International Journal For Technological Research In Engineering
Volume 3, Issue 9, May-2016 *ISSN (Online): 2347 - 4718*

REVIEW ON MODELING AND SIMULATION OF GRID CONNECTED SOLAR PHOTOVOLTAIC SYSTEM

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Abstract: The human activities contribute to the global warming of the planet. As a result, every country strives to reduce carbon emissions. Lots of efforts are being undertaken by the Governments around the world to explore alternative energy sources and to achieve pollution reduction. Solar electric or photovoltaic technology is one of the biggest renewable energy resources to generate electrical power and the fastest growing power generation in the world. Photovoltaic (PV) System is a huge topic that can be researched and studied on such as the arrangement of PV array is one of the issues that can be studied. The main aim of the work is to analyze, the modeling and simulation photovoltaic array under the different irradiation condition and the interface of photovoltaic system to DC/DC converter & the Grid. In this thesis the step of modeling with MATLAB and Simulink of the photovoltaic system is shown and simulation results are provided. Overall findings indicate that the modeling using MATLAB / SIMULINK can be further used for investigation and make improvement in order to identify the effect of irradiation and temperature on grid connected Photovoltaic (PV) system. This project would mainly concern on the PV-array modeling and connection with Grid and with DC/DC converter. The Simulink model of the PV could be used in the future for extended study with different DC/DC converter topology. Optimization of MPPT algorithm can be implemented with the existing Photovoltaic and DC/DC converter and also with inverters.

I. INTRODUCTION

The human activities contribute to the global warming of the planet. As a result, every country strives to reduce carbon emissions. Lots of efforts are being undertaken by the Governments around the world to explore alternative energy sources and to achieve pollution reduction. The Photovoltaic System (PV) is getting popular day by day as the crude oil price increases and unstable in the market. The photovoltaic maybe one of the solution for better as well as cleaner energy as it is naturally harness from the Sun energy. Although the technology is mainly well known in the space mission, yet it's still an alien for domestic usages. That's only because of the high initial cost, generation efficiency and reliability [1]. On the other hand, to answer the finding for alternative energy has made the PV system popular among the researchers. Said so, in the rural areas where the grid connection is extremely expensive, PV Systems have been implied to give hope to these areas. While for the urban area, the PV Water Heater is common and can be found on the roof of the houses. The PV array output has highly non-linear behavior, and to simplify the array model to a constant voltage source or a current controlled voltage source is often not appropriate. Several models for solar PV arrays such as mathematical model, circuit based models have been proposed in the literature [2],[3] whose level of complexity is sometimes not relevant for power system transient studies. A circuit model based on Piecewise Linear approach is model proposed in [4] is simple and easy to implement in power system studies but it has not considered the effect of atmospheric temperature on PV array output. Hence this paper extends the model proposed in [4] to include the effect of temperature and solar insolation in the PV array model. The schematic diagram of a grid connected PV system, with two-stage energy conversion system, using a DC/DC boost converter and DC/AC converter, is shown in Fig. 1. The PV array provides maximum power output for a particular loading, therefore at certain reference voltage, across its terminals. This is called maximum power point (MPP) [5]-[6]. The MPP Tracker has an algorithm which generates the MPP reference voltage. The DC-DC converter is controlled so as to track the MPP of the PV array. The output of the DC-DC converter is fed to an inverter (DC-AC converter), which is controlled to produce output current in phase with the utility voltage to obtain a Unity Power Factor(UPF) operation. There exists a vast literature on MPPT algorithms [7]. However, in this paper a MPPT based on Perturb and Observe (P&O) algorithm is presented. The design of controller for the DC/DC converter based on proportional and integral (PI) control and other advanced methods have been dealt in the literature [8]-[11]. However, very few papers dealt with the detailed controller design procedures and the effectiveness of the controller under varying atmospheric conditions. This paper proposes a new control method called K factor method for DC/DC boost converter [12] for effective tracking of PV array MPP under standard and varying atmospheric conditions. The advantage of K factor control method is that it has faster transient response compared to that of the simple PI control method and is more stable. In this paper, detailed modeling of DCDC boost converter is performed using state space averaging approach the design of passive components of the boost converter as per the system specification is also presented. The paper is organized as follows. Section II briefly presents the modeling the solar PV array and DC/DC boost converter and design of converter passive components. Descriptions of K factor control method, controller design procedure, MPPT algorithm are also presented in section II. Simulation and analysis of results, showing the PV array characteristics and illustrating the effectiveness of the proposed K factor control method under varying atmospheric conditions are given in Section III.

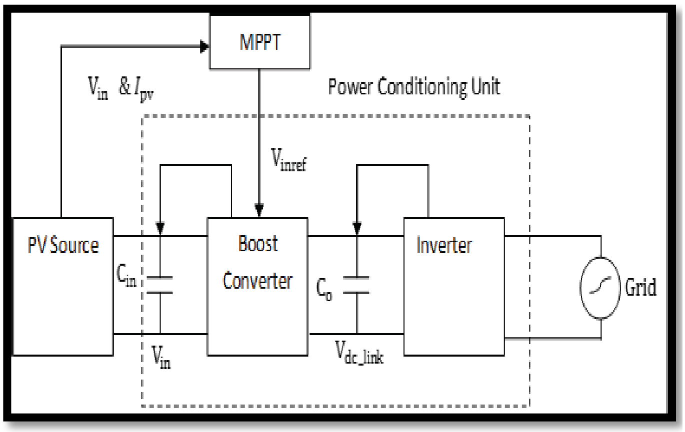


Fig –Proposed Topology

Objectives:-

The objectives to be achieved at the end of this project work.

- To study solar cell circuit model.
- To model and simulate PV array and dc-dc boost converter in MATLAB.
- To determine the output of PV array connecting to dc-dc converter and grid at different irradiation condition.

Modeling the photovoltaic array

In order to study the photovoltaic system in distributed generation network, a modeling and circuit model of the PV array is necessary. A photovoltaic device is a nonlinear device and the parameters depend essentially on sunlight and temperature. The photovoltaic cell converts the sunlight into electricity. The photovoltaic array consists of parallel and series of photovoltaic modules. The cell is grouped together to form the panels or modules. The voltage and current produced at the terminals of a PV can feed a DC load or connect to an inverter to produce AC current. The model of photovoltaic array is obtained from the photovoltaic cells and depends on how the cells are connected. The basic equation from the theory of semiconductor to describe mathematically the I-V characteristic of the ideal photovoltaic cell. It is a semiconductors diode with p-n junction. The material used is mono-crystalline and polycrystalline silicon cells. Figure 2.5 is the model of photovoltaic cell with the internal resistance and diode. A real photovoltaic device must include the effects of series and parallel resistance of the PV.

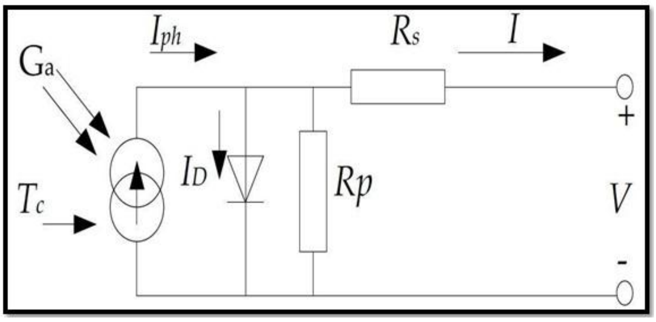


Figure: Single diode equivalent circuit of a solar cell

The equations that give the behavior of the PV are:

$$I = I_{pv} - I_0\left[exp\left(\frac{qV}{akT}\right) - 1\right]$$

$$I = I_{pv} - I_0\left[exp\left(\frac{V + R_s}{V_t a}\right)\right] - \frac{V + R_s I}{R_p} \qquad \text{…………… (2.1)}$$

Where,

Ipv: current generated by the incident light

I0: reverse saturation

q: electron charge (1,602 10^{0}-19^{0}C) k :Boltzmann constant

T: the temperature of the p-n junction

Vt: the thermal voltage of the array

Rs: the resistance series

Rp: the resistance parallel.

DC/DC converter stage

Boost

The boost converter is widely used to pinpoint the ultimate point of power of the PV array. It is a simple circuit with good response speed. Any algorithm of maximum power point is flexible to implement with software and hardware. The boost converter circuit is shown in figure 2.6. The boost converter can operate in continuous conduction mode along with discontinuous conduction mode [10]. The mode of conduction depends of the capacity for storage of energy along with the relative timeframe of the switching. The output voltage is dependent of the duty cycle; it is adjusted by the maximum power controller. The relation of the output voltage with the input voltage as function of duty cycle is given by-

$$\frac{V_0}{V_i} = \frac{T_s}{t_{off}} = \frac{1}{1-D} \qquad \text{…………….(2.2)}$$

V0= average output voltage

Vi: the input voltage, PV voltage Ts: switching period

D: duty cycle

Toff: switching off of the IGBT

The boost converter in [11] is designed for all possible duty cycles and for all irradiations of the PV array.

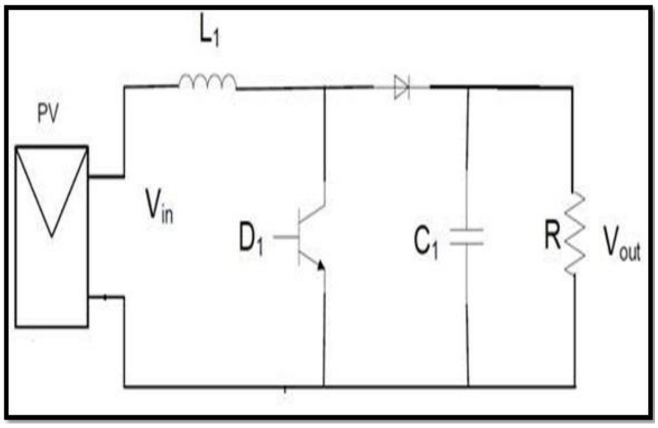


Figure: Boost converter for PV [11]

II. SOLAR CELL STRUCTURE

Introduction

The solar cell is an electronic device which directly converts sunlight into electricity. Light shining on the solar cell produces both a current and a voltage to generate electric power. This process requires firstly, a material in which the absorption of light raises an electron to a higher energy state, and secondly, the movement of this higher energy electron from the solar cell into an external circuit. The electron then dissipates its energy in the external circuit and returns to the solar cell. A variety of materials and processes can potentially satisfy the requirements for photovoltaic energy conversion, but in practice nearly all photovoltaic energy conversion uses semiconductor materials in the form of a p-n junction

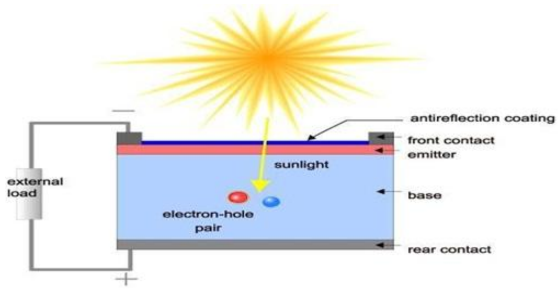


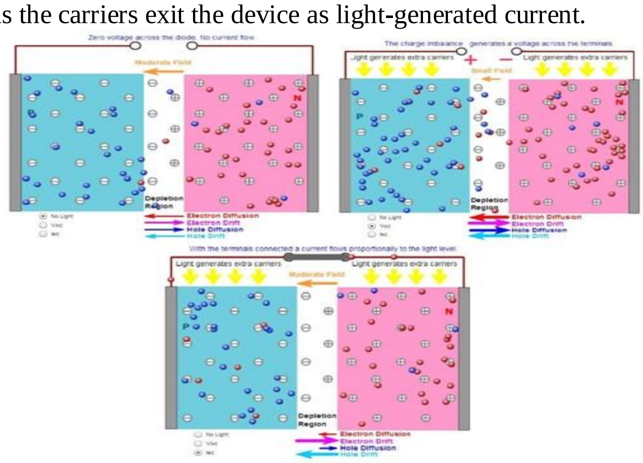
Figure : Solar Cell Structure[2]

The basic steps in the operation of a solar cell are:

- the generation of light-generated carriers;
- the collection of the light-generated carries to generate a current;
- the generation of a large voltage across the solar cell; and
- The dissipation of power in the load and in parasitic resistances.

The photovoltaic effect

The collection of light-generated carriers does not by itself give rise to power generation. In order to generate power, a voltage must be generated as well as a current. In photovoltaic cell voltage is generated by a process known as the "photovoltaic effect". The collection of light-generated carriers by the p-n junction causes a movement of electrons to the n-type side and holes to the p-type side of the junction. Under short circuit conditions, there is no build up of charge, as the carriers exit the device as light-generated current.



Short-Circuit Current

when the solar cell is short circuited the voltage across the solar cell is zero. Usually written as ISC, the short-circuit current is shown on the IV curve below.

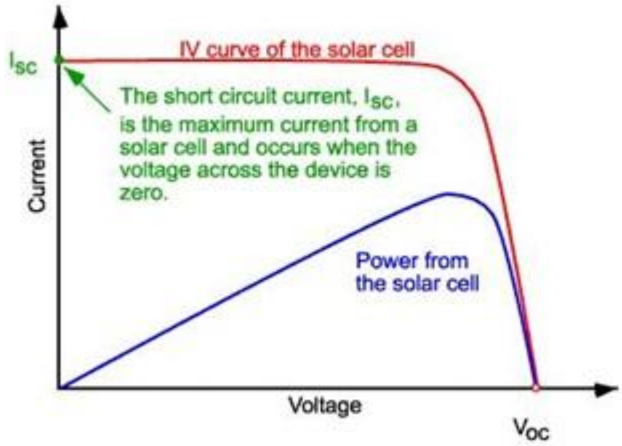


Figure: The I-V curve of a solar cell showing the short-circuit current.

Short-circuit current is due to the generation and collection of light-generated carriers. For an ideal solar cell at most moderate resistive loss mechanisms, the short- circuit current and the light-generated current are identical. Therefore, the short-circuit current is the largest current which may be drawn from the solar cell.

III. MAXIMUM POWER POINT TRACKING (MPPT)

Introduction

Renewable energy sources play an important role in electric power generation. Various renewable sources such as solar energy, wind energy, geothermal etc. are harness for electrical power generation. Solar energy is good choice for power generation. By solar photovoltaic module the solar energy is directly converted into electrical energy. The photovoltaic modules are made up of silicon cells. The silicon solar cell which give output voltage of around 0.7V under open circuit condition. When many such cells are connected in series we get a solar PV module. Normally in a module there are 36 cells which amount for open circuit voltage of about 20V. The current rating of the modules depends on area of individual cells. Higher the cell area high is the current output of the cell. For obtaining higher power output the solar PV modules are connected in series and parallel combinations forming solar PV arrays. A typical characteristic curve of the called current and voltage curve and power and voltage curve of the module.

Need of Maximum Power Point Tracking

The power output of a solar PV module changes with change in solar radiation and change in temperature.

As seen in PV curve of the module there is a single maximum of power. There is exists a peak power corresponding to a particular Voltage and current. We know that the efficiency of solar PV module is low about 14 - 18%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and radiation condition. Hence maximization of power improves the utilization of the solar PV module. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar PV module. A DC/DC converter serves the purpose of transferring maximum power from the solar PV module to the load. A DC/DC converter acts as an interface between the load and module. By changing the duty cycle the load impedance as seen by the source is

How Maximum Power Point is obtained

The maximum power point is obtained by introducing DC/DC converter in between the load and solar PV module. The duty cycle of the converter is changed till the peak power point is obtained.

Vo = D*Vi……………… (5.1)
Vo = Output voltage of converter
Vi = Input voltage of converter
D= Duty cycle of converter
Solving for impedance transfer ratio
$Ro = D^2 * R_i$……………… (5.2)
Ro is output impedance
Ri is input impedance as seen by the source
$Ri = R_o/D^2$…………………(5.3)

Thus the output resistance Ro is remains constant and by changing the duty cycle the input resistance Ri seen by the source changes. So the resistance corresponding to the peak power point is obtained by changing the duty cycle.

IV. CONCLUSION AND FUTURE SCOPE

MPPT part different MPPT methods can use with using artificial intelligence to get better power output. As grid connected system in power electronics part the different DCDC converter and inverters can also studied too to achieving a better quality energy output.

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