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Buck-Boost Converter System Modeling and Incremental Inductance Algorithm for Photovoltaic System via MATLAB/Simulink

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***Abstract*— In this paper, we present the results of the characterization and modeling of the electrical current-voltage and power-voltage of the Msx60 PV Solar Photovoltaic module with Matlab /Simulink , using a new approach based on the Incremental inductance technique. The I-V & PV characteristics are obtained for various values of solar insolation and temperature. Also from the simulation it is inferred how the maximum power point is tracked using Incremental inductance algorithm to maximize the power output of the PV array.**

***Keywords*— system modeling, Photovoltaic, Incremental inductance algorithm, Buck-Boost Converters, Simulation, MATLAB/Simulink.**

I. INTRODUCTION

Energy is important for the human life and economy. Consequently, due to the increase in the industrial revolution, the world energy demand has also increased. In the later years, irritation about the energy crisis has been increased Photovoltaic (PV) system has taken a great attention since it appears to be one of the most promising renewable energy sources. The photovoltaic (PV) solar generation is. preferred over the other renewable energy sources due to advantages such as the absence of fuel cost, cleanness, being pollution-free, little maintenance, and causing no noise due to absence of moving parts. However, two important factors limit the implementation of photovoltaic systems. These are high installation cost and low efficiency of energy conversion [1]. In order to reduce photovoltaic power system costs and to increase the utilization efficiency of solar energy, the maximum power point tracking system of photovoltaic modules is one of the effective methods [3].Maximum power point tracking, frequently referred to as MPPT, is a system used to extract the maximum power of the PV module to deliver it to the load [4]. Thus, the overall efficiency is increased [4].

A. Mathematical Model of PV cell

A general mathematical description of I-V output characteristics for a PV cell has been studied for over the past four decades. Such an equivalent circuit-based model is mainly used for the MPPT technologies [3,4,5,6]. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the current flow, is shown in Fig.1.

The voltage-current characteristic equation of a solar cell is given as :

$$\boldsymbol{I = Iph - Is\left(exp\left(\frac{V+RsI}{a}\right) - 1\right) - \frac{V+RsI}{Rsh}} \quad (01)$$

IPH is a light-generated current or photocurrent, *IS* is the cell saturation of dark current, *q* (= 1.6 × 10-19 C) is the electron charge, *k* (= 1.38 × 10-23 J/K) is Boltzmann constant, *T* is the cell working temperature, *A* is the ideal factor, *RSH* is the shunt resistance, and *RS* is the series resistance.

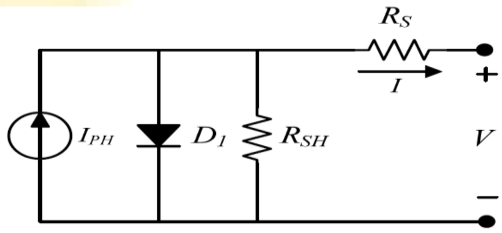

Fig. 1 The equivalent circuit of a PV cell.

Table 1 The PV module characteristics at (25 C° and 1000 W/m2)

Parameter	Value
Maximum Power	**60W**
Tension at Pmax	**17.1 V**
Current at Pmax	**3.5A**
Open Circuit VoltageVoc	**21.1V**
Short Circuit CurrentIsc	**3.8A**

B.Current-voltage and power voltagecharacteristics:

One way ofstudying theconsistency of the modelisdevelopedto studythe shape of thecurrent-voltage characteristicsI (V) ,Figure (2) and P-power voltage(V)Figure (3) , wasobtainedusing the equationsthe electricalmodel(01)

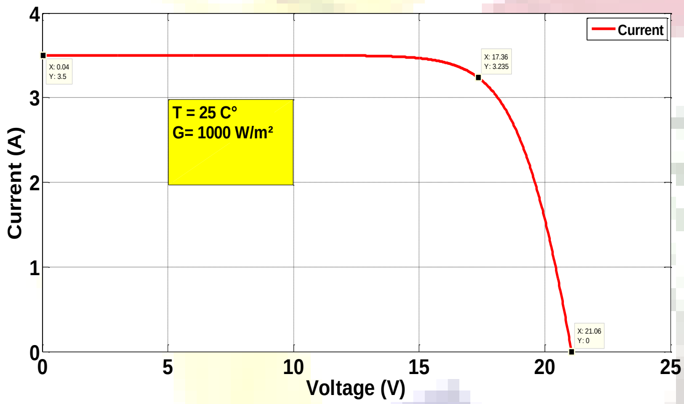

Fig 2.I-V characteristic curve of PV arraysimulation

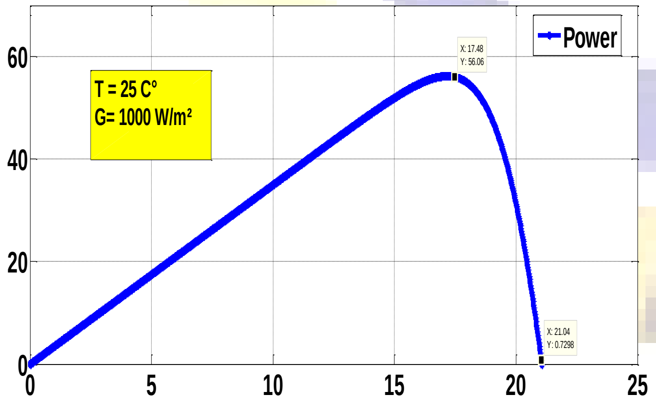

Fig 3.P-V characteristic curve of PV arraysimulation

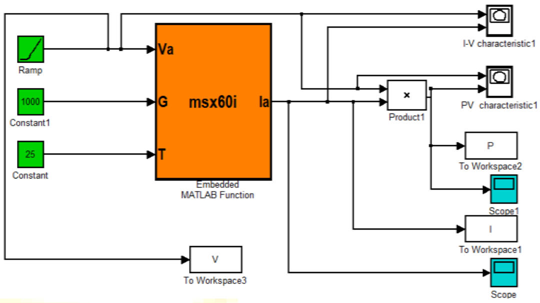

Fig. 4 Masked PV model

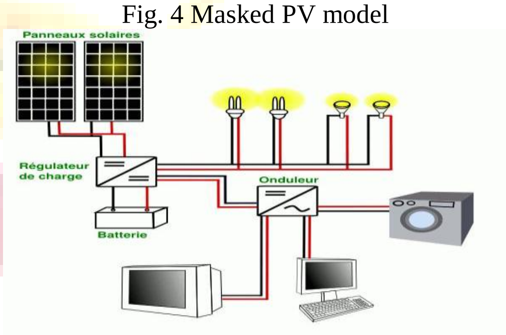

Fig. 5 photovoltaic electrical installations

1) Influence of temperature

To characterize PV cells, we used the model of one diode, -presented above -, to provide the values of voltage (V), current product (I) and the power generated (P). We present the IV and PV characteristics in Figures 7 and 8 respectively of Msx60 PV panel, for G = 1000W/m2 given, and for different values of temperature.If the temperature of the photovoltaic panel increases, the short circuit current Isc increased slightly, to be near 0.1 A at 25°C, while the open circuit voltage Voc decreases, the temperature increase is also reflected in the decrease of the maximum power supplies. The temperature increase is also reflected by the decrease of the maximum power.

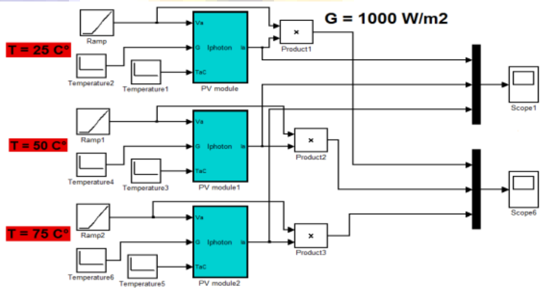

Fig. 6 PV model under changing temperature.

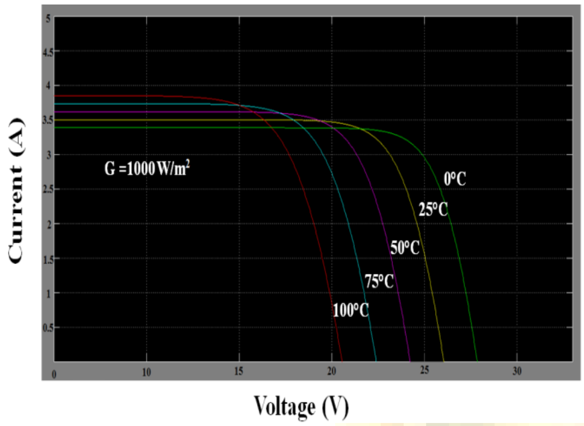

Fig. 7 Simulate I-V curves of PV module influenced by temperature

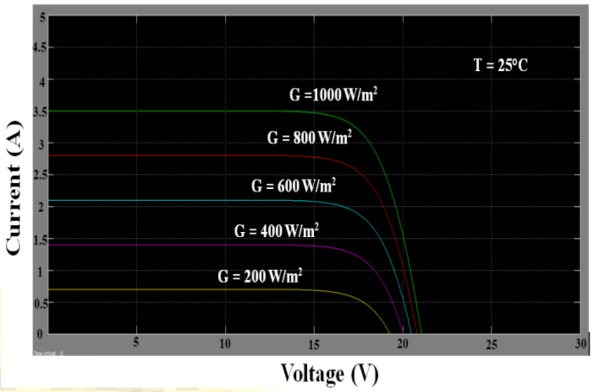

Fig. 10 Simulated I-V curves of PV module influenced by solar illumination

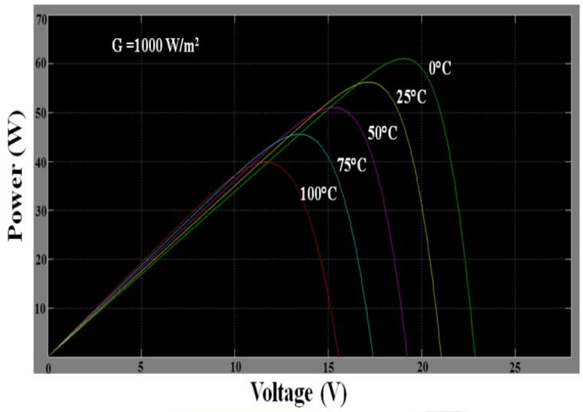

Fig. 8 Power versus voltage curves influence by temperature

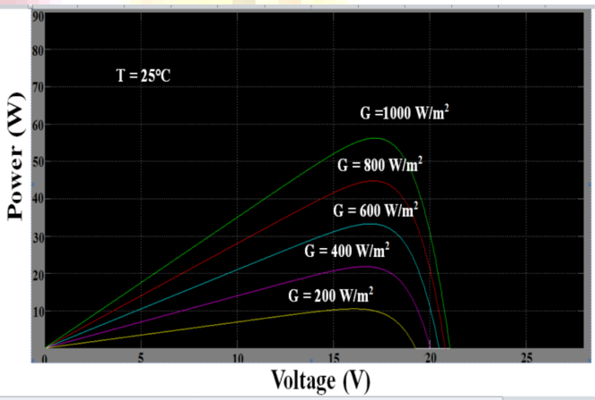

Fig. 11 Power versus voltage curves influence by the solar illumination

2) Influence of irradiation

Now, we present the I-V and P-V characteristics in Figures 10 and 11 respectively of the Msx60 photovoltaic module at a given temperature T = 25 ° C for different solar illumination levels.

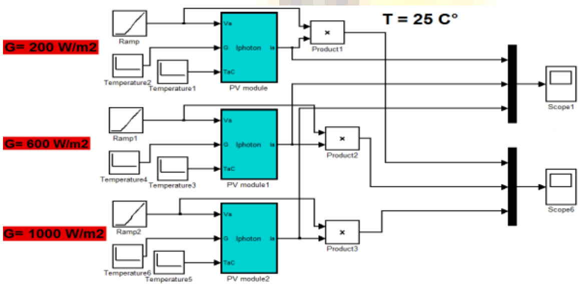

Fig. 9 PV model under changing solar radiation.

C. Buck-Boost Converter basics

The buck-boost DC-DC converter offers a greater level of capability than the buck converter of boost converter individually, it as expected it extra components may be required to provide the level of functionality needed[8-9-10].

There are several formats that can be used for buck-boost converters:

- ***+Vin, -Vout:*** This configuration of a buck-boost converter circuit uses the same number of components as the simple buck or boost converters. However this buck-boost regulator or DC-DC converter produces a negative output for a positive input. While this may be required or can be accommodated for a limited number of applications, it is not normally the most convenient format.

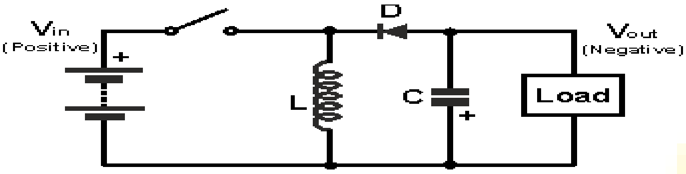

Fig 12. DC/DC Buck-Converter (negative Type)

When the switch in closed, current builds up through theinductor. When the switch is opened the inductor suppliescurrent through the diode to the load.Obviously the polarities (including the diode) within the buck-boost converter can be reversed to provide a positive output voltage from a negative input voltage.

+Vin, +Vout: The second buck-boost converter circuit allows both input and output to be the same polarity. However to achieve this, more components are required. The circuit for this buck boost converter is shown below.

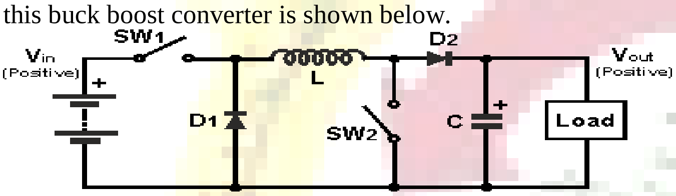

Fig 13. DC/DC Buck-Converter (Positive Type)

In this circuit, both switches act together, i.e. both are closed or open. When the switches are open, the inductor current builds. At a suitable point, the switches are opened. Theinductor then supplies current to the load through a pathincorporating both diodes, D1 and D2. In Fig. 5 a DC-DC buck-boost converter is shown. The switching period is T and the duty cycle is D. Assuming continuous conduction mode of operation, when the switch is ON, the state space equations are given by, [1]

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(V_{in}) \\ \frac{dv_o}{dt} = \frac{1}{C}(-\frac{v_o}{R}) \end{cases}, \quad 0 < t < dT, \quad Q: ON \tag{02}$$

and when the switch is OFF

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(v_o) \\ \frac{dv_o}{dt} = \frac{1}{C}(-i_L - \frac{v_o}{R}) \end{cases}, \quad dT < t < T, \quad Q: OFF \tag{03}$$

D. MPPT Control Algorithm

The configuration of MPPT controller is shown in Figure 13. The inputs of MPPT controller are voltage and current of the PV module, while the output is PWM (pulse width modulation) for controlling the duty cycle of the buck 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 [7-8-9-10].

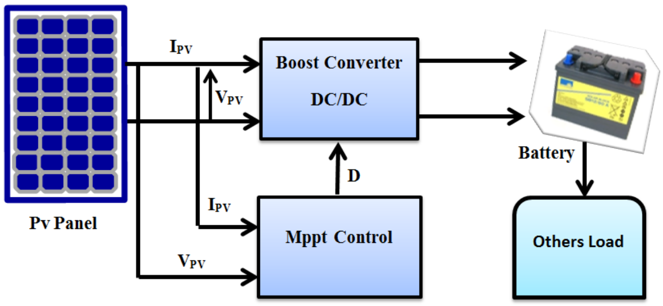

Fig 14. PV System with Power Converter and MPPT Control

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 right [2,4,11]. 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 right [2,4,11,12]. Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} = I + V\frac{\Delta I}{\Delta V} \tag{04}$$

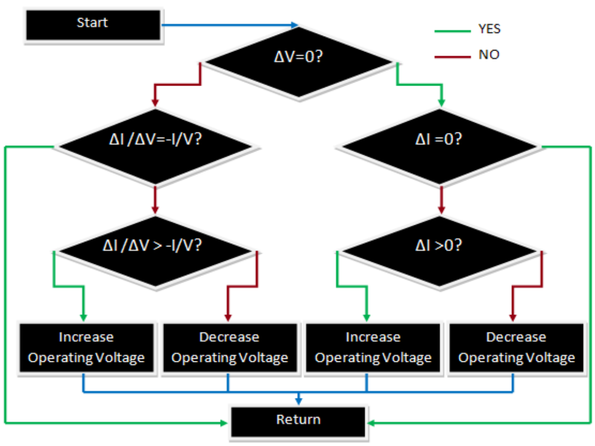

Fig 15. Organigram of Incremental inductance algorithm

Where P= V*I

$$\begin{cases} \frac{\Delta I}{\Delta V} = -\frac{I}{V} & \text{at the MPP} \\ \frac{\Delta I}{\Delta V} > -\frac{I}{V} & \text{Left of the MPP} \\ \frac{\Delta I}{\Delta V} < -\frac{I}{V} & \text{Right of the MPP} \end{cases} \quad (05)$$

The MPP can be tracked by comparing the instantaneous conductance to the incremental conductance, as shown in the flowchart of figure 14. The detailed Simulink model is shown in Fig. 15. The Vpv and Ipv are taken as the inputs to MPPT unit, duty cycle D is obtained as output.

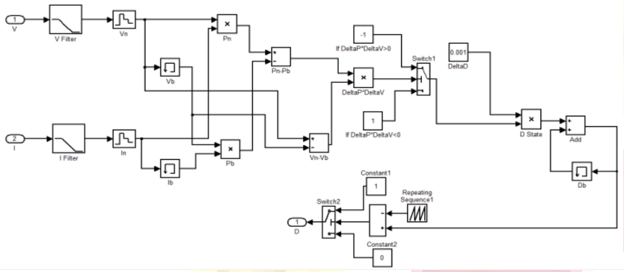

Fig. 16. Maximum power point tracking by incremental conductance method

II. SIMULINK MODEL OF PV SYSTEM WITH INCREMENTAL INDUCTANCE ALGORITHM

The model shown in Fig. 17 represents a PV solar panel connected to resistive load through a dc/dc boost converter with Incremental Inductance Algorithm.

The dc-Buck boost system specifications are given as follows:

Load R: 10 Ω-Buck Boost inductance: 0.01 H.

Output capacitance: 1000 μF-Switching frequency: 15 kHz.

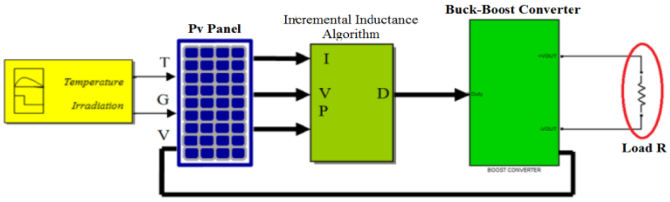

Fig. 17 PV system structure with Incremental Inductance MPPT controller.

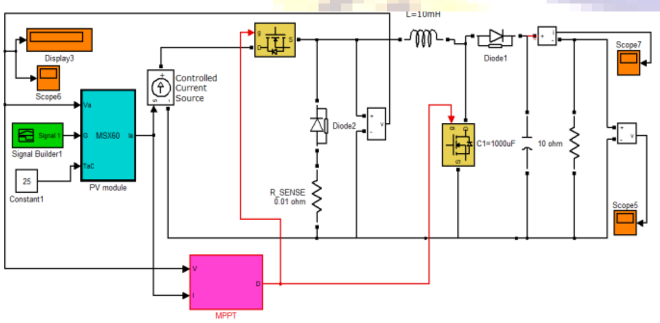

Fig.18 Boost converter circuit with PV input.

Fig. 19 presents how the irradiance that falls on PV solarpanel is changing. The voltage and the current vary dependingonirradiance. The curve of variable irradiance is plotted usinga signal builder, where the irradiance is not very realistic,because this are instantaneous changing irradiance, what willbe equivalent to do very fast cloud moving for example, what allowing to the sun changing instantaneous which is nothappen, but allow to give an idea of measure of how fast thecontroller responds [1].

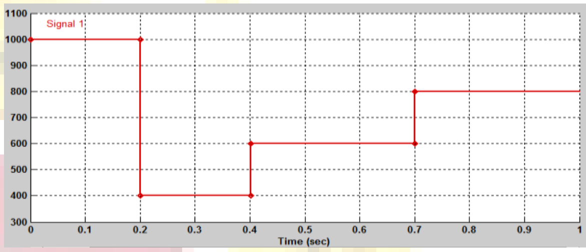

Fig19.Variation of solar radiation.

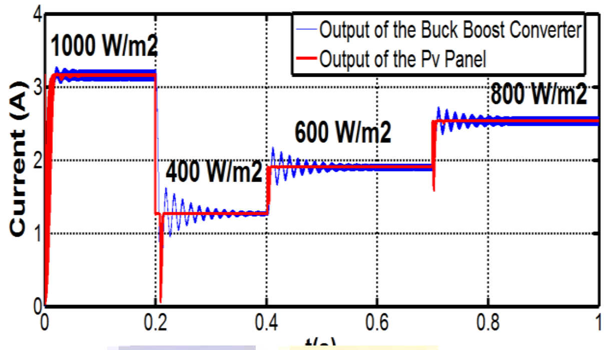

Fig. 20 Output current of the Buck Boost converter and output current of the PV panel

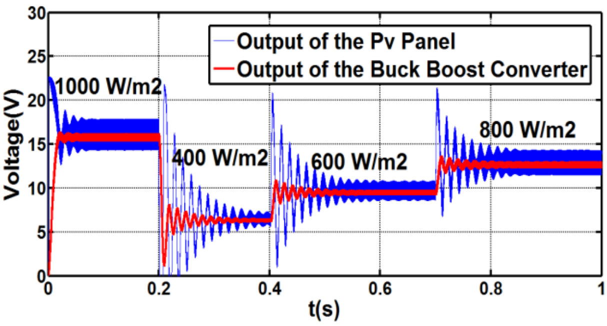

Fig. 21 Output Voltage of the Buck Boost converter and output Voltage of the PV panel

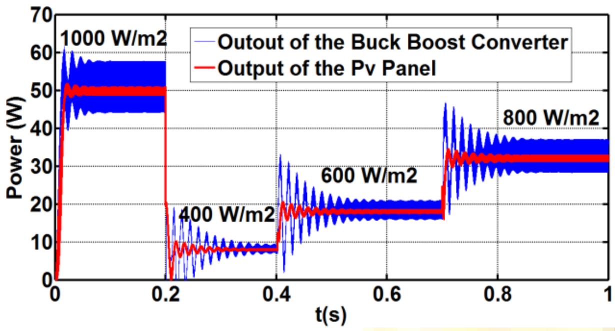

Fig. 22 Output Power of the Buck Boost converter and output Power of the PV panel

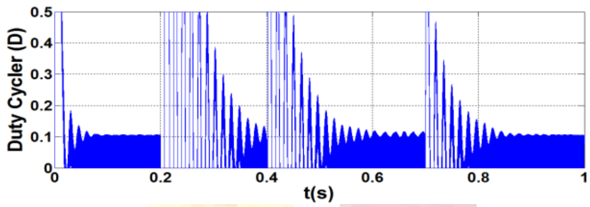

Fig. 23Duty cycler

Figure 20 to 22 presents the results of the simulation model PV panel. The voltage, current 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: 200 ,400, 600, 800 and 1000 W/m^2.

To test the operation of the system, the change of solar radiation was modeled. The temperature is fixed at 25 ° and the level of solar radiation is varied with four levels. The first level of illumination is set at 1000W /m ², at the moment 0.2 s the solar irradiation level pass abruptly at the second level 400 W/m ²), and then the third again 600 W /m²), at time 0.4s and finally passed at the last level G= 800 W/m^2 at time 0.7 s .An illustration of the relationship between the radiation and the output power of PV panel is shown in figure 19 to 21 to explain the effectiveness of the algorithm mentioned.According to the simulation results presented above, allquantities to regulate I_{PVout} , V_{Pvout} and P_{PVout} converge well toreferences I_{PV}, V_{PV} and P_{PV} after a time acceptable response t = 0.01s respect to slow dynamics of the profile of the primary source (radiation and temperature).

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 buck boost converter. From these results we see that the variation of the radiation has a remarkable effect on the functioning of the system.

III.CONCLUSIONS

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. The disadvantage of this method is that it takes longer to compute the MPP and it slows down the sampling frequency of the operating voltage and current.

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