

A MATLAB /Simulink Model of Triple-Junction Solar Cell and MPPT Based on Incremental Conductance Algorithm for PV System

Mamta Thakur¹, Baljit Singh²

M tech Student¹, DAV Institute of engineering and technology, Jalandhar

Assistant professor², DAV Institute of engineering and technology, Jalandhar

Abstract

Photovoltaic energy is the most important energy resource since it is clean, pollution free, and unlimited. In current years, a large number of techniques have been projected for tracking the maximum power point. Maximum power point tracking is used in photovoltaic systems to maximize the photovoltaic array output power, irrespective of the temperature and radiation conditions and of the load electrical characteristics the PV array output power is used to directly control the boost converter, thus reducing the complexity of the system. The method is based on use of a Incremental conductance of the PV to determine an optimum operating current for the maximum output power. The implementation of a PV model is based on the triple-junction solar cell in the form of masked block in Matlab/Simulink software package that has a user-friendly icon. It is fast and accurate technique to follow the maximum power point. This paper presents a new Matlab/Simulink model of a PV module and a maximum power point tracking (MPPT) system for high efficiency InGaP/InGaAs/Ge triple-junction solar cell.

Keywords: Photovoltaic System (PV), Maximum power point tracking (MPPT), Modeling of Multijunction solar cell, Incremental conductance Algorithm (ICA), Boost Converter and Simulation Results.

I. INTRODUCTION

As the consumption of the energy is increasing day by day, idea of exploring renewable energy sources are also growing. Due to our limited energy sources, renewable energy sources are the future. However, solar energy systems generally suffer from their low efficiencies and high costs. In order to overcome these drawbacks, maximum power should be extracted from the PV panel using MPPT techniques to optimize the efficiency of overall PV system [1]. The photovoltaic technology is an attractive option because it features several advantages such as absence of fuel cost, low maintenance requirement and environmental friendliness. The energy conversion efficiency of a PV generation system is low because the solar cell exhibits nonlinear current versus voltage and power versus voltage characteristics. These nonlinear characteristics are functions of weather conditions such as solar insulation and panel temperature [2]. In order to maintain efficient operation, maximum power point tracking algorithm which has quick response and can extract maximum power from the PV arrays in real time becomes essential in PGSS. Fueled by the advance in semiconductor technology, solar cells are one of the most promising candidates for alternate energy sources. Photovoltaic (PV) system is a green power source that converts sunlight to electricity. It has many

applications as in space satellites and orbital stations, solar vehicles, power supply for loads in remote areas, and street lighting systems. Motivated by superior performance and high efficiency, multi-junction solar cells have received much attention in the concentrated solar cell systems due to their ultimate features. A multi-junction solar cells used in concentrated PV systems are different from silicon PV cells as they are capable of converting very large amounts of sunlight into energy at high efficiency. Multi-junction solar cells have high conversion efficiency with a record value of more than 40% [3].

1.1 Photovoltaic cell: Photovoltaic cell generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect. It directly converts sunlight into electricity. PV module represents the fundamental power conversion unit of a photovoltaic system. The output characteristics of PV module depend on the solar radiation, cell temperature and output voltage of PV module. Since a PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of a maximum power point tracking for PV system applications. In order to get a maximum output power from the solar cells, a maximum power point tracker system is highly recommended. The output power delivered by a PV

module can be maximized using MPPT control system. It consists of a power conditioner to interface the PV output to the load, and a control unit, which drives the power conditioner for extracting the maximum power from a PV array. The PV model based on a multi-junction solar cell is implemented in the Matlab/ Simulink software package in the same way of Matlab block libraries or other component-based electronics simulation software packages [4][5].

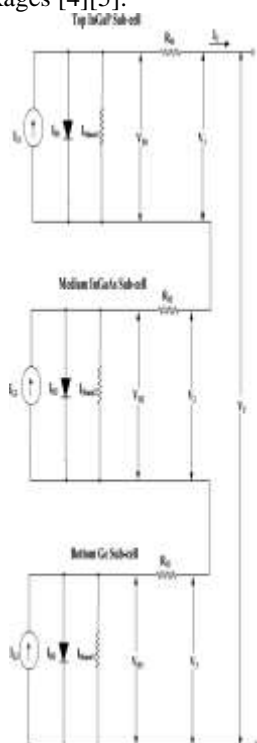


Fig 1. Equivalent circuit model of triple junction solar cell model

1.2 Triple junction solar cell: Investigational procedures face greater challenges when more materials to be added on the sandwich stack. Based on data of lattice constant for IIIeV semiconductor material, it has been seen that AlAs, GaAs, and Ge are matched on its lattice constant. Because of that these materials are able to be grown with less strain. Their band gap variation is also quite wide to perform a great absorption. Therefore, they can be used on the process of making the MJSC. However, the researchers stated that the band gap variation is not showing the satisfactory choice. Therefore, AlAs is considered having too high bandgap energy and can be substituted by InGaP. Because of that a 3 junctions solar cell designed by stacking InGaP, GaAs, and Ge all together with statistic as shown in . This is simply similar with the first double cell experiment but with addition of germanium. Option on choosing the Ge as third layer is not just by its lattice and band gap matched with the other two, but its characteristic is

similar with the silicon. Purified germanium can appear close to elemental silicon [6][7].

1.3 Modeling in Matlab Simulink: Based on those theory and equations, the model of a MJSC is created by MATLAB/Simulink. Extraction result from MATLAB/Simulink Based on the Simulink models, tandem cell performance can be plotted in terms of generated power and voltage. In order to create a better comparison method, several results/plotted graphs are compared. As result, the MJSC is able to generate more energy than the conventional single cell.

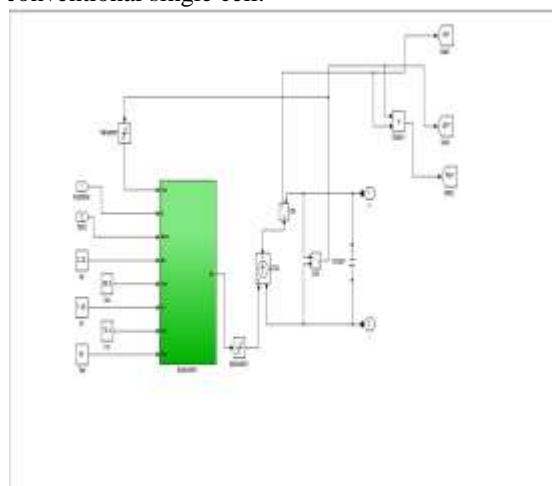


Fig. 2 Basic model of triple junction solar cell

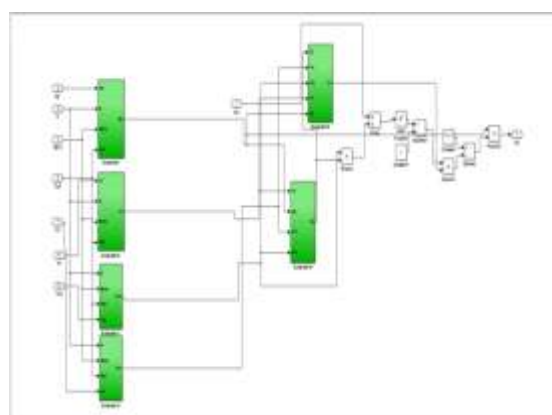


Fig 3. Subsystem of triple junction solar cell simulink model for photovoltaic system

1.4 Incremental conductance method:

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.

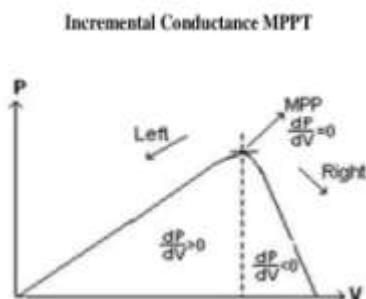


Fig 4. Basic idea of incremental conductance method on a P-V Curve of solar module

Fig 4.shows that the slope of the P-V array 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.

$$dI/dV = -IV \text{ at MPP}$$

$$dI/dV > -IV \text{ Left of MPP}$$

$$dI/dV < -IV \text{ Right of MPP}$$

Where I and V are P-V array output current and voltage respectively. The left hand side of equations represents incremental conductance of P-V module and the right hand side represents the instantaneous conductance. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at the maximum power point.

1.5 Incremental Conductance MPPT Algorithm:

This method exploits the assumption of the ratio of change in output conductance is equal to the negative output Conductance Instantaneous conductance. We have,

$$P = V I$$

Applying the chain rule for the derivative of products yields to

$$\partial P / \partial V = [\partial (VI)] / \partial V$$

$$\text{At MPP, as } \partial P / \partial V = 0$$

The above equation could be written in terms of array voltage V and array current I as $\partial I / \partial V = -I/V$ (9)

The MPPT regulates the PWM control signal of the dc - to - dc boost converter until the condition: $(\partial I / \partial V) + (I/V) = 0$ is satisfied. In this method the peak power of the module lies at above 98% of its incremental conductance.

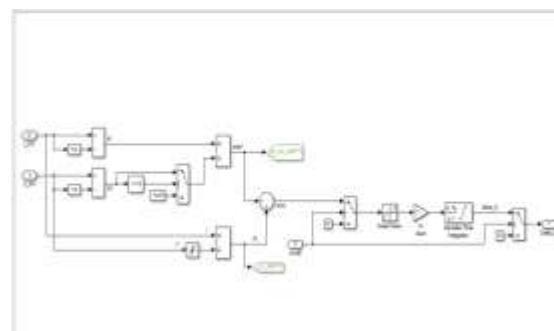


Fig 5. Matlab simulink modal of incremental conductance

1.6 Flow chart of incremental conductance:

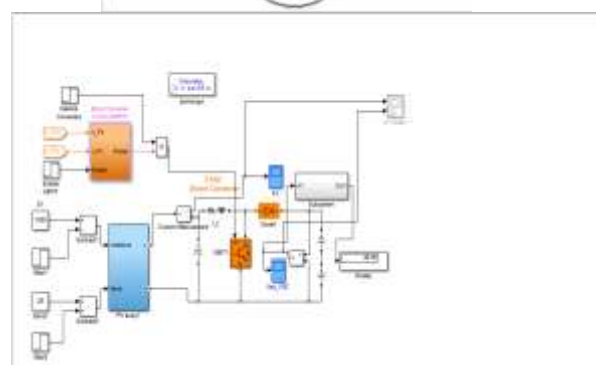
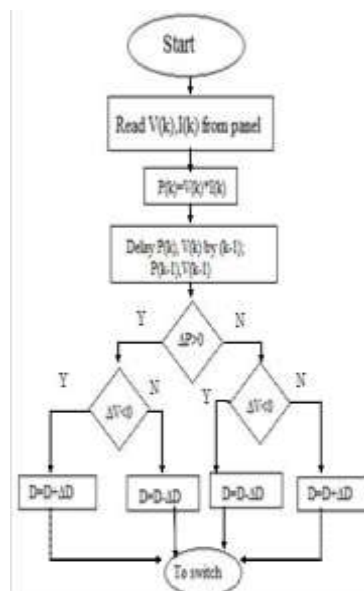


Fig 6. Matlab Simulink modal of MPPT using incremental conductance with multi junction solar cell.

II. Simulation results

Simulation of solar PV module in MATLAB/Simulink The model of triple-junction solar cell is implemented in the MATLAB/Simulink as shown Fig 6. The proposed

PV module is made of triple-junction solar cells in series and provides.

A) The output of current from PV system with using incremental conductance:

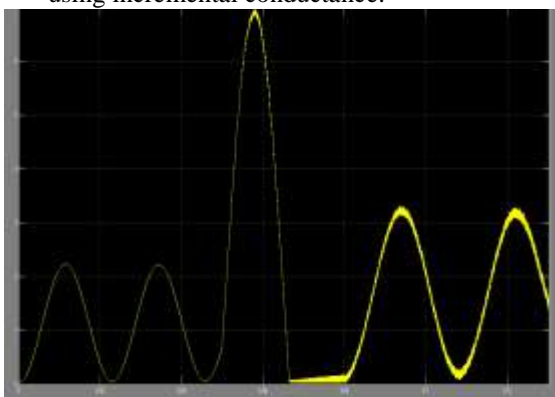


Fig6. Output of current from PV system using incremental conductance

b) The output value of voltage from PV system with incremental conductance:

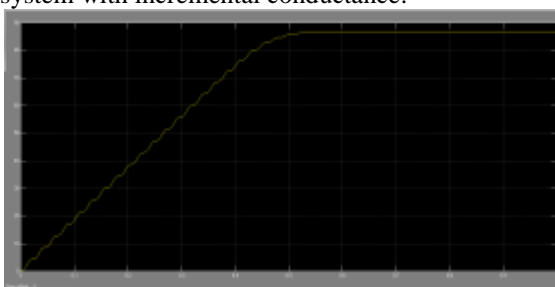


Fig.7 Output value of voltage from PV system with incremental conductance.

III. Conclusion

A new Matlab/Simulink model of PV module based on high effectiveness InGaP/InGaAs/Ge triple-junction solar cell is proposed. The proposed model represents the PV cell, module, And array for easy use on the simulation policy. The paper proposes a simple MPPT method that requires only measurements of Incremental conductance. The proposed MPPT algorithm is called Incremental conductance Method. However, by using this MPPT method we have increased efficiency. This method computes the maximum power and controls directly the extracted power from the PV. The proposed method offers different advantages which are good tracking efficiency, response is high and well control for the extracted power.

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