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Modeling and Simulation of Incremental Conductance MPPT Algorithm for Photovoltaic Applications

Saravana Selvan. D
Faculty of Engineering and Computer Technology, Aimst University,
Bedong- 08100, kedah, Malaysia
s_selvan@aimst.edu.my

Abstract – Photovoltaic (PV) is a technical name in which radiant (photon) energy from the sun is converted to direct current (dc) Electrical Energy. PV power output is still low, continuous efforts are taken to develop the PV converter and controller for maximum power extracting efficiency and reduced cost factor. The maximum power point tracking (MPPT) is a process which tracks one maximum power point from array input, varying the ratio between the voltage and current delivered to get the most power it can. A number of algorithms have been developed for extracting maximum power. This paper details the study of incremental conductance MPPT algorithm. And it can be experimentally verified by modeling the PV system with MPPT algorithm in Matlab/Simulink Software.

***Keywords* - PV Module, MPPT, Incremental Conductance (IC) Algorithm**

I. Introduction

Solar Energy is the ultimate source of energy, which is naturally replenished in a short time period of time, for this reason it is called "Renewable Energy" or "Sustainable Energy". Due to the severity of the global energy crisis and environmental pollution, the photovoltaic (PV) system has become one kind of important renewable energy source. Solar energy has the advantages of maximum reserve, inexhaustibleness, and is free from geographical restrictions, thus making PV technology a popular research topic. In this world 80 % of the green houses gases are released due to the usage of fossil fuel based. The world primary energy demand will have increased almost 60% between 2002 and 2030, averaging 1.7% increase annually, increasing still further the Green House Gases [1]. Oil reserves would have been exhausted by 2040, natural gas by 2060, and coal by 2300 [2]. This causes issues of high per KW installation cost but low efficiency in PV generators. [3-5]. Currently more research works has been focussed on how to extract more power effectively from the PV cells. There are two ways such as solar tracking system and Maximum Power Point Tracking (MPPT) [6, 7]. In the literature survey show that there will be an increasing percentage of 30-40 % of energy will be extracted compared to the PV system without solar tracking system [8, 9]. The Maximum Power Point Tracking (MPPT) is usually used as online control strategy to track the maximum output power operating point of the Photovoltaic generation (PVG) for different operating condition of insolation and temperature of the PVG. The author [10, 11] compares and evaluates the percentage of power extraction with MPPT and without MPPT. It clearly shows that when we use MPPT with the PV system, the power extraction efficiency is increase to 97%. The study of developing a PV charging system for Li-ion batteries by integrating MPPT and charging control for the battery is reviewed. [12]. The author [13] reviews the various types of non isolated Dc-Dc converters for the photo voltaic system. Optimal operating performances by different converter topologies are one of the main points which can be summarized in this research work. [13] It concludes that the best type of converter for PV system is the buck-boost Dc/Dc converter. The overall block diagram of PV panel with Dc-Dc converter and MPPT is shown in this figure 1.

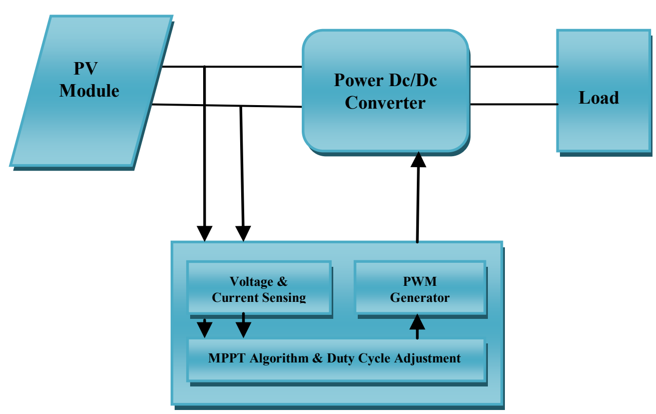

Fig.1 Overall Block Diagram

This paper reviews the basic characteristics of the PV cell and the simulation model of the circuit with the help of Matlab/simulink software. The MPPT Controller is necessary for any solar systems need to extract maximum power from PV module. It forces PV module to operate at close to maximum power operation point to draw maximum available power. The MPPT algorithm used in this paper is of variable step size Incremental Conductance (IC) Method. But the optimal performance of the PV system mainly depends on the power converter. The simulation model of the PV based system with MPPT algorithm will be implemented in the Matlab/Simulink.

II. MODELING OF PV CELL

The solar cell is the basic unit of a PV system. An individual solar cell produces direct current and power typically between 1 and 2 W, hardly enough to power most applications. Solar Cell or Photovoltaic (PV) cell is a device that is made up of semiconductor materials such as silicon, gallium arsenide and cadmium telluride, etc. that converts sunlight directly into electricity. The voltage of a solar cell does not depend strongly on the solar irradiance but depends primarily on the cell temperature. PV modules can be designed to operate at different voltages by connecting solar cells in series. When solar cells absorb sunlight, free electrons and holes are created at positive/negative junctions. If the positive and negative junctions of solar cell are connected to DC electrical equipment, current is delivered to operate the electrical equipment. The equivalent circuit of the PV cell is shown in figure 2.

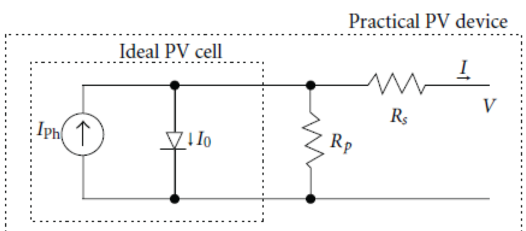

Fig. 2 PV cell Modeled as a diode circuit

For simplicity, the single-diode model of Figure 2 is used in this paper [14]. This model offers a good compromise between simplicity and accuracy with the basic structure consisting of a current source and a parallel diode. In Figure 2, I_{ph} represents the cell photocurrent while *R*sh and *Rs* are, respectively, the intrinsic shunt and series resistances of the cell. The module photocurrent I_{ph} of the photovoltaic module depends linearly on the solar irradiation and is also influenced by the temperature according to the following equation:

$$I_{ph} = [I_{SC} + K_i(Tk - T\mathrm{ref})] * \lambda / 1000$$

where I_{ph} [A] is the light-generated current at the nominal condition (25∘C and 1000W/m^2), K_i is the short-circuit current/temperature coefficient (0.0017A/K), T_k and T_{ref} are, respectively, the actual and reference temperatures in *K*, λ is the irradiation on the device surface (W/m^2), and the nominal irradiation is 1000W/m^2. The value of module short-circuit current is I_{SC} taken from the datasheet of the reference model. The detailed simulink model of PV cell is presented in Figure 3. Iph for different values of insolation and temperature is shown in Table 1.

S. No	Insol W/m^2	Value of Iph (A)			
		20^{o}c	30^{o}c	40^{o}c	50^{o}c
1	1000	2.54	2.557	2.578	2.593
2	500	1.278	1.279	1.288	1.299
3	100	0.252	0.254	0.257	0.259

Table .1 Iph for various Insolation and Temperatures

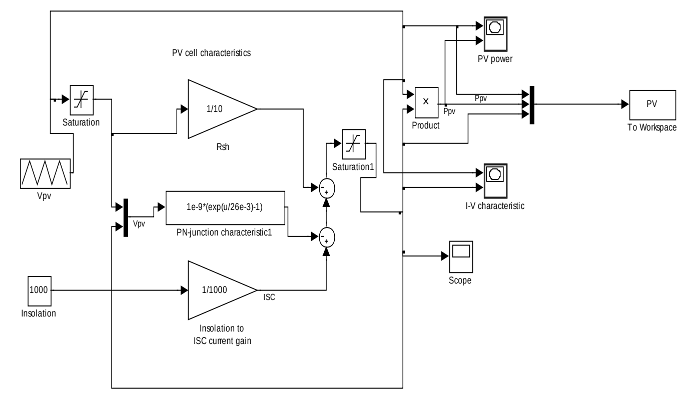

Fig.3 Simulink Model of PV cell

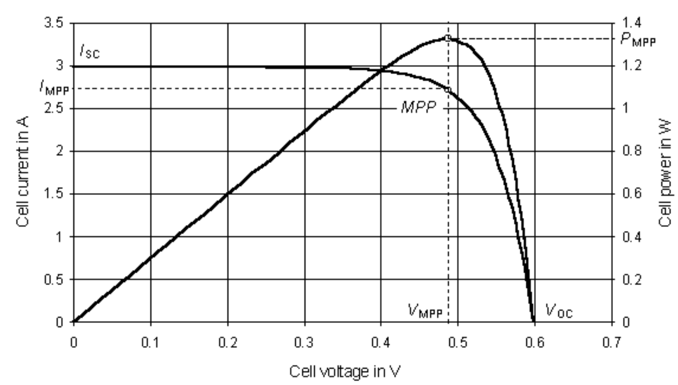

Fig.4 I-V & P-V Characteristics of PV cell

III. INCREMENTAL-CONDUCTANCE MPPT ALGORITHM

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum

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available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day and it can also rise to 18 V on a very cold day. MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. MPPT algorithm can be applied to both buck and boost power converter depending on system design. Normally, for battery system voltage is equal or less than 48 V, buck converter is useful. On the other hand, if battery system voltage is greater than 48 V, boost converter should be chosen. In incremental conductance method the array terminal voltage is always adjusted according to the MPP voltage it is based on the incremental and instantaneous conductance of the PV module.

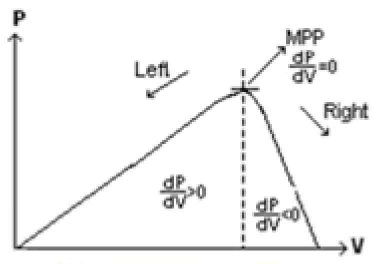

Fig.5 Basic Concept of Incremental Conductance on a PV Curve

The basic concept of Incremental conductance on a PV curve of a solar module is shown in figure 5. The slope of the P-V module power curve is zero at The MPP, increasing on the left of the MPP and decreasing on the Right hand side of the MPP. The basic equations of this method are as follows.

dP/dV=0 at MPP
dP/dV>0 left of MPP
dP/dV<0 right of MPP

$$dP/dV = d(VI)/d(V)= I + V*dI/dV$$

The dP/dV is defined as Maximum power point identifier factor. By utilizing this factor, the IC method is proposed to effectively track the MPP of PV array [15]. The following definitions are considered to track the MPP.

$\Delta I/\Delta V = -I/V$ *at MPP,* $\Delta V_n = 0$
$\Delta I/\Delta V > -I/V$ *left of MPP,* $\Delta V_n = +\delta$
$\Delta I/\Delta V < -I/V$ *right of MPP,* $\Delta V_n = -\delta$

The MPPT regulates the PWM control signal of the dc to dc power converter until the condition: (dI/dV) + (I/V) = 0 is satisfied. Consider the n^{th} iteration of the algorithm as a reference, and then n+1 iteration process can be determined by using the above equations. The Flow chart of incremental conductance MPPT is shown in figure 6. The output control signal of the IC method is used to adjust the voltage reference of PV array by increasing or decreasing a constant value ($\Delta V=\delta$) to the previous reference voltage. In this method the tracking of MPP is accomplished by a fixed step size ($\pm$ δ) regardless to the gap between the operating point of PV and MPP location. In this method the peak power of the module lies at above 97% of its incremental conductance.

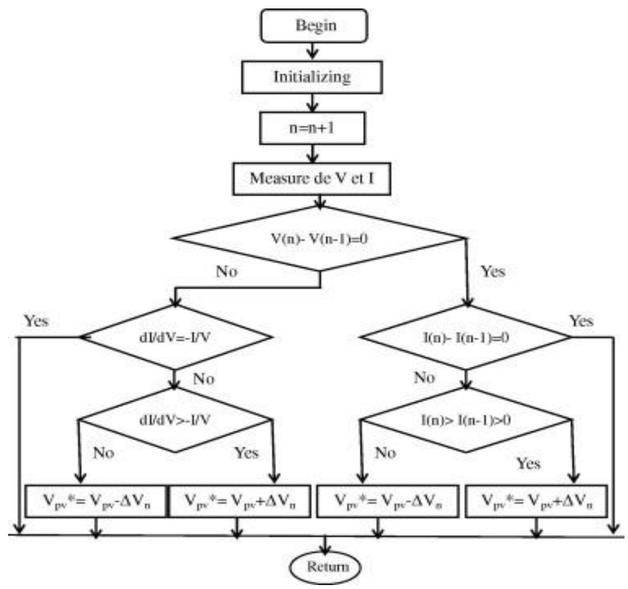

Fig.6 Flow chart of MPPT Incremental Conductance

IV. DC-DC POWER CONVERTER

DC-DC converters can be used as switching mode regulators to convert an unregulated dc voltage to a regulated dc output voltage. The regulation is normally achieved by PWM at a fixed frequency and the switching device is generally BJT, MOSFET or IGBT.

There are several different types of dc-dc converters, buck, boost, buck-boost and cuk topologies, have been developed and reported in the literature to meet variety of application specific demands. The important requirement of any DC–DC converter

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used in the MPPT scheme is that it should have a low input-current ripple. Buck converters will produce ripples on the PV module side currents and thus require a larger value of input capacitance on the module side. On the other hand, boost converters will present low ripple on the PV module side, so here in this experimental work, boost converter is used to verify the output power results.

V. SIMULATION AND RESULTS

The flowchart of the incremental conductance MPPT algorithm has been implemented in Matlab/ Simulink. The figure7 illustrated the modeling diagram for the above algorithm. The simulation results of the ouput power of the PV module and the MPPT pulse width modulated output is shown in figure 8. The modelling diagram of figure 9 represents the whole PV system with MPPT along with the boost converter has been implemented in the Matlab/ simulink.

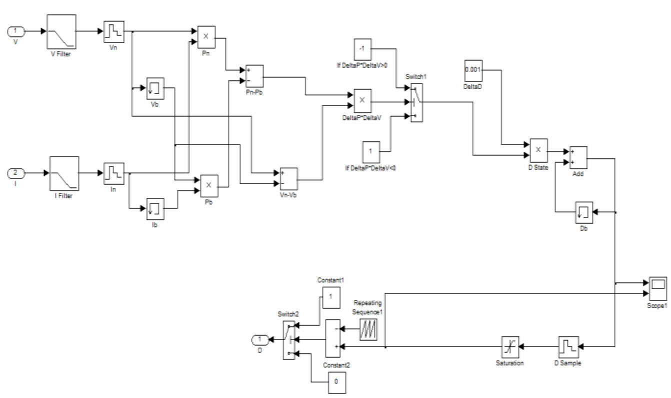


Fig. 7 Incremental Conductance Algorithm in simulink Modeling

The low ripple output current of Dc-Dc converter is shown in figure 10. The figure 11 represents the output power of the Dc-Dc converter with MPPT algorithm.

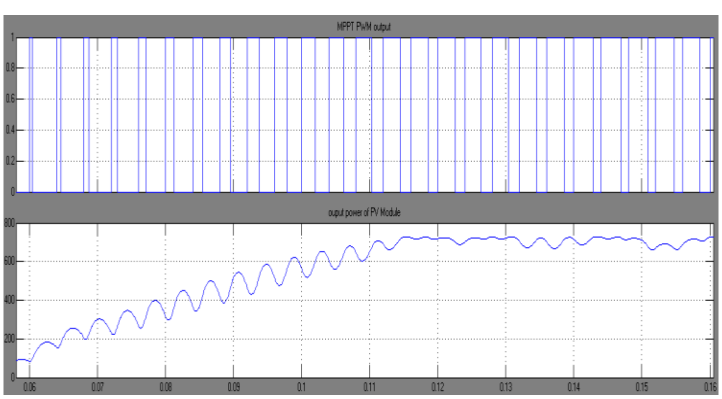


Fig .8 MPPT PWM output and output power of PV Module

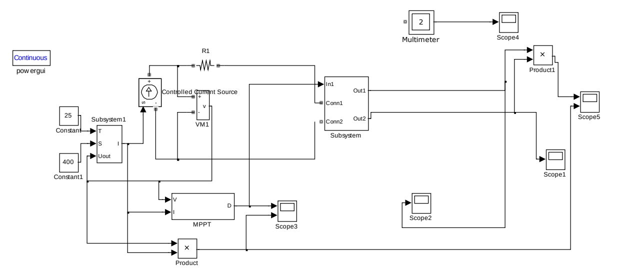
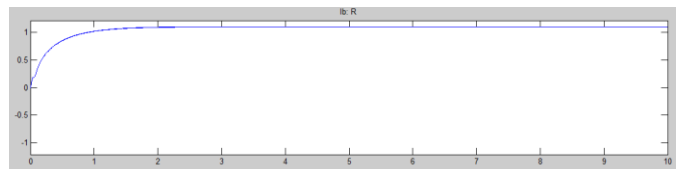


Fig .9 Modeling of PV Module with MPPT Algorithm of Dc-Dc Converter



ig .10 Low ripple Output Current of Dc-Dc Converter

VI .CONCLUSION

By this experimental work, the simulation of the PV system with Incremental conductance MPPT algorithm has been successfully implemented in the Matlab/Simulink. So that it forces the PV module to operate at close to maximum power operation point to draw maximum available power. The results of the output converter power shows that it is achieving the maximum extracting power and it is constantly working near the maximum operating point of the PV Module.

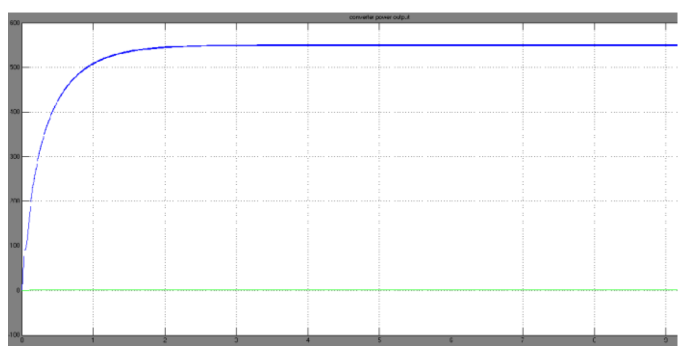


Fig.10 output power of the DC-Dc converter

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