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# Sliding Mode Control Strategy For Analysis And Simulation Of Maximum Power Point Tracker Of Photovoltaic System

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***Abstract*— Control of the DC-DC converter is a complex task of the nonlinearity inherent in the converter and introduced by the external changes. We propose in this article to study an application of sliding mode control strategy to track maximum power of photovoltaic generator. We compared the results with those obtained using the Perturb & Observer method. In this control system, it is necessary to measure the PV array output power and to change the duty cycle of the DC/DC converter control signal. The Sliding mode control and results has been presented with MATLAB Simulink software to analyse the performance of photovoltaic system with different conditions of the irradiation, temperature. Obtained results are presented and show the performances of sliding mode control strategy under the parameter variation environments.**

***Keywords*— Solar energy, photovoltaic arrays modelling, optimization, Sliding mode MPPT controller.**

## I. INTRODUCTION

Modern electronic systems require high small, lightweight, reliable, and efficient power supplies. So the DC/DC converters are widely used in many industrial and electrical systems. The most familiar are switching power supplies, DC drives, photovoltaic systems and Fuel cell. Design of controller for these converters is a major concern in power converters design [1-3]. Different control techniques are applied to regulate the DC-DC Converters, especially buck boost converters, in order to obtain a robust output voltage.

Sliding mode control is a well-known discontinuous feedback control technique which has been exhaustively explored in many books and articles. The technique is naturally suited for the regulation of switched controlled systems, such as power electronics devices, in general, and DC/DC power converters, in particular [2].

We present firstly in this paper the studied system with the proposed MPPT. Then the modelization of the overall system is developed. Finally obtained simulation results and some experimental ones are presented to show the performances of sliding mode control comparing to P&O method.

*A. Proposed description system:*

The configuration of the studied system is shown in Fig.1.It consists of a PV array, converter, an MPPT power stage and a sliding controller.

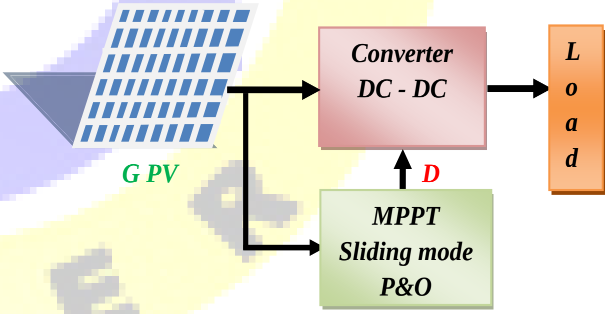


Fig.1. Schematic of the conversion chain.

*B. Modeling of the proposed system*

*1) Model of PV Array*

Solar cells are basically p-n junctions. In the dark, their *I-V* characteristic is similar to that of a diode. Most of the models used in the literature include an ideal diode, related to the junction behavior, and a series resistance, taking into account the ohmic losses. We obtain then the equivalent circuit diagram drawn at the figure 1 [1][2].

The characteristic *I-V* of the cell is then given by the implicit equation.

$$I = I_L - I_0 \, [\exp\left(\frac{q\,(V + R_S . I)}{\gamma . K . T_c}\right) - 1] \qquad (1)$$

Where: $I_L$, $I_0$, $I$, $V$, are the photocurrent, saturation current, Operating current and voltage, $Rs$ and $\gamma$ are series resistance and diode quality which depend on the incident solar irradiation and the cell's temperature. At fixed temperature, the model offers four degrees of freedom, namely $I_L$, $I_0$, $\gamma$ and $R_S$.

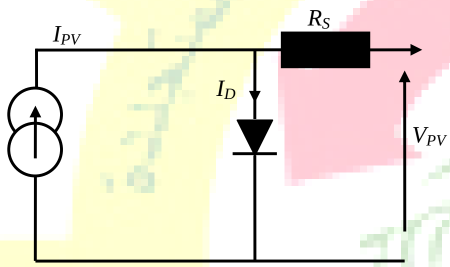


Fig .2 Equivalent circuit of PV cell

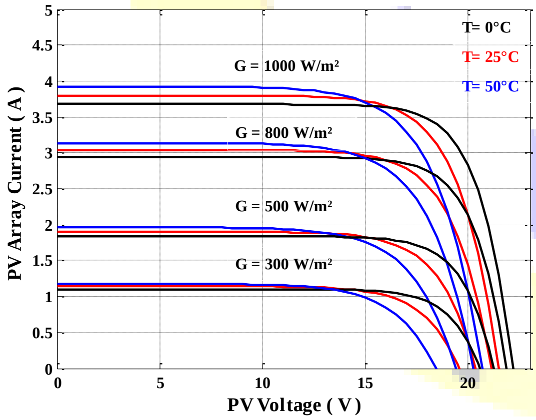


Fig. 3. *I (V)* Characteristics of PV panel

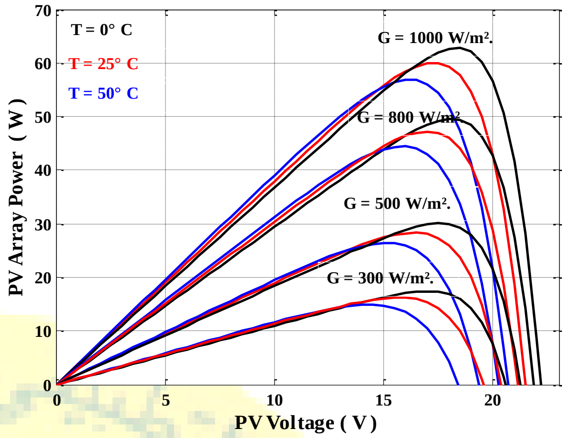


Fig. 4. *P (V)* Characteristics of PV panel

*C. Perturb and Observe (P&O) method [11][12]*

A P&O method is the most simple, which moves the operating point toward the maximum power point periodically increasing or decreasing the PV array voltage by comparing power quantities between in the present and past. The block diagram of P&O method is illustrated in Fig. 5.

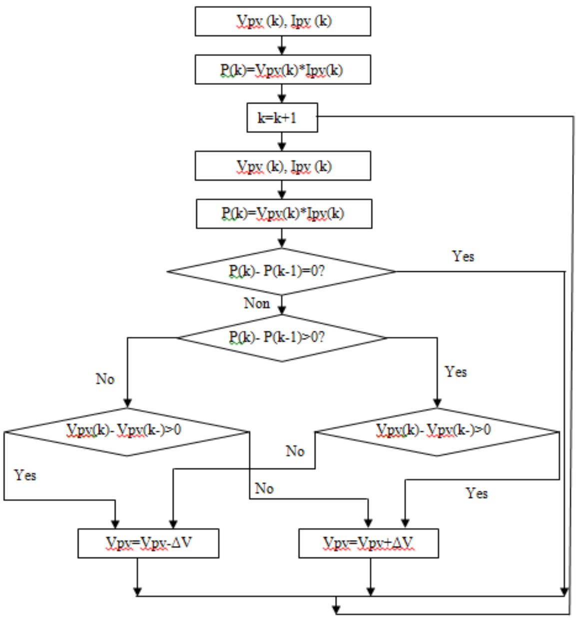


Fig 5.Flow chart diagram of P&O MPPT method

*D. Solar subsystem.*

The dynamic model of the solar subsystem written in terms of voltage and current between input and output of the buck-boost converter can be expressed as: [5].

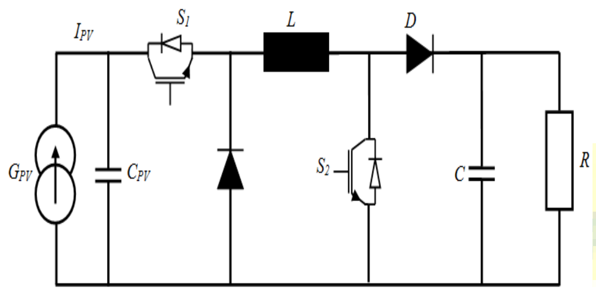


Fig. 6 Simplified non-inverting Buck-Boost converter.

$$\begin{cases} \dfrac{dV_{PV}}{dt} = \dfrac{i_{PV}}{C_{PV}} - \dfrac{i}{C_{PV}} u \\ L\dfrac{di}{dt} = (1-u).V + u.V_{PV} \\ C\dfrac{dV}{dt} = -(1-u)i - \dfrac{V}{R} \end{cases} \quad (2)$$

Where $i_{PV}$ is the current injected on the *DC-DC* converter, *L*, *C* are electrical parameters of the *DC-DC* converter, *u* is the duty cycle [7][8].

*E. Sliding mode controller*

*1) Sliding Mode Controller Surface*

A sliding mode controller is a variable structure control where the dynamics of a nonlinear system is altered via the application of a high frequency switching control. In sliding mode control, the trajectories of the system are forced to reach a sliding manifold of surface, where it exhibit desirable features, in finite time and to stay on the manifold for all future time. It is achieved by suitable control strategy [9][10]. To apply sliding mode control we have to know if the system can reach the sliding manifold. Once the systems reach the sliding manifold, the controller has to force the system to stay in the manifold for all future time [3].

PV array output power $P_{PV} = V_{PV}.i_{PV}$

The state of maximum output power *($\partial P_{pv} / \partial I_{pv} = 0$).*

Based on the solar array characteristic curve shown in figure.4, when the solar array is operating in its maximum output power state, we can get [4][5].

- The Controller Design

PV array output power

$$P_{PV} = V_{PV}.i_{PV} \quad (3)$$

$$\frac{\partial P_{PV}}{\partial V_{PV}} = \frac{\partial (V_{PV}.i_{PV})}{\partial V_{PV}} = 0 \quad (4)$$

$$S = \frac{\partial P_{PV}}{\partial V_{PV}} = \frac{\partial i_{PV}}{\partial V_{PV}} V_{PV} + i_{PV} \quad (5)$$

The system equation (2) can be written as follows:

$$\dot{x} = f(x) + g(x)u \quad (6)$$

Where:

$$\dot{x} = \begin{bmatrix} \dot{V}_{PV} \\ \dot{i} \\ \dot{V} \end{bmatrix} \quad f(x) = \begin{bmatrix} \dfrac{i_{PV}}{C_{PV}} \\ \dfrac{V}{L} \\ -\dfrac{i}{C} - \dfrac{V}{RC} \end{bmatrix} \quad g(x) = \begin{bmatrix} -\dfrac{i}{C_{PV}} \\ \dfrac{V_{PV} - V}{L} \\ \dfrac{i}{C} \end{bmatrix}$$

Where the switch control signal can be selected as

$$u_n = \begin{cases} 0 & S \geq 0 \\ 1 & S < 0 \end{cases} \quad (7)$$

Let

$$\dot{S}(x) = \frac{\partial S}{\partial x^T} \dot{x} = \frac{\partial S}{\partial x^T} f(x) + \frac{\partial S}{\partial x^T} g(x) u_{eq} \quad (8)$$

Then the duty cycle of control

$$u_{eq} = -\frac{\frac{\partial S}{\partial x^T} f(x)}{\frac{\partial S}{\partial x^T} g(x)} = -\frac{L_f S(x)}{L_g S(x)} \quad (9)$$

Among them

$$L_f h_2 = \frac{\partial h_2}{\partial x^T} f(x) = \left( \frac{\partial^2 i_{PV}}{\partial^2 V_{PV}} V_{PV} + 2\frac{\partial i_{PV}}{\partial V_{PV}} \right) \frac{i_{PV}}{C} \quad (10)$$

$$L_g h_2 = \frac{\partial h_2}{\partial x^T} g(x) = \left( \frac{\partial^2 i_{PV}}{\partial^2 V_{PV}} V_{PV} + 2\frac{\partial i_{PV}}{\partial V_{PV}} \right) . -\frac{i}{C} \quad (11)$$

Putting the equations (10) and (11) into (9); obtain the equivalent control variable.

$$u_{eq} = -\frac{i_{PV}}{i} \quad (12)$$

From the (7), (12) the control input

$$u = u_{eq} + u_n$$

$$u = \frac{-i_{PV}}{i} + K_u . \mathrm{sgn}(S(i_{PV})) \quad (14)$$

## II. SIMULATION RESULTS AND DISCUSSION

In the figure.6(a) where we get the optimal point for the intensity of current equal to 3.5A with a short transient 0.0 15s , but with the largest transient equal 0.03s ( figure.6( b ) ) for radiation of 1000 W/m$^2$. After changing the radiation level, which drops to 300 W/m$^2$, also shows that the current panel is adjusted to its new optimal value, which is 1.08A for this level of radiation. After increase at the new different of radiation to 500W/m$^2$, and after about a shorter transitional regime, there is the optimum adjustment point is = 1.8A.
This shows that the optimization can significantly improve the system by reducing the transient.

Another result which demonstrates the effectiveness of the method of the sliding mode is the rapid variation of the duty ratio corresponding to the maximum power, with very short transient as shown in figure .8(a).

The variation of the voltage VP is shown in figure.9 (a). In the same way that the current intensity for above, the change of the voltage, the sliding mode controller adapt to the new value. The values obtained at steady state are near to the optimal voltage values which are 1000 W/m$^2$ to 17.5 V, and 15 V to 16.2 V for 300W/m$^2$ 500W/m$^2$.

The variation of the instantaneous power of PV is shown in figure 10(a). Its optimal values are about 60 W for a radiation of 1000 W / m$^2$, 16.15 W 28.25 W 300 W/m$^2$ and 500 W/m$^2$.

The disadvantage of the technique (P & O), such as that of the case of rapidly changing weather conditions (mobile cloud). In this case, this method can move the maximum point tracking to the wrong direction. Therefore, they appear transient peaks at each variation of the radiation level, figures .6 (b) and figure.10 (b).

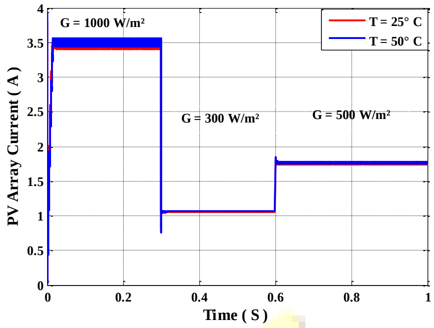


Fig .7 (a) PV Current (S mode)

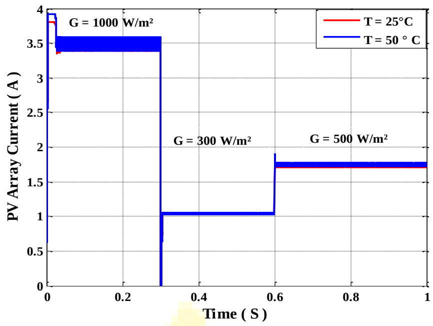


Fig .7 (b) PV Current (P&O)

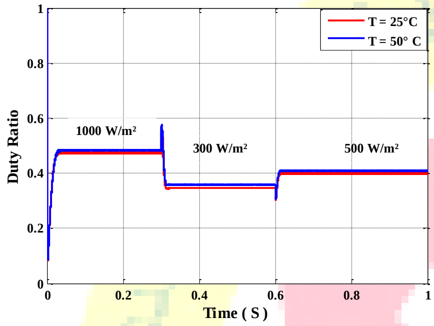


Fig .8 (a) Duty Ratio (S mode)

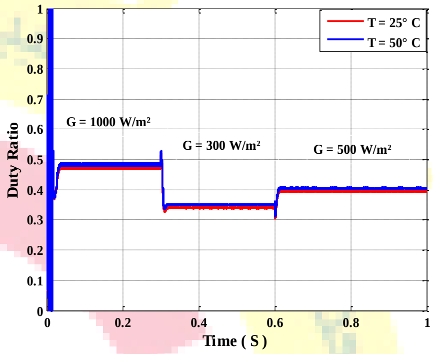


Fig .8 (b) Duty Ratio (P&O)

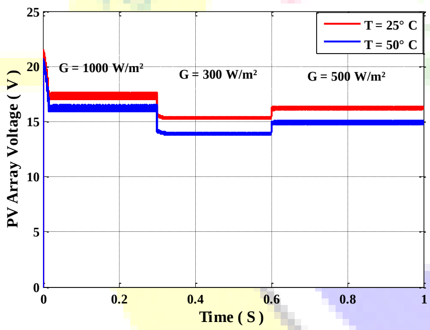


Fig .9 (a) PV Voltage (S mode)

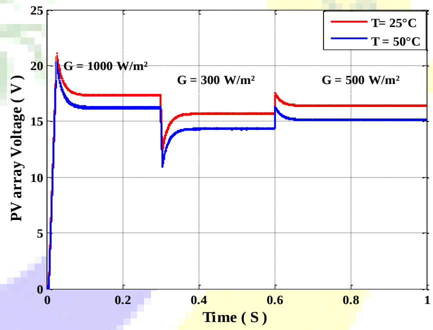


Fig .9 (b) PV Voltage (P&O)

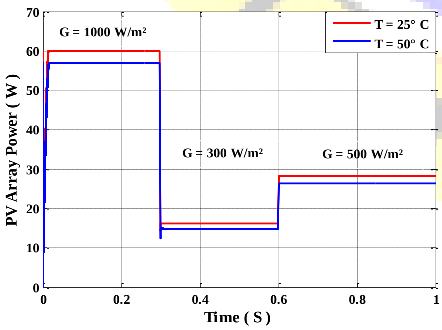


Fig .10 (a) PV Power (S mode)

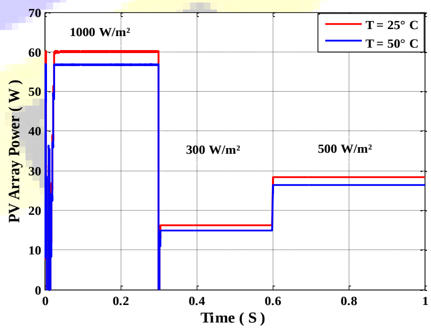


Fig.10 (b) PV Power (P&O)

## III. CONCLUSION

The maximum power point technique is used with PV system to improve its conversion efficiency. To eliminate mismatch between the load line and V-I characteristic, an MPPT control algorithm is necessary. Therefore In this article, we studied sliding mode (SM) optimization, we proposed a surface characterized by robustness under varying the power of GPV. The sliding mode controller which it is based on the independency of PV panel parameters (radiation and temperature), allows the optimization of the overall and robustness at any variation possible of the parameter. It was limited in this work to show how SM controller allows the continuation of the maximum power point in a sudden change of light and temperature. We could extend this study to show this sensitivity to sudden change, either in terms of oscillations parameters or response time of the system. he results obtained during the application of SM technique showed a satisfactory behavior of the system and high performance, but it has the disadvantage of requiring an oscillation around power point.

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