

Boost converter system modelling and incremental conductance algorithm for photovoltaic system via Matlab/Simulink

Benlafkih Abdessamad and Chafik Elidrissi Mohamed
ab.benlafkih@gmail.com, labogem15@gmail.com

Laboratory of Engineering Energy and Materials, Faculty of Sciences
University Ibn Tofail, Kenitra, Morocco

Abstract. This paper presents a method of modeling and simulation of photovoltaic panel in MATLAB/Simulink using solar cell block from SimElectronics library. The method is used to determine the characteristic of a particular photovoltaic cell panel I-V & P-V, and to study the influence of different values of solar radiation at different temperatures concerning performance of photovoltaic cells and to study the influence of different values of temperatures at different solar radiation. Also from the simulation it is inferred how the maximum power point is tracked using Incremental conductance algorithm to maximize the power output of the PV panel.

Keywords: System modeling, solar cell, MPPT, photovoltaic panel, boost converter, Incremental conductance algorithm, simulation, Matlab/Simulink.

1 Introduction

Renewable energy sources offer clean production of electrical power using sunlight, wind, biomass, tidal waves etc. Renewable energy generation have grown greatly due to the concerns of climate change and the increase in oil prices. The growth in renewable energy has been very consistent in the last two decades. Not only the increasing concerns regarding climate change and the soaring of oil prices but also the great support by renewable energy legislation and incentives with a close to 150 billion US Dollars in 2007 have brought this alternative source of electrical power generation to the big picture [1]. Photovoltaic (PV) systems are one of the most popular renewable energy sources. It is an interesting energy source as it is not only renewable but also inexhaustible and non-polluting unlike the conventional fossil fuels such as coal, oil and gas. These unique features have made power generation through Photovoltaic sources one of the most popular renewable energy sources in last decade [2]. Photovoltaics convert sunlight into electrical energy using photoelectric effect. Sun's radiation is converted directly into usable electricity by the photovoltaic systems. Photovoltaic (PV) systems are made of photovoltaic modules which are semiconductor devices that convert the incident solar radiation directly into electrical energy. PV power depends greatly on solar irradiation and temperature. As a result the power generated by solar systems are not constant. Apart from this clean conversion of solar energy into electrical energy, one thing which is holding back the photovoltaic systems is their lack of reliability. Depending on different solar irradiation levels and temperatures, their production rate varies. Therefore by adding a supplemental source of power, Solar Power's reliability can be greatly increased where this supplement energy source will work as a backup

energy source. Whenever the load demand will not be fully met by the primary solar energy source it will be supported by the backup energy source. And on the other hand when the demand will be less than the generation, the primary solar source will energize the backup source.

2 PV MODEL

Figure 1 presents the widely used single-diode equivalent circuit model to represent the characteristics of the PV panel for analyzing and simulating the PV system. The circuit model represents the PV panel as a current source I_{ph} in parallel with a single diode and a shunt resistor R_P as well as a series resistor R_S . The current I_{PV} and voltage V_{PV} from the PV panel is characterized by the following Equations (1) and (2):

$$I_{PV} = I_{ph} - I_D - \frac{V_{PV} + R_S I_{PV}}{R_S} \quad (1)$$

$$I_D = I_0 \left[\exp \left(\frac{q(V_{PV} + R_S I_{PV})}{nAKT} \right) - 1 \right] \quad (2)$$

where I_{ph} is the current generated by the incident light, I_D is the diode current, I_0 is the reverse saturation current, q is the electron charge (1.602×10^{-19} C), K is the Boltzmann constant (1.38×10^{-23} J/K), T is the operating temperature of the cell in Kelvin (K), A is the diode ideality constant, and n is the number of diodes in series to form the single-diode model. The current source I_{ph} mainly depends on the irradiation level of sun light as well as the operation temperature of the solar panel.

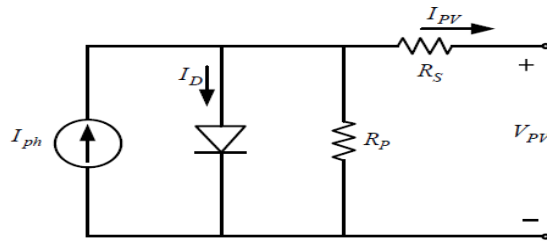


Fig. 1. Single-diode equivalent circuit model

In this study, the PV module was selected to conduct the design and circuit simulation; the table 1 present the PV model characteristics at (25 C° and 1000 W/M²).

Table 1. The PV MODEL characteristics at (25 C° and 1000 W/M²)

| Paramerter | Value |
|-----------------------|----------------|
| Maximum Power | 61.24 W |
| Tension at Pmax | 17.32 V |
| Current Pmax | 3.5 A |
| Open circuit Voltage | 21.02 V |
| Short circuit Current | 3.8 A |

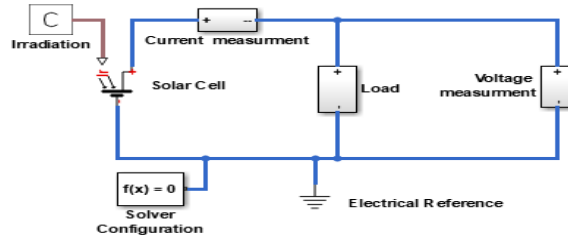


Fig. 2. PV Model Simulation

2.1 Current -Voltage and Power-Voltage characteristics

One way of studying the consistency of the model is developed to study the shape of the current-voltage characteristics I-V, Fig. 3 and P-V, power-voltage, Fig. 4, was obtained using the equations the electrical model (1) and (2)

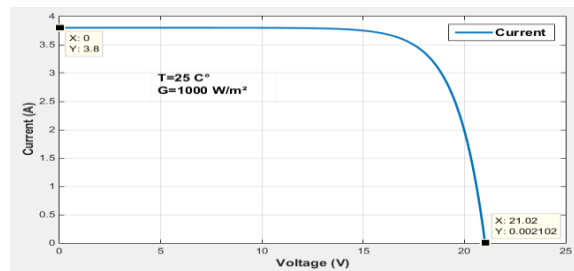


Fig. 3. Single diode equivalent circuit Model

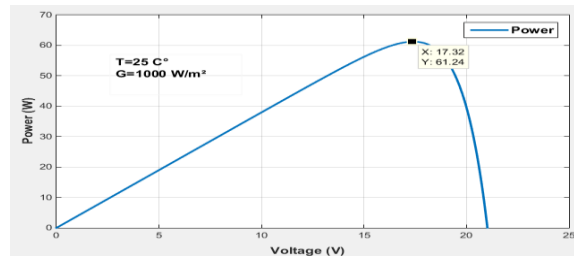


Fig. 4. P-V Characteristics curve of PV panel Simulation

2.2 Influence of temperature

To characterize PV cells, we used the model Fig.2, to provide the values of voltage, current product and the power generated. We present the I-V and P-V characteristics in figures 5 and 6 respectively of PV panel, for $G = 1000 \text{ W/m}^2$ given, and for different values of temperature. If the temperature of the photovoltaic panel increases, the open circuit voltage V_{oc} decreases. The temperature increase is also reflected by the decrease of the maximum power.

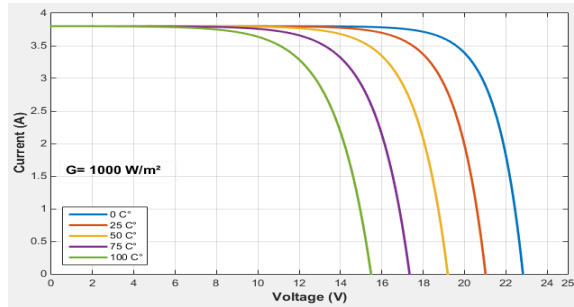


Fig. 5. Simulated I-V Curves of PV Model influenced by temperature

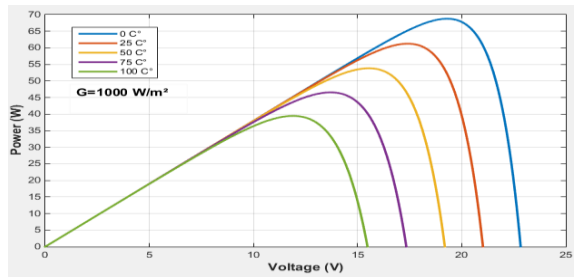


Fig. 6. Power versus Voltage P-V curves influenced by temperature

2.3 Influence of irradiation

Now, we present the I–V and P–V characteristics in figures 7 and 8 respectively of the PV photovoltaic model at a given temperature $T = 25^\circ\text{C}$ for different solar illumination levels.

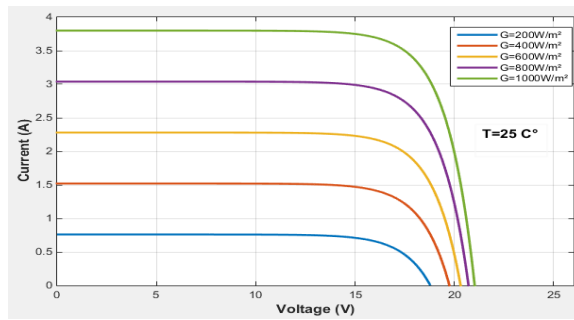


Fig.7. Simulated I-V curves of PV model influenced by solar illumination

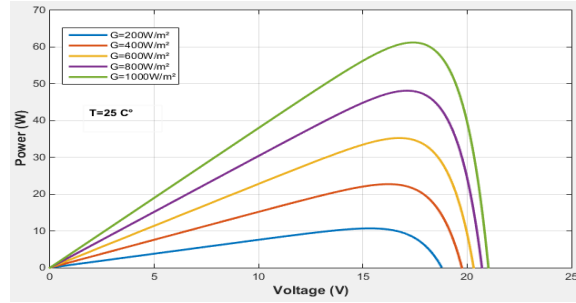


Fig. 8. Power versus voltage P-V curves influenced by solar illumination

2.4 DC/DC boost converter

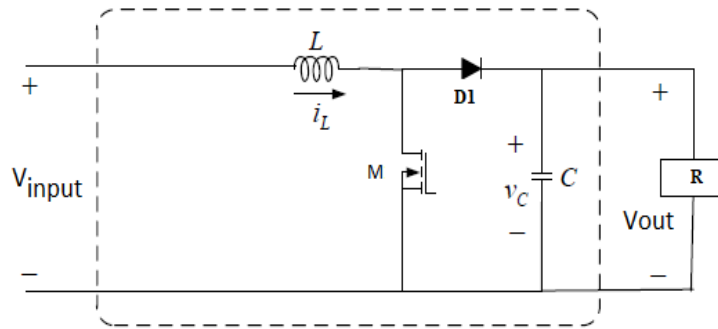


Fig.9. DC/DC boost converter

The boost DC/DC converter offers a greater level of capability, it as expected it extra components may be required to provide the level of functionality needed [3], [4], [5]. In Fig. 9 a DC/DC Boost converter is shown. The switching period is T and the duty cycle is D . Assuming continuous conduction mode of operation, during T_{ON} the period of the cycle, switch M is ON and the input voltage is impressed across the inductor. Since the load current is instantaneously provided by the output capacitor during this interval, the capacitor voltage (output voltage) decreases, the state space equations are given by Eq.(3).

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L} [v_{in}] \\ \frac{dv_C}{dt} = -\frac{1}{C} \left(\frac{v_C}{R}\right) \end{cases} \quad (3)$$

During the other interval of the switching period (T_{OFF}), Diode $D1$ is turned ON and the inductor energy is transferred to the output, providing both the load current and also charging the output capacitor, the equations are given by Eq.(4).

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L} [v_{in} - v_c] \\ \frac{dv_c}{dt} = \frac{1}{c} \left(i_L - \frac{v_c}{R} \right) \end{cases} \quad (4)$$

2.5 MPPT Control algorithm

The configuration of MPPT controller is shown in Fig.10. The inputs of MPPT controller are voltage and current of the PV model, while the output is PWM (pulse width modulation) for controlling the duty cycle of the boost converter. The system is simulated using Matlab/Simulink. Many MPPT techniques have been proposed in the literature; examples are the Perturb and Observe (P&O), Incremental Conductance (IC), Fuzzy Logic, and so forth. The P&O algorithm is very popular and simple [6], [7], [8], [9], [10].

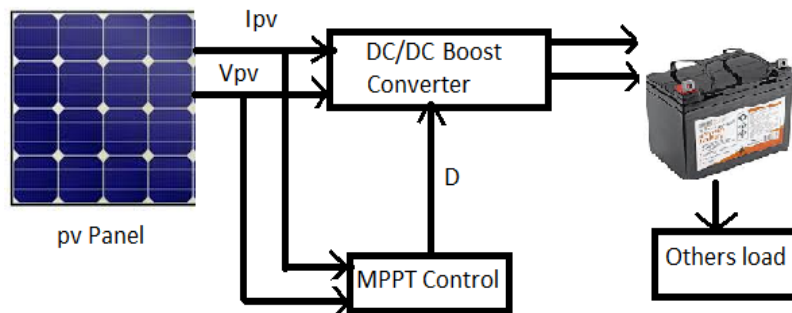


Fig.10. PV System with Power conveter and MPPT Control

2.6 Incremental conductance method

This method is based on the fact that the slope of the power curve of the panel is zero at the MPP, positive to the left and negative to the right. This method is based on the fact that the slope of the power curve of the panel is zero at the MPP, positive to the left and negative to the right [11], [12], [13], [14]. Since :

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V \frac{dI}{dV} = I + V \frac{\Delta I}{\Delta V} \quad (5)$$

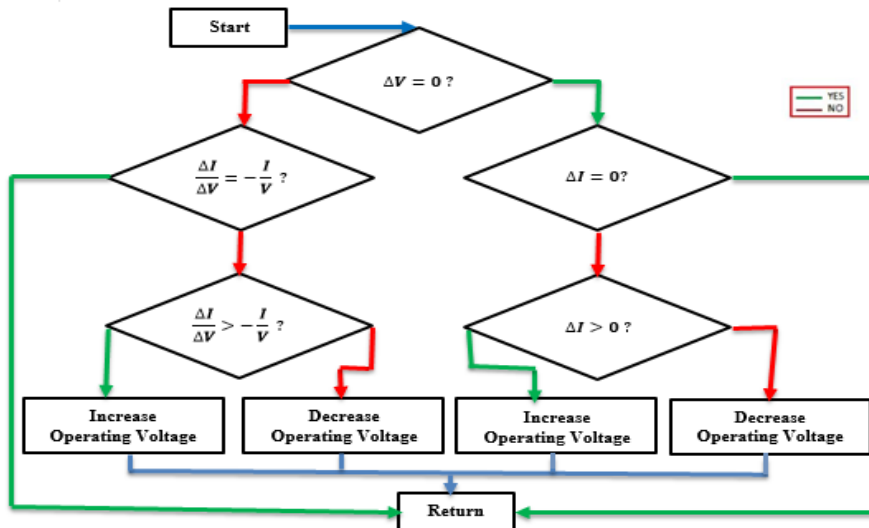


Fig.11. Organigram of incremental conductance algorithm

$$\begin{cases} \frac{\Delta I}{\Delta V} = -\frac{I}{V} & \text{at the MPP} \\ \frac{\Delta I}{\Delta V} > -\frac{I}{V} & \text{left of the MPP} \\ \frac{\Delta I}{\Delta V} < -\frac{I}{V} & \text{right of the MPP} \end{cases} \quad (6)$$

The MPP can be tracked by comparing the instantaneous conductance to the incremental conductance, as shown in the organogram of Fig.11. The detailed Simulink model is shown in Fig.12. The V_{pv} and I_{pv} are taken as the inputs to MPPT unit, duty D cycle is obtained as output.

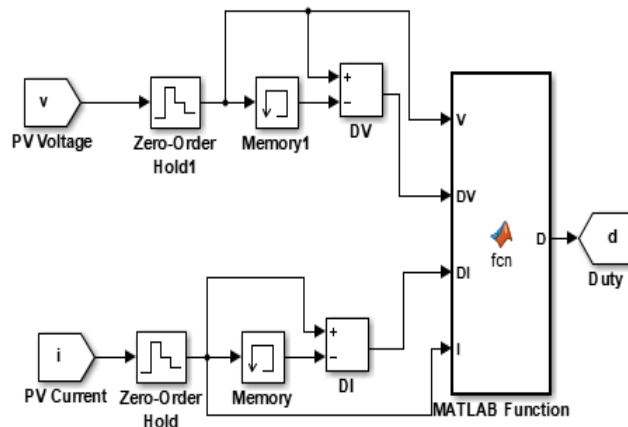


Fig.12. Maximum power point tracking by incremental conductance method

3 Simulation model of PV system with incremental conductance algorithm

The model shown in Fig.13 represents a model of PV solar panel connected to resistive load through a DC/DC boost converter with Incremental Conductance Algorithm. The boost system specifications are given as follows:

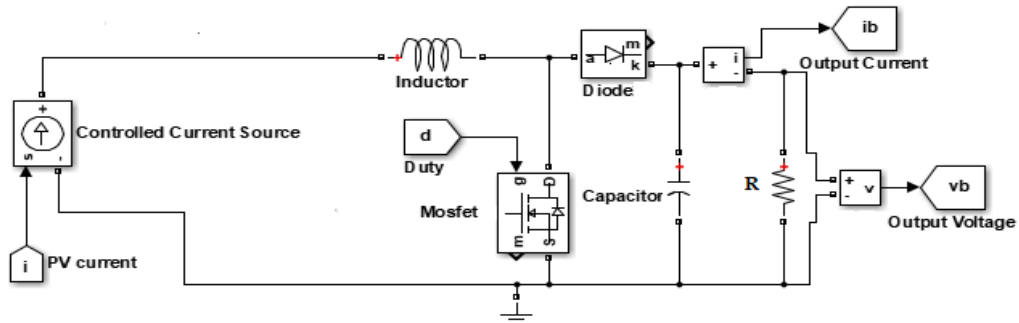


Fig.13 Boost converter circuit with PV input

Figure 14 presents how the irradiance that falls on PV solar panel is changing. The voltage and the current vary depending on irradiance. The curve of variable irradiance is plotted using a signal builder, where the irradiance is not very realistic, that will be equivalent to do very fast cloud moving for example, what allowing to the sun changing instantaneous which is not happen, but allow to give an idea of measure of how fast the controller responds [15].

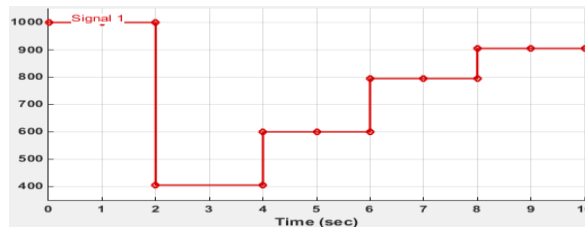


Fig.14. Variation of solar radiation

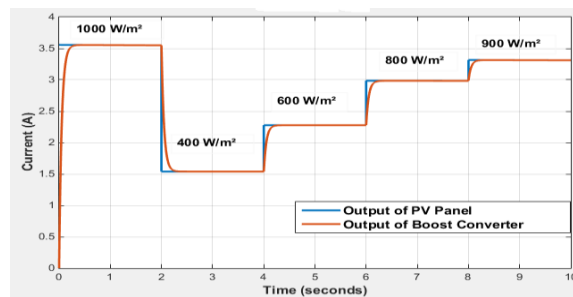


Fig.15. Output current of the Boost converter and output current of the PV panel

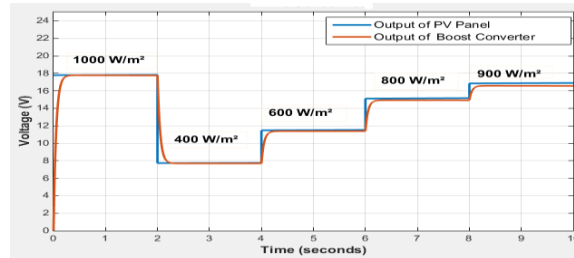


Fig.16. Output Voltage of the Boost converter and output Voltage of the PV panel

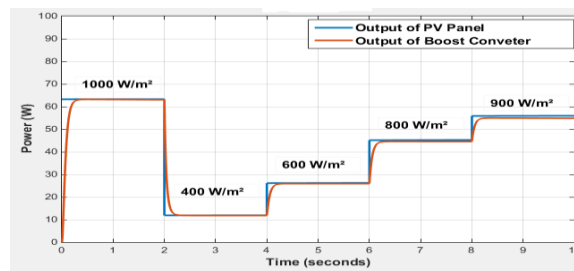


Fig.17. Output power of the Boost converter and output power of the PV panel

Figure 15 to 17 presents the results of the simulation model PV panel. The current, voltage and power output of PV panel and at the output of circuit connected to the photovoltaic panel. The Irradiance is variable, passing successively through the following values: 1000, 400, 600, 800 and 900 W/m². To test the operation of the system, the change of solar radiation was modeled. The temperature is fixed at 25 °C and the level of solar radiation is varied with five levels. The first level of illumination is set at 1000 W/m² then at 2 second the solar irradiation level passed abruptly at the second level 400 W/m², next at 4 second, it passed at the third level 600 W/m², after that at 6 second, it passed at the 800 W/m², Finally at 8 second, it passed at the last level G=900 W/m². An illustration of the relationship between the irradiation and the output power of PV panel is shown in figure 15 to 17 to explain the effectiveness of the algorithm mentioned. According to the simulation results presented above, all quantities to regulate, and converge well to references, and after a few time acceptable response = 0.1s These results show the effectiveness of the algorithm and the relationship between the illumination and the output power of the PV panel, and show the operation of the boost converter.

4 Conclusion

In this paper, a standalone PV system has been simulated by Matlab/Simulink. Incremental conductance algorithm has been used for maximum power point tracking. Simulation results show that the system operates in the maximum power point. This technique has an advantage over the perturb and observe method because it can determine when you reach the MPP without having to oscillate around this value. It can also perform MPPT under rapidly increasing and decreasing irradiance conditions with higher accuracy than the perturb and observe method.

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