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

MATLAB MODELING AND SIMULATION OF GRID CONNECTED SOLAR PHOTOVOLTAIC SYSTEM WITH BOOST CONVERTER

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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.

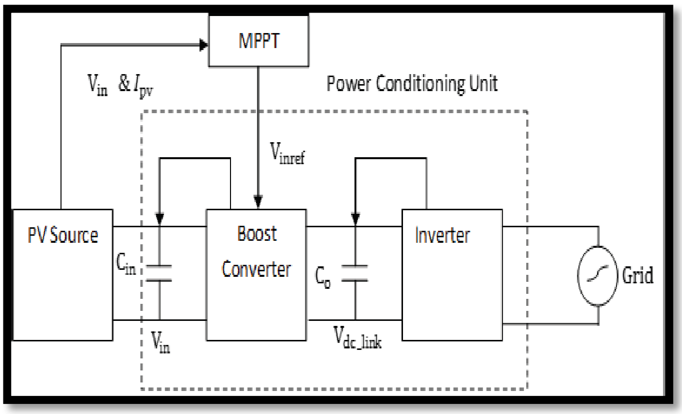


Fig –Proposed Topology

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.

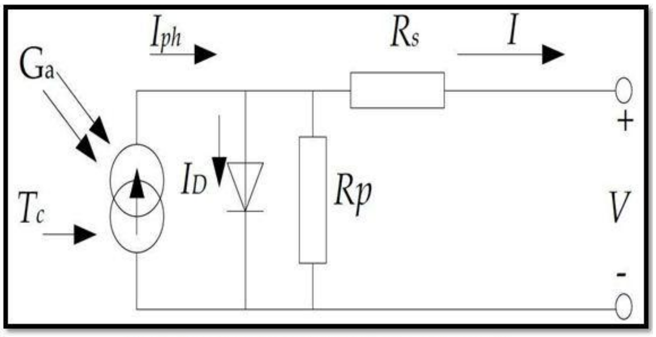


Figure: Single diode equivalent circuit of a solar cell

The equations that give the behavior of the PV are:

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

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

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-

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

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.

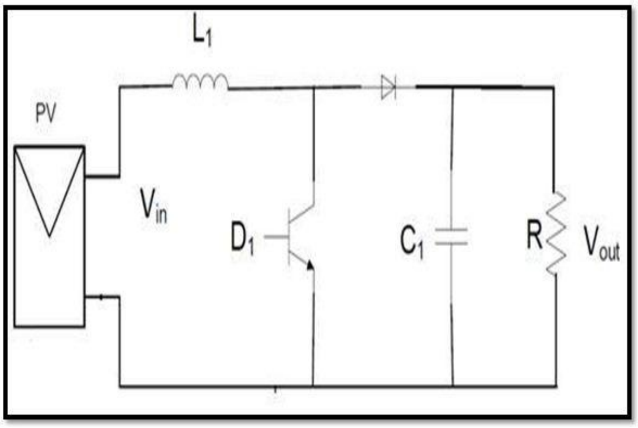


Figure: Boost converter for PV [11]

II. DC –DC CONVERTER

Introduction

DC-DC converter is widely used in dc power supplies and dc motor drive for purpose of converting unregulated DC input into regulated DC output at desired voltage level. There are no of different topologies for DC-DC converters. They are categorized into isolated or non isolated topologies. The isolated topologies use a small sized high frequency electrical isolation transformer which provides the benefits of dc isolation between input and output and step up or step down of output voltage by changing the transformer turns ratio. They are very often used in switch mode DC power supplies; In PV application, the grid connected system use these type of converter is use to step up the DC output of pv module.

DC-DC Boost (step-up) Converter

The main principle is that drives the boost converter is the tendency of an inductor to resist changes in current. The output voltage is always higher than the input voltage in a boost converter. A schematic of a boost power stage is shown in Figure;

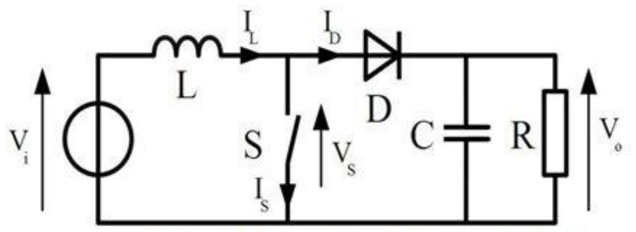


Figure 4.1: BOOST (STEP-UP) DC-DC CONVERTER

When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores the energy. Polarity of the left side of the inductor is positive.

When the switch is opened, current will be reduced as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

Incremental conductance MPPT Algorithm[15]

There are a large numbers of algorithms that are able to track MPPs. Some are simple, such as those based on voltage and current feedback, and some are complicated, such as perturbation and observation (P&O) or the incremental conductance (Inc Cond) method. They also varying complexity, sensor requirement, speed of convergence, cost, range of operation, popularity, ability to detect multiple local maxima, and their applications. Having a curious look at the recommended methods, hill climbing and P&O are the algorithms that were in the center of consideration because of their simplicity and ease of implementation. Hill climbing is perturbation in the duty ratio of the power converter, and the P&O method is perturbation in the operating voltage of the PV array. However, the P&O algorithm cannot compare the array terminal voltage with the actual MPP voltage, since the change in power is only considered to be a result of the array terminal voltage perturbation. As a result, they are not accurate enough because they perform steady-state oscillations, which consequently waste the energy. By minimizing the perturbation step size, oscillation can be reduced, but a smaller perturbation size slows down t he speed of tracking MPPs. There are some disadvantages with these methods, where they fail when rapidly changes in atmospheric conditions. The Inc-Cond method is the one which overrides over the aforementioned draw backs. In this 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. 1 shows that the slope of the PV array power curve is zero at the MPP, increasing on t he left of the M PP and decreasing on the right-hand side of the M PP. The basic equations of this method are as follows.

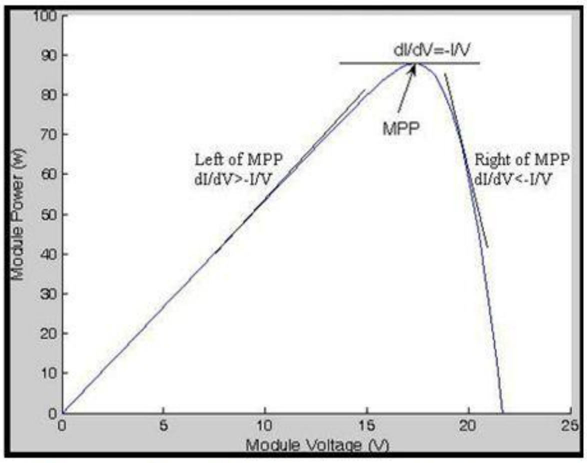


Figure Basic idea of the Inc Cond method on a P –V curve of a solar module. [15]

dI/dV = - (I / V) at M

dI/dV > - I / V left of MPP …………….(5.2)

dI/dV < - I / V right of MPP………………(5.3)

where I and V are the PV array output current and voltage, respectively. The left-hand side of the equations represents the IncCond of the PV module, and the right-hand side represents the instantaneous conductance. From (5.1)–(5.3), it is obvious that when the ratio of change in the output conductance is equal to the negative output conductance, the solar array will operate at the MPP. In other words, by comparing the conductance at each sampling time, the MPPT will track the maximum power of the PV module. The accuracy of t his method is proven in [15], where it mentions that the IncCond method can track the true MPPs independent of PV array characteristics. Also, Roman et al. [20] described it as the best M PPT method, where it has made a comprehensive comparison between P&O and the IncCond method with boost converter and show s that the efficiency of experimental results is up to 95%.

In Fig. 5.1, it is clear that the MPP is located at the knee of the I –V curve, where t he resistance is equal to the negative of differential resistance.

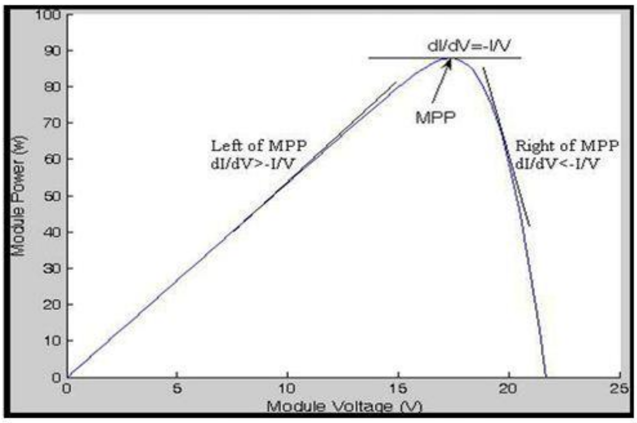


Fig-V-I curve for MPPT algorithm

V / I = - V / I …………..(5.4)

This is following the general rule used in the P&O method, in which t he slope of the PV curve at the MPP is equal to zero

dP / dV = 0……………(5.5)

Now, equation (5.5) can be rewritten as follows:

dP / dV = I*dV/dV + V * dI / dV ……….(5.6)

dP / dV = I + V * dI / dV ……………(5.7) and hence,

I + V * dI / dV = 0 ……………..(5.8)

Eq. (5.8) which is the basic idea of the IncCond algorithm. One noteworthy point to mention is that (5.4) or (5.5) rarely occurs in practical implementation, and a small error is usually permitted. The size of this permissible error (e) determines the sensitivity of the system. This error is selected with respect to the swap between steady-state oscillations and risk of fluctuating at a similar operating point. The flow chart of the IncCond algorithm within the direct control method is shown In Fig. 5.2. According to the MPPT algorithm, the duty cycle (D) is calculated. This is the desired duty cycle that the PV module must operate on the next step. Setting a new duty cycle in t he system is repeated according to the sampling time.

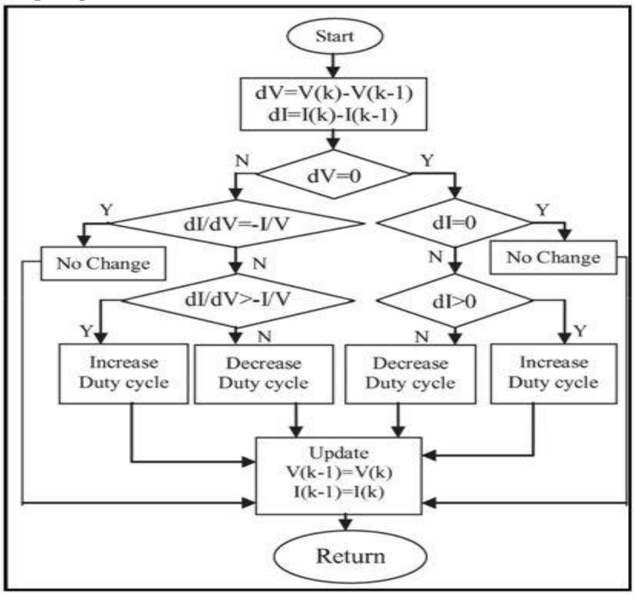


Figure 5.2 Flowchart of the IncCond method [15]

III. MODELING USING MATLAB/SIMULINK

Introduction

The MATLAB/SIMULINK software used for the modeling and simulation purposes. This software prepares all the electrical and mathematical blocks that needed in the project under Power System Block set, Signal Routing and Math Operations (Simulink).This software is easy to use on graphical user interface pertaining to building or modeling any circuits or mathematical equations. The method of modeling of the PV array is shown clearly. First the modeling of the mathematical equation for the diode current and the light generated photovoltaic current for the array model. Next will be modeling for the DC-DC boost converter and connection of PV array with dc-dc boost converter and grid. The Building of the Mathematical Modeling and Circuit To model diode current(Id), the light generated photovoltaic current, solar irradiation block, the components that being use are the voltage measurement block, current measurement block, go to block, from block and control current source block. The circuitry part, DC-DC boost converter, inverter, load, PWM generator, isolation transformer, diode and resistor needed and grid block to fulfil the model.

The SIMULINK does not have component for resistor as inductor and capacitor are joined together in the RLC branch, as a user we should know how to set the branch in order to get the needed components. Figure 6.1 Showers some light on this matter.

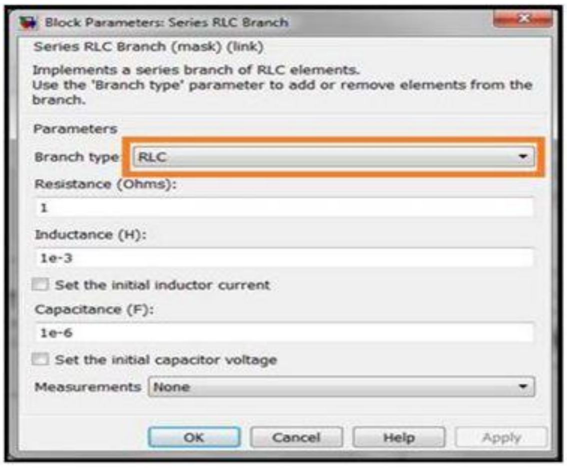


Figure 6.1: Parameter for resistor blocK

Figure 6.2 shows PV array after the mask process and its user friendly menu in Figure 6.3

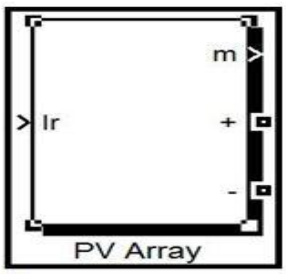


Figure 6.2: PV array after the mask process

Figure 6.3: PV Array Menu after Mask Process

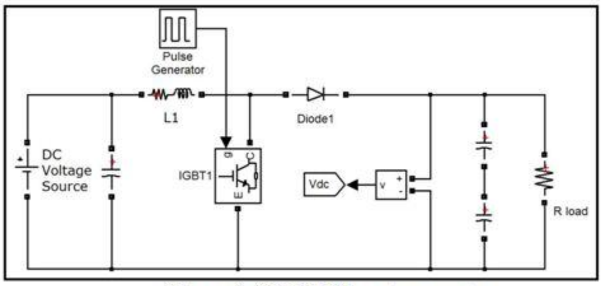


Figure 6.4: DC-DC boost converter

IV. SIMULATION RESULTS

Introduction

Before simulating the circuit, the POWERGUI block will be set to discrete mode and the sampling time, Ts =1e-06 s

The next step will be configuring the simulation parameters.

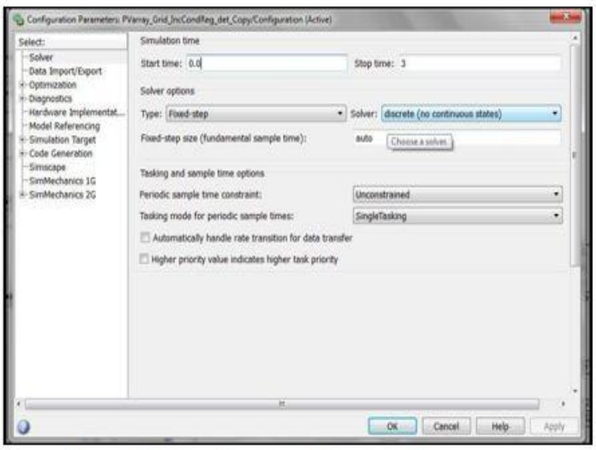


Figure 7.1: Configuring of the simulation parameter

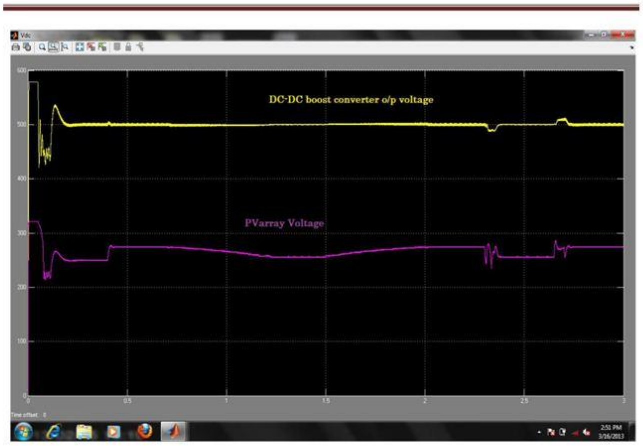


Fig- O/P Voltage of DC-DC Boost converter when PV array o/p voltage is I/P of converter

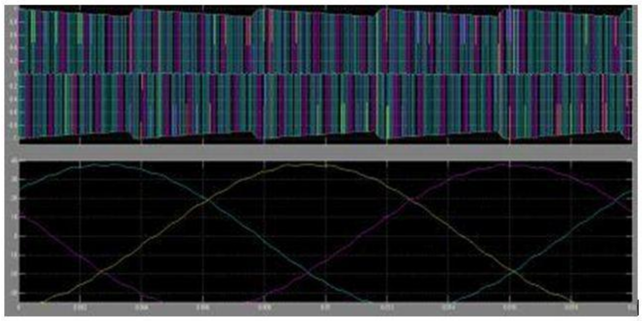
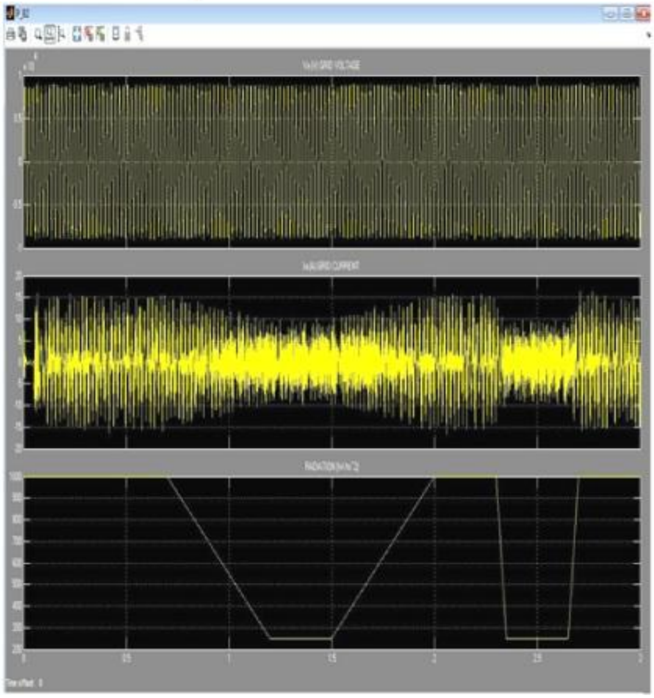


Fig-OUTPUT OF PV SYUN WITH GRID



V. CONCLUSION AND FUTURE SCOPE

CONCLUSION

- From the theory of the photovoltaic, a model of the PV array has been presented.
- Then, the photovoltaic system with DC-DC boost converter and Grid has been designed.

- Finally, the system has been simulated with Simulink MATLAB.
- Solar cells are connected in series to increase its open circuit voltage.
- The PV modules are connected in series to increase its open circuit voltage and this type of series strings is connected in parallel to increase the short circuit current.
- When PV array connecting to dc-dc converter and grid the out-put current, voltage and power is increases when irradiation is increase.

Finally the grid connected PV model can be use for energy output estimation and it's a user friendly system.

FUTURE SCOPE

In the modeling part, instead of just modeling one parameter which is solar radiation the cell temperature can be use with solar radiation for accuracy simulation result which is help for estimating energy output while designing the PV system. Another one is in 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.

REFERENCES

[1] A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment, by Yun Tiam Tan, *Student Member, IEEE, Daniel S. Kirschen, Senior Member, IEEE, and* Nicholas Jenkins, *Senior Member, IEEE.*

[2] PVSIM : A Simulation Program for Photovoltaic Cells, Modules, and Arrays by David L. King, James K. Dudley, and William E. Boyson Sandia National Laboratories.

[3] Micro-grid powered by photovoltaic and micro turbine by Ph. Degobert, S. Kreuawan and X. Guillaud, Laboratoire d'Electrotechnique et d'Electronique de Puissance de Lille, France.

[4] Study of Dynamic Behavior of Load Voltage PV-grid Connected under Islanding Phenomena via PSPICE Program by Krissanapong Kirtikara, King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

[5] Kjaer, S.B., Pedersen, J.K. and Blaabjerg, F., "A Review of single-phase grid connected inverters for photovoltaic modules," Industry Applications, IEEE Transactions, vol. 41, September 2005, pp.1292-1306.

[6] Jain, S. and Agarwal, V., "A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking," IEEE Transactions on Power Electronics, vol. 22, September 2007, pp. 1928-1940.

[7] Calais, M., Myrzik, J., Spooner, T. and Agelidis, V.G., "Inverters for single-phase grid connected photovoltaic systems – an overview," Power Electronics Specialists Conference, 2002. pesc 02. 2002 IEEE 33rd Annual, vol. 4, November 2002,pp. 1995 - 2000.

[8] Meza, C., Negroni, J.J., Guinjoan, F. and Biel, D., "Inverter Configuration Comparative for Residential PV-grid connected systems,"32nd Annual Conference on IEEE Industrial Electronics, IECON 2006, April 2007, pp. 4361 - 4366.

[9] Altas, I.H. and Sharaf, A.M., "A photovoltaic array simulation model for matlab Simulink GUI environment," International Conference on Clean Electrical Power, 2007. ICCEP '07, July 2007, pp. 341 – 345.

[10] Villalva, M.G., Gazoli, J.R. and Filho, E.R.; "Modeling and circuit-based simulation of photovoltaic arrays," Power Electronics Conference, IEEE 2009. COBEP '09. Brazilian, December 2009, pp. 1244 - 1254.

[11] MATLAB/Simulink Model of a Single-Phase Grid-Connected Photovoltaic System", Power Electronics Conference, IEEE 2009. COBEP '09. Brazilian, December 2009, pp. 1244 - 1254.

[12] Yang Chen and Keyue Smedley*, Fellow, IEEE:"* Three-Phase Boost-Type Grid-Connected Inverter*",* IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 23, NO. 5, SEPTEMBER 2008.

[13] Stefan Eidelloth, Felix Haase, and Rolf Brendel:"Simulation Tool for Equivalent Circuit Modeling of Photovoltaic Devices", IEEE JOURNAL OF PHOTOVOLTAICS, VOL. 2, NO. 4, OCTOBER 2012.

[14] Jih-Sheng Lai, *Fellow,* Chien-Liang Chen, Baifeng Chen, *Student Member, IEEE*;"High Reliability and Efficiency Single-Phase Transformerless Inverter for Grid-Connected Photovoltaic Systems" IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 28, NO. 5

[15] Azadeh Safari and Saad Mekhilef, *Member, IEEE "*Simulation and Hardware Implementation of Incremental Conductance MPPT With Direct Control Method "IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 58, NO. 4, APRIL 2011.

[16] Mohammad H. Rashid, "Power Electronics: Circuits, Devices and Applications", Prentice-Hall, Inc., Englewood Cliffs, Book, Second Edition, 1993.

[17] B. W. Williams, " Power Electronics; Devices, Drivers, Applications and Passive Components", Book, Second Edition, Educational Low-Priced Books Scheme; ELBS, 1992.

[18] Mohan Ned, Undeland Tore M. and Robbins William P.,"Power Electronics, Converters Applications and Design", John Wiley & Sons, Inc., Book, 1995.

[19] B. M Hasaneen and Adel A. Elbaset Mohammed "Design and simulation of dc/dc boost converter" 978-1-4244-1933-3/08/$25.00 ©2008 IEEE

