Modelling and Control of Photovoltaic System using the incremental conductance method for maximum power point tracking

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ABSTRACT

This paper presents the modeling and simulation of the electrical operation of a photovoltaic (PV) system. A DC-DC boost converter was chosen for the regulation of the output voltage at the peak power point while also providing a constant voltage. Maximum Power Point Tracker (MPPT) control that allows extraction of maximum available power from the photovoltaic (PV) panel has been included. The maximum efficiency is achieved when PV works at its maximum power point which depends on insolation and temperature. Since the insolation and temperature always change with time, a PV system which able to track the maximum power point needs to be developed to produce more energy. This research was aimed to explore the performance of a maximum power point tracking system which implements Incremental Conductance (IC) method. The IC algorithm was designed to control the duty cycle of Boost converter and to ensure the MPPT control work at its maximum efficiency. The simulation results obtained with Matlab / Simulink show the instantaneous oscillation of the operating point of the photovoltaic module around the MPP independently to weather changes, the proper functioning of the converter which provides a voltage at its output greater than that supplied by the PV generator, (a yield of the order of 90%) and the low power losses supplied by this module (less than 10%) allowed to conclude that the PV system simulated during this work was working properly and was satisfactory.

I. Introduction

Photovoltaic (PV) energy is a renewable, inexhaustible and non-polluting source of energy. To be used for different applications and to satisfy economic constraints, the design and implementation of PV systems are necessary and currently pose many problems. The PV system produced must be robust, reliable and have a high efficiency [1]. The search for alternative energy resources has therefore become a crucial question these days. Much scientific research has been carried out not only in the field of nuclear power generation, but also in the area of Unlimited energy sources, such as wind power generation and energy transformation solar [2]. In the latter case, the design, optimization and production of Photovoltaic systems are topical problems since they surely lead to better exploitation of solar energy. For a photovoltaic installation, the variation of 50% of the insolation or of the load induces a degradation of the power supplied by the PV generator of the order of 50%; in addition, the PV generator no longer works under optimum conditions [3]. In this context, our work consists in designing, modeling and simulating in the Matlab / Simulink environment the electrical operation of a photovoltaic system adapted by a digital control (MPPT control: Incremental Conductance) ensuring the pursuit of the maximum power supplied by the photovoltaic generator. The objective of this work is to optimize the performance of a photovoltaic generator and improve the voltage in its output, in order to obtain a good source which can be used as an electricity generator.

II. Materials and Methods

II.1. Photovoltaic Generator

To develop a precise equivalent circuit for a PV cell, it is necessary to understand the physical configuration of the elements of the cell as well as the electrical characteristics of each element. According to this philosophy, several electric models have been proposed to represent the photovoltaic cell. The single equivalent circuit diode as shown in Figure (1) is the most commonly used model for large PV generators [4].

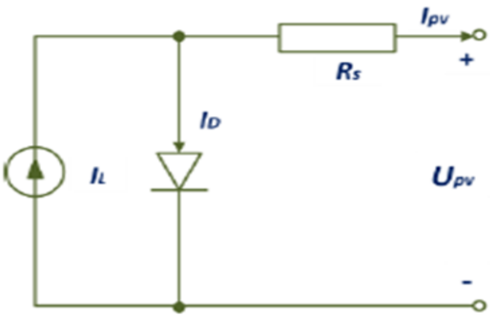


Figure 1. The equivalent PV cell circuit.

The output voltage and the load current are related by the following expression [5]:

$$I_{pv} = I_L - I_D = I_L - I_0\left[\exp\left(\frac{U_{pv} + I_{pv}R_s}{\alpha}\right) - 1\right] \tag{1}$$

Where:

$I_L\,[A]$ Photovoltaic current

$I_0\,[A]$ Saturation current

$I_{pv}\,[A]$ Laod current

$U_{pv}\,[V]$ Output voltage

$R_s\,[\Omega]$ Series resistance

$\alpha\,[V]$ Thermal saturation factor

For a PV module with Ns series connected cells and Np parallel connected cells, the current-voltage characteristic is given by:

$$I_{pv} = I_L - I_D = N_p I_L - N_p I_0 \left[\exp\left(\frac{\frac{U_{pv}}{N_s} + \frac{I_{pv} R_s}{N_p}}{\alpha} \right) - 1 \right] \qquad (2)$$

II.2. Adaptation by the DC-DC Converter

In the DC-DC boost converter (duty cycle *D*), is interposed between the PV model and the load Rs, it is possible to modify the operating point of the panel due to an extreme control law in order to permanently maximize the energy transferred.

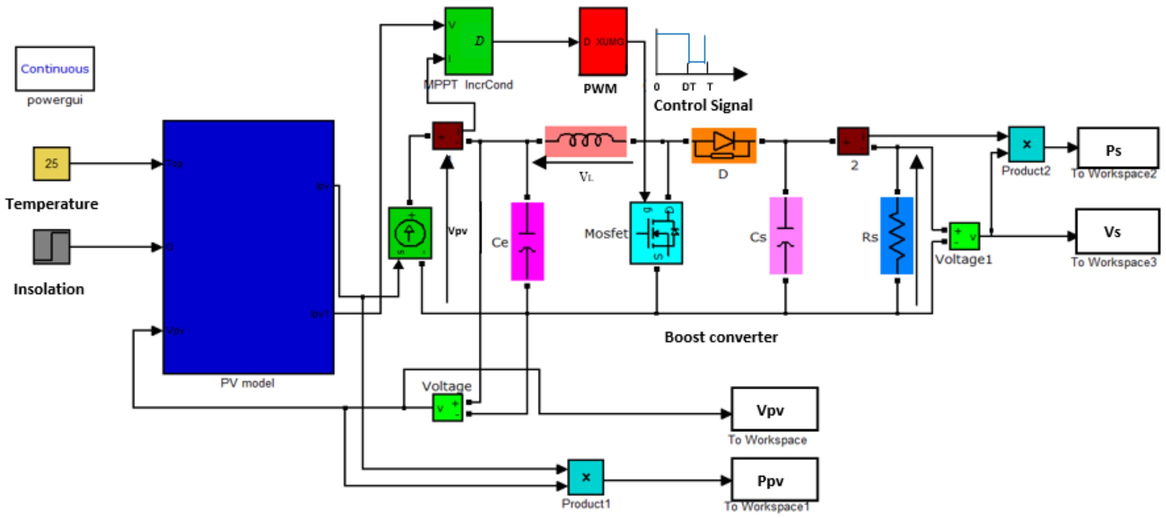


Figure 2. PV system includes a PV model, Boost converter and a load (Rs). Mosfet switch is controlled by a signal of period T and of duty cycle *D*.

The quantities of the output (Vs and Is) are linked to those of the input (Vpv and Ipv) as a function of duty cycle D:

$$Vs = \frac{Vpv}{1-D} \qquad (3) \qquad\qquad Is = (1 - D)\, Ipv \qquad (4)$$

The output resistance *Rs*:

$$Rpv = (1-D)^2 . Rs \qquad (5)$$

The duty cycle *D*:

$$D = 1 - \sqrt{\frac{Rpv}{Rs}} \qquad (6)$$

Note: Under optimal conditions and for a known Rs load the previous relationship therefore:

$$Rpv = Ropt \quad \text{et} \quad D = Dopt$$

$$Ropt = (1 - Dopt)^2 . Rs \qquad (7)$$

The relationship (7) shows that, for an incident power W, the optimal power transferred to the load could only be maximum for a well defined duty cycle (*D*opt) (point MPP) [6].

II.3. MPPT Control

The MPPT control (Maximum Power Point Tracking) is a functional organ of the PV system and makes it possible to track the optimal operating point of the PV generator which depends on the metrological conditions and the variation of the load [7], [8], [9]. Its regulation principle is based on the automatic variation of the duty cycle D at the appropriate value so as to continuously maximize the power at the output of the PV panel, whatever the weather instabilities or sudden variations in loads that can occur at any time.

- Incremental Conductance Method

The incremental conductance method is derived by deriving the power of the photovoltaic panel P from the voltage V and putting the result equal to zero. This can be described by the following equations [3], [10], [11]:

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \tag{8}$$

$$\frac{1}{V}\frac{dP}{dV} = \frac{I}{V} + \frac{dI}{dV} \tag{9}$$

The conductance of the source is defined as $G = \frac{I}{V}$ and incremental of the conductance $\Delta G = \frac{dI}{dV}$. Since the voltage V of the panel is always positive, the relationships (10,11,12) explain that the maximum power point MPP is reached if the conductance of the source G equals incremental of the conductance ΔG of the source with a negative sign, and that it is to the left of this point when the conductance G is higher than incremental conductance ΔG and vice versa [3], [10], [11] as following:

$$\frac{dP}{dV} > 0 \quad si\ \frac{I}{V} > -\frac{dI}{dV} \tag{10}$$

$$\frac{dP}{dV} = 0 \quad si\ \frac{I}{V} = -\frac{dI}{dV} \tag{11}$$

$$\frac{dP}{dV} < 0 \quad si\ \frac{I}{V} < -\frac{dI}{dV} \tag{12}$$

The advantage of this algorithm is the precision and speed of searching for the MPP when atmospheric conditions change rapidly [3], [12], [13]. IC algorithm can be seen on Figure (3).

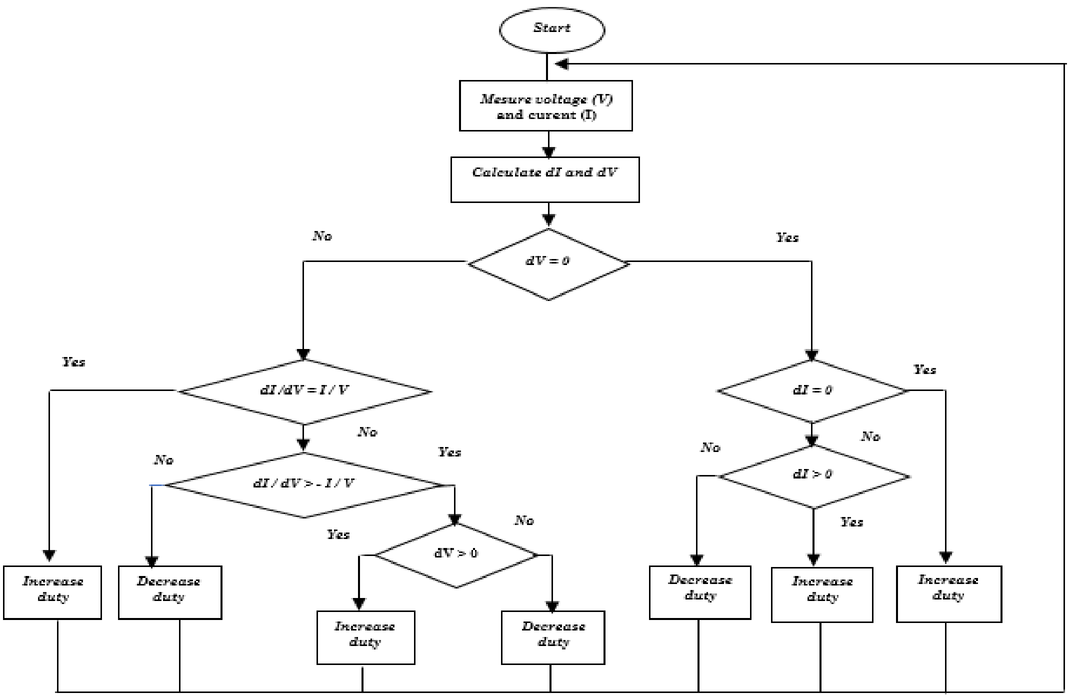
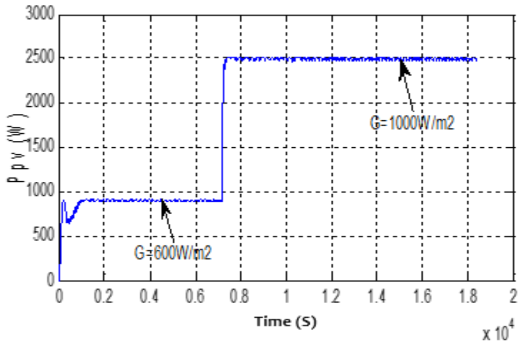


Figure 3. Incremental Conductance flowchart.

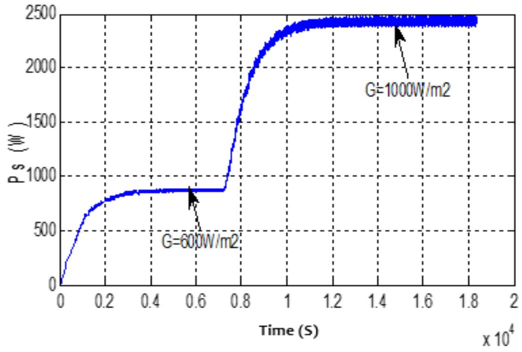
III. Simulation results

When the PV generator undergoes variations in the insolation, the temperature the Figures (4), (5) show their effect on the electrical quantities (power, voltage) at the panel output and at the output of the boost converter.

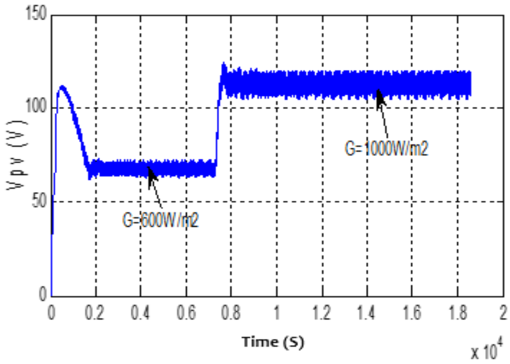
1) The incident is a sudden change in the insolation



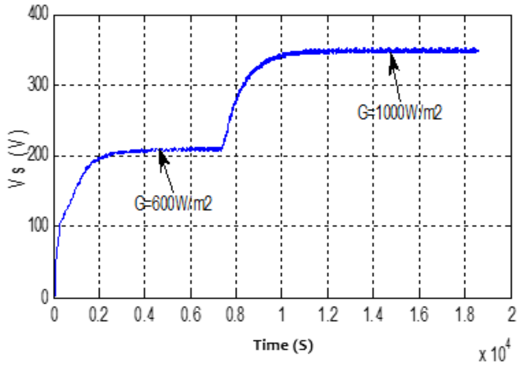
(a)



(b)



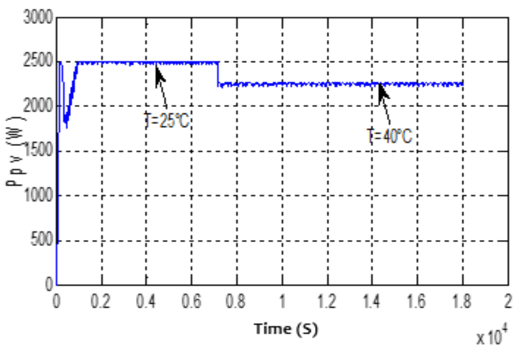
(c)



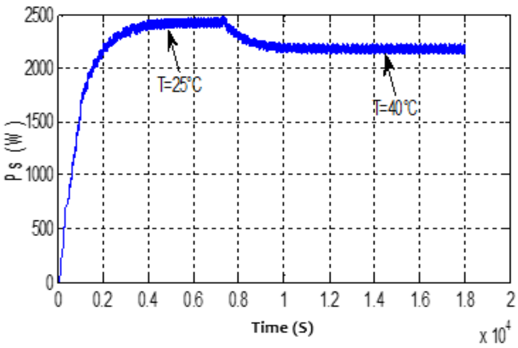
(d)

Figure 4. Influence of the change of insolation on electrical quantities (power and voltage) at the panel output ((a), (c)) and the boost converter output ((b), (d)), Rs = 50 Ω, temperature of 25°.

2) The incident is a sudden change in temperature



(a)



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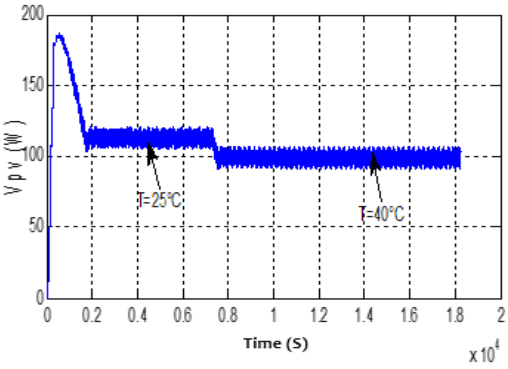
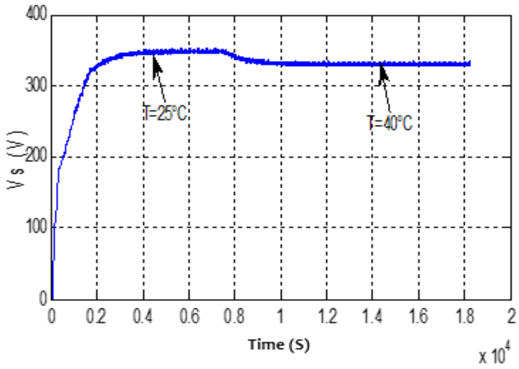


(c)



(d)

Figure 5. Influence of the change of temperature on the electrical quantities (power and voltage) at the panel output ((a), (c)) and the boost converter output ((b), (d)), Rs = 50 Ω, insolation of1000W/m².

It seems that:

After a transient regime of duration 0.2 S, the MPPT control oscillates the operating point around the MPP point.

At time t = 0.78 S, the insolation intensity changed in figure (4), the temperature will increase to 40°C in figure (5) it appears that:

the system converges to a new MPP, the different electrical quantities (powers, voltages) stabilize around constant values.

It should be noted that the performance of the PV generator degrades with increasing temperature, decreasing the intensity of the illumination and variations in the load.

The results obtained show that the DC-DC converter and the MPPT control (Incremental Conductance) perform their roles correctly. The converter provides in optimum conditions a voltage at its output greater than that supplied by the PV generator. The MPPT control adapts the PV generator to the load: transfer of the maximum power supplied by the PV generator.

IV. Conclusion

This article analyzed in the MATLAB environment the functioning of a PV system adapted by a DC-DC energy converter (boost), regulated by an MPPT control (Incremental Conductance). Through simulation it is observed that the system completes the maximum power point tracking successfully despite of fluctuations. When the external environment changes suddenly the system can track the maximum power point quickly.

These results, which are very interesting, show that the use of the MPPT control makes it possible to considerably improve the efficiency of photovoltaic installations.

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