditions. Here, the main aspect to consider is the dynamic performance in terms of the speed at which the system converges on maximum power point, and the ripple in the power due to oscillations around the maximum power point at steady state conditions

TABLE 1: Standard Test Conditions (STC) of the Solarex MSX-60 PV Module

Maximum PV Power	Pmax = 60 Wc
MPP Voltage	Vmpp 17.1 V
MPP Current	Impp = 3.5 A
Open-Circuit Voltage	Voc = 21.1 V
Short-Circuit Current	Isc = 3.8 A

TABLE 2: Boost Converter Parameters

PV Input Capacitance	C1 = 1000µF
Inductance	L = 220µH
Boost Converter Output Capacitance	C2 =470µF
Resistive Load	R = 30Ω
Switching Frequency	fp =10 kHz

The performance of the two controllers are analyzed in the following conditions:

- Operation under Standard Test Conditions (STC)

In this case, the temperature and irradiation are considered constant. The values are taken under standard conditions: temperature 25°C and irradiation in 1000W/m2. Figures 12 to 15 show the results under STC.

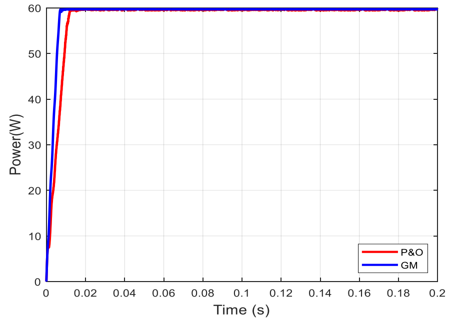

Fig.12 PV power comparison under STC

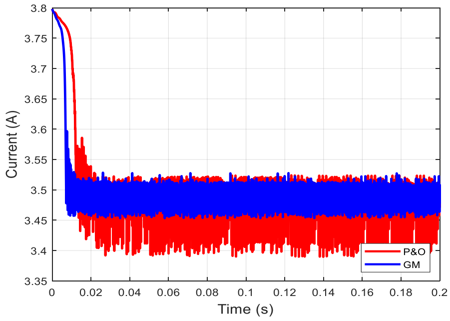

Fig.13 PV current comparison under STC

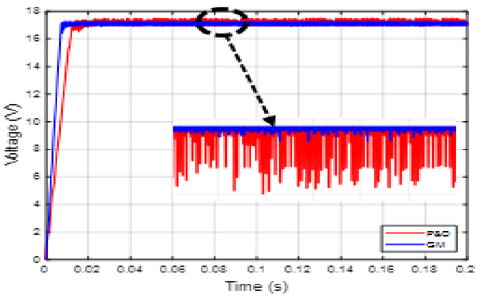

Fig.14 Voltages comparison under STC

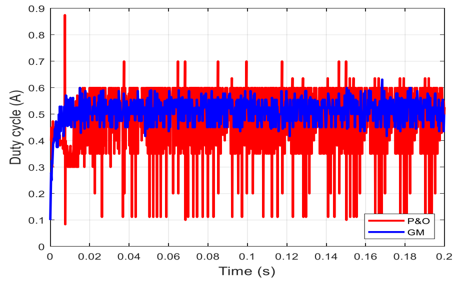

Fig. 15 Duty cycle comparison under STC

The comparisons between GM and P&O are shown in Fig.12 to Fig.15. For the initial MPP tracking, GM requires 10ms compared to P&O, which needs 20ms. Furthermore, P&O exhibits lengthier fluctuations in the transient state because the algorithm has to perform more checks while converging to MPP. However, in steady state both methods track the MPP perfectly.

- Operation with Variable Conditions (OVC) : In this case, the temperature is constant (T = 25°C) and irradiation is changing with time under different condition. The step change in irradiance arises when a cloud passes over a PV array at a very fast rate. To evaluate the performance of the algorithm under such condition, three steps of the irradiation (G=700, 1000 and 850 w/m2) are imposed on the PV array. Figures 16 to 19 show the different simulation results.

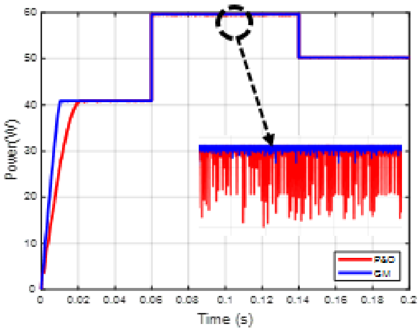

Fig. 16 Powers comparison under OVC (T=25°C)

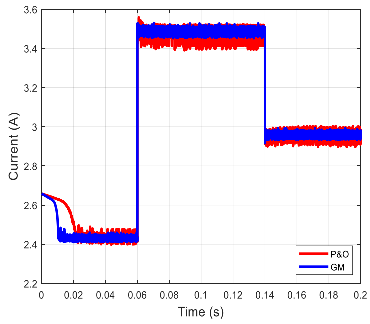

Fig.17 Currents comparison under OVC (T=25°C)

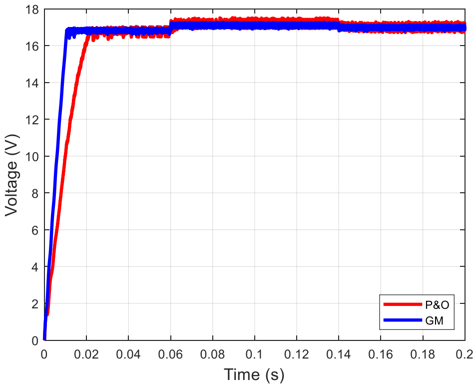

Fig.18 Output Voltages comparison under OVC

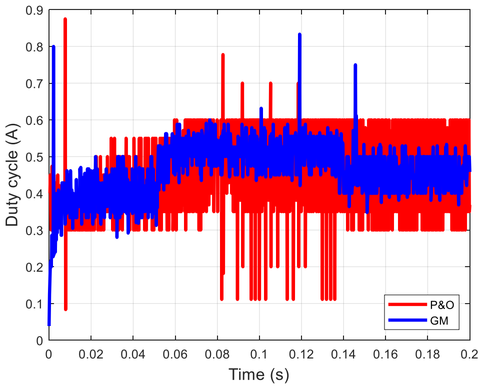

Fig.19 Duty cycles comparison

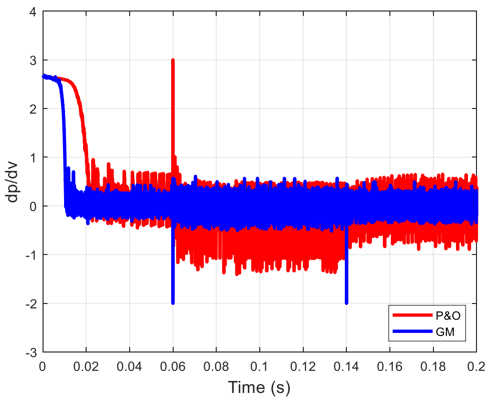

Fig.20 ΔP/Δ comparison

Fig.16, Fig.17 and Fig.18 show that GM-MPPT provides a fast response time (less than 10ms) to track the maximum power point with high stability and less oscillation compared to P&O which shows a lot of oscillation in the three steps; this result confirm how the GM-MPPT can truck the Maximum Power Point with high performances. Fig.19 and Fig.20 present the duty cycle and ΔP/ΔV curves with fixed temperature and variable irradiation. The results obtained in the two figures show that the response produced with the P&O presents most important oscillations because the P&O controller is tracking in the wrong way when sudden variations of solar irradiance occurs and adjusts itself in the right direction after few times.

III. CONCLUSION

In this paper, a novel control strategy for the MPPT was presented. Numerical simulations were performed in MATLAB/Simulink to assess the effectiveness of the generalized method control law against sudden variations of weather conditions. The theoretical maximum power was reached; it can be concluded that the sudden variations of solar irradiance do not degrade the performance of the proposed MPPT technique. Furthermore, it was shown that the GM has some advantages compared to the P&O algorithm related to the PV system response. Indeed, simulation results confirmed that the proposed MPPT method presents best performances related to higher tracking speed, faster convergence towards the MPP, better tracking efficiency and lower power oscillations at MPP. All these remarks lead to say that GM-MPPT controller is interesting and moreover it is easy to implement.

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