

Simulation and Implementation of Incremental Conductance Maximum Power Point Tracking Algorithm for Photovoltaic System

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In this work, we simulate a photovoltaic (PV) array to obtain maximum power point (MPP) of the system. We used an incremental conductance (IC) algorithm to track MPP. We gave a detailed explanation of IC tracking system algorithm. In addition, we used MATLAB simulation results. Simulation results show the accuracy of the results since we obtained output power equals 200.13 W. We expected 200.143 W. Also, we did not get any oscillation around the output value. Thus we recommend IC for fast and accurate results.

Keywords: PV, MPPT, Incremental Conductance Algorithm, Simulation.

1. INTRODUCTION

Electrical energy can be directly derived from solar energy using photovoltaic module (PV). Figure 1 exhibits the block diagram of the solar PV panel system. This system has been modeled using MATLAB 2011 and Simulink.¹ In the coming paragraphs, details description of each part of the circuit (Fig. 1) is given.

PV module consists of PV cells connected in series and parallel configuration. However, the output power of PV module is usually low, so modules are connected to form an array to supply the load. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current.² Figure 2 exhibits the equivalent circuit of PV cell. The equivalent circuit consists of a photo current, a diode, a parallel resistor R_{SH} expressing a leakage current, and a series resistor R_S describing an internal resistance to the current flow. The terminal current is given by Eq. (1).³

$$I = I_{PH} - I_S \left[\exp \left(q \frac{(V + IR_S)}{KT_C A} \right) - 1 \right] - \frac{V + IR_S}{R_{SH}} \quad (1)$$

where I_{PH} is a photocurrent, I_S is the dark current, $q = 1.6 \times 10^{-19}$ C is an electron charge, $k = 1.38 \times 10^{-23}$ J/K is Boltzmann's constant, T_C is the temperature in Kelvin, A is an ideal factor.

The output power from PV is the result from multiplying PV terminal voltage and PV output current. Obtaining

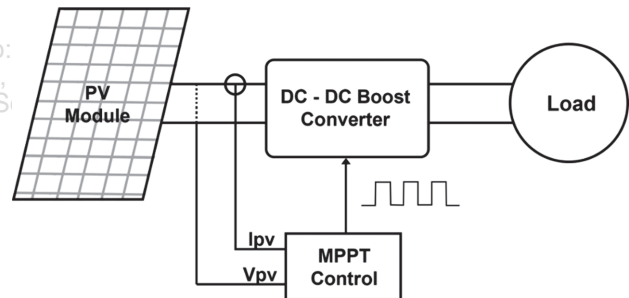


Fig. 1. Diagram of MPPT in a PV system.

the maximum power point (MPP) automatically from a solar modules or in other words making the system operates at maximum efficiency, depends on the used MPP tracking algorithm (MPPT). These algorithms take into account the varying of irradiation and temperature over time also the load impedance. These factors affects MPP thus reflected in the amount of electricity generated.

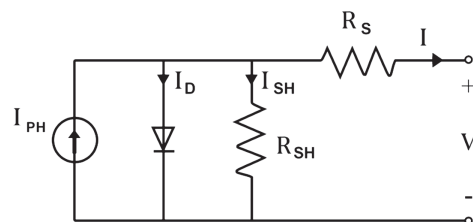


Fig. 2. Equivalent circuit models of PV cell.

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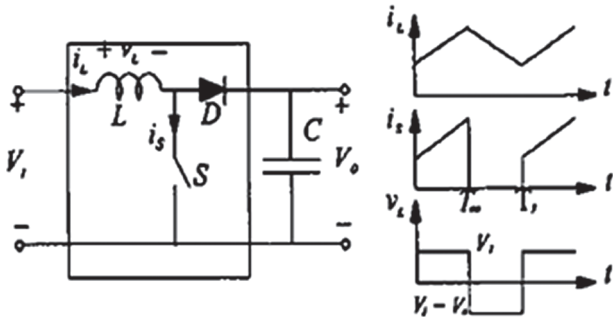


Fig. 3. Equivalent circuit of a boost converter.

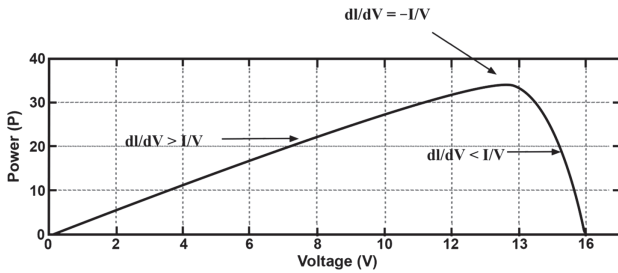


Fig. 4. The slope of the P-V array power curve.

The most commonly known MPPT systems are perturb and observe (P&O), incremental conductance (IC), open-circuit voltage control, neural network, fuzzy logic control and several other MPPT methods. A review of MPPT algorithms are available in Ref. [4]. Each tracking system has its own advantages and disadvantages. It is left to the users to choose the suitable system that fit with their applications. In this paper, a detailed explanation to

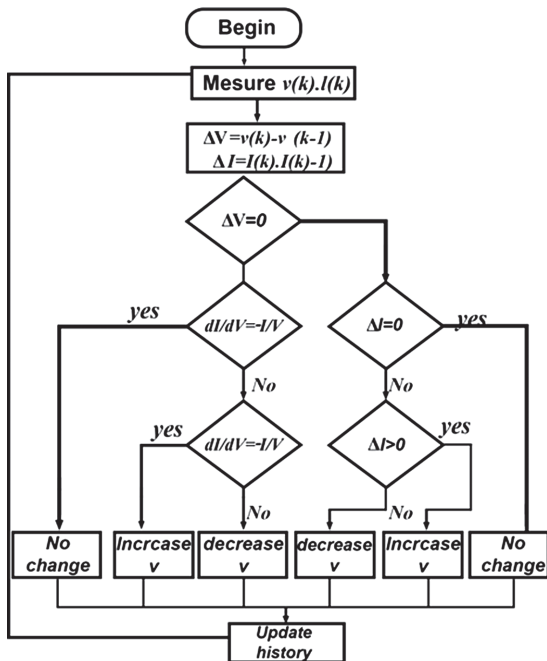


Fig. 5. Flowchart of algorithm.

the Incremental conductance MPPT algorithm method is provided.

The DC-DC boost converter is also known as the step-up converter (Fig. 3). It can be used in the cases where the

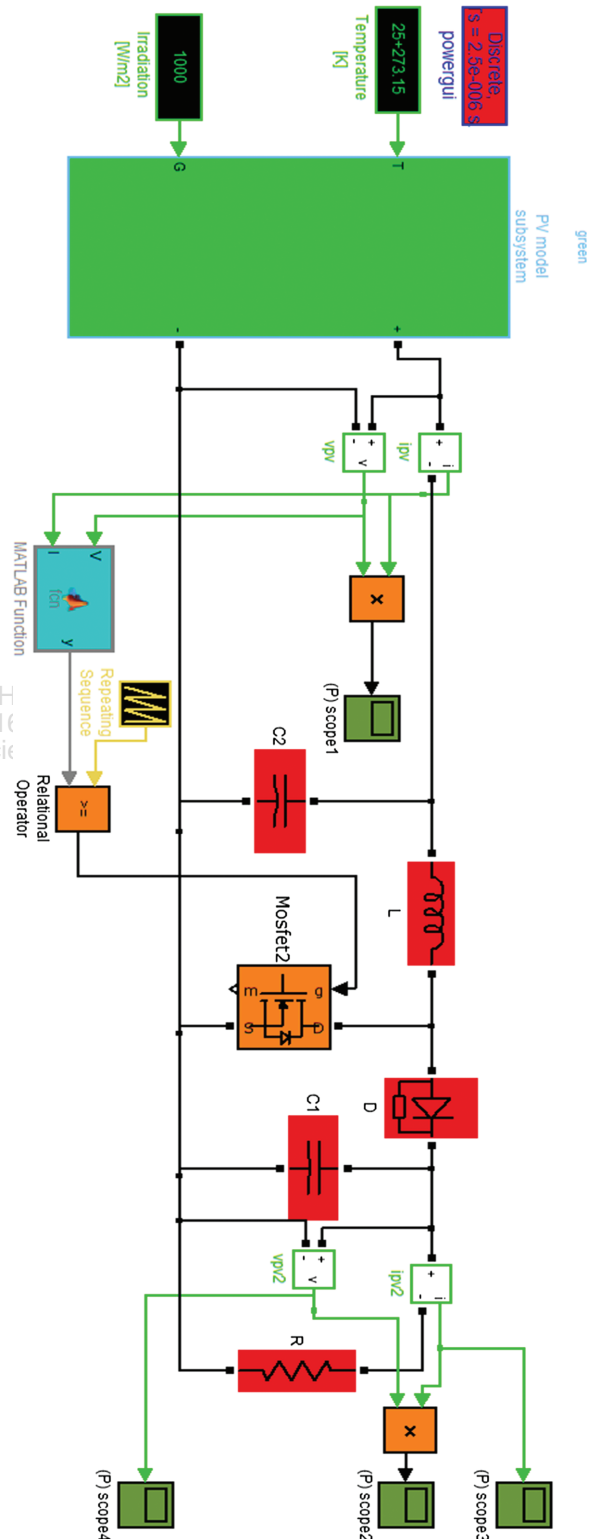


Fig. 6. Circuit diagram of the incremental conductance method.



Fig. 7. Output voltage as function of time.

output voltage greater than the input voltage. Grid system is an example which use a boost converter. The conversion ratio between input and output voltage is.⁵

$$\mu = \frac{V_o}{V_i} = \frac{T}{t_{\text{off}}} = \frac{1}{1-D} \quad (2)$$

where t_{off} is the duration that the switch is not active and D is the duty ratio of the switch.

2. INCREMENTAL CONDUCTANCE ALGORITHM

The main idea of this algorithm comes from the fact that the sum of the instantaneous conductance (I/V) and the incremental conductance is zero at MPP. Because it is negative on the right side of MPP and positive on the left side of the MPP. This relationship is derived from the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right. Figure 4 shows the slope of the $P-V$ array power curve. Thus, incremental conductance can determine that the MPPT has reached and stop perturbing the operating

point of the PV array. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the above concept.

Incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than other known methods like perturb and observe (P&O). However, this algorithm is increased complexity when compared to P&O.⁶⁻¹⁰

3. OPERATION PRINCIPLE

The flowchart shown in Figure 5 explains the operation of this algorithm where the MPP can be tracked by comparing the instantaneous conductance (I/V) to the incremental conductance ($\Delta I/\Delta V$). It starts with measuring the present values of PV module voltage and current. Then, using the present values and previous values of voltage and current it measures the incremental changes, dI and dV . The track depend on below relationships.

$$\frac{\Delta I}{\Delta V} = \frac{-I}{V} \quad \text{at MPPT} \quad (3)$$



Fig. 8. Output current as function of time.

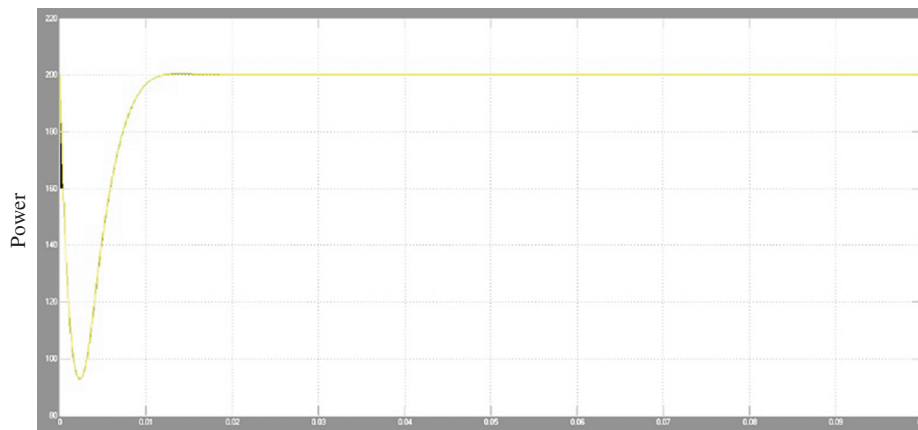


Fig. 9. Output power as function of time.

$$\frac{\Delta I}{\Delta V} > \frac{-I}{V} \quad \text{at left of MPPT} \quad (4)$$

$$\frac{\Delta I}{\Delta V} < \frac{-I}{V} \quad \text{at right of MPPT} \quad (5)$$

If Eq. (3) is not satisfied, then as we start from zero point it is assumed that the operating point is at the left side of the MPP. Thus the tracker must be moved to the right by increasing the module voltage. Similarly, if the condition satisfies the inequality Eq. (5), it is assumed that the operating point is at the right side of the MPP, thus the tracker must be moved to the left by decreasing the module voltage. When the operating point reaches at the MPP, the condition satisfies the Eq. (3). At the end of cycle, it updates the history by storing the voltage and current data that will be used as previous values in the next cycle.^{8,11}

4. SIMULATION CIRCUIT

Figure 6 presents the simulation circuit. The parameters on our simulation are taken from KC200GT solar array datasheet.¹² The inputs to the solar PV panel are temperature (T_a) and solar irradiation (G). Simulation circuit diagram contain block of the Incremental Conductance method.² In general, a power source is operated in conjunction with a dc–dc power converter (boost and sepic), whose duty cycle is modulated in order to track the instantaneous MPP of the PV source.⁸

5. SIMULATION RESULTS

In our simulation, we assumed that the photovoltaic cell is exposed to Irradiance $G = 1000 \text{ w/m}^2$ and $T_a = 25 \text{ oc}$. Then, the circuit is simulated with maximum power point tracking controller (IC controller). The results of the simulations appear in Figures 7–9. Figure 7 presents the output voltage. While, Figure 8 displays output current. Finally, Figure 9 exhibits output power. The incremental conductance gives the duty cycle to extract the maximum power from PV system. We found that the MPP equals 200.13 W

compared to the expected value 200.143 W.¹² We noticed that the MPP has been achieved without oscillation around the final value.

6. CONCLUSION

The paper proposes a simple MPPT method that requires only measurements of Incremental conductance. Incremental conductance algorithm of MPPT is implemented using Boost converter. The model is simulated with MATLAB/SIMULINK. It is shown that PV system output power 200.13 W. We expected 200.143. We explain the small loss due the experimented error. The incremental conductance gives the duty cycle to extract the maximum power from PV system. The proposed method give different advantages which are: good tracking efficiency, response is high also we get maximum power point without oscillating around finale value.

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