Modeling and Simulation of Grid Connected Solar System with Boost Converter and MPPT

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Abstract: ***Radiation from the sun is an amount that is produced each hour by the Sun and is a critical information for the outline and decide the productivity of a photovoltaic plant and ambient temperature enormously influence the execution of the solar power. In this paper a new approach is projected for analysis on style and control of grid solar system the project is based on power control of tie line. This technique of low stress on utilization of customized control topology. The working principle of described method is that the grid is developed by the solar system for the distribution of energy and tie line control is developed with the help of two parameters viz. frequency and power. For obtaining this we are using here maximum power point tracking (mppt)and boost converter for increasing the efficiency of photovoltaic cell. The maximum power point tracking is an important function in all photo voltaic power systems. The simulation results shows that the proposed mppt control can avoid tracking deviation and result in improved performance in both dynamic response and steady state response.***

Keywords: Maximum power point tracking (MPPT), photovoltaic (PV) power system, maximum power point (MPP), switching mode DC-DC converter, switching duty cycle, Perturb & Observe control

1. Introduction

Photo voltage genration is becoming increasingly attractive as renewable energy source. In order to overcome the ever increasing power needs in many industrial applications such as artificial satellite the best available solution is to use of renewable energy sources such as solar and wind it is inexhaustible and fee of pollution. It had the advantages of learning and maintenance cost and also noiseless operation.

The voltage power characteristics of photovoltaic array is nonlinear and time varying because of the changes caused by the atmospheric conditions. As a photovoltaic cells exhibits nonlinear behaviour, while interfacing the ac load to photovoltaic modules dc-dc converter and inverter are needed.

The proposed scheme here uses a boost dc-dc to generate utility voltage to a constant desired value. when the solar radiation and temperature where is the output power of the PV module also changes. In order to obtain the maximum efficiency of PV module it must operate at maximum point of the PV Characteristics.

Therefore it is necessary to operate the PV module at its maximum power point for all irradiance and temperature conditions. To obtain maximum power from photovoltaic array photovoltaic power system usually required maximum power point tracking controller (mppt)

2. PV Cell Equivalent Circuit

The building block of PV arrays is the solar cell, which is basically a p-n semiconductor junction, shown in Fig.1. The V-I characteristic of a solar array is given by Eq. (1)

$$I = I_{ph} - I_o \left[e^{q\left(V + I.\frac{Rs}{\alpha kT}\right)} \right] - \left(\frac{V + I.Rs}{Rp} \right) \qquad (1)$$

Where:

- V and I represent the output voltage and current of the PV, respectively.
- Rs and Rp are the series and shunt resistance of the cell.
- q is the electronic charge.
- Iph is the light-generated current.
- Io is the reverse saturation current.
- alpha is a dimensionless factor.
- k is the Boltzman constant, and Tk is the temperature in oK.

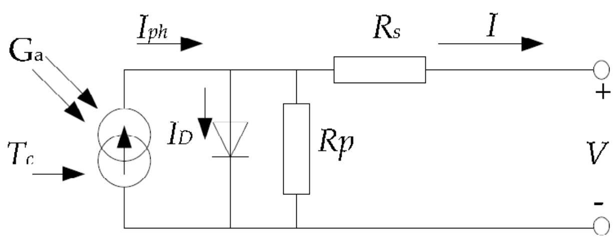

Figure 1: Equivalent circuit of PV array

Equation (1) was used in computer simulations to obtain the output characteristics of a solar cell, as shown in Fig. 2. This curve clearly shows that the output characteristics of a solar cell are non-linear and are crucially influenced by solar radiation, temperature and load condition [2,5]. Each curve has a MPP, at which the solar array operates most efficiently

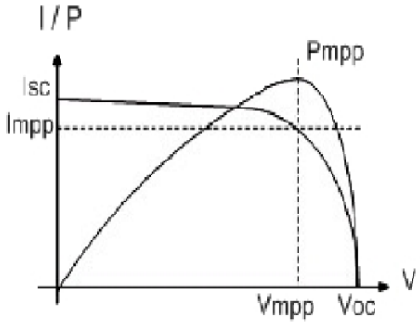

Figure 2: I/P-V characteristic of a solar cell.

3. Boost DC/DC Converter

The main purpose of the DC/DC is to convert the DC input from the PV into a higher DC output. The maximum power point tracker uses the DC/DC converter to adjust the PV voltage at the maximum power point. The boost topology is used for stepping up the low voltage input from the PV. A boost type converter steps up the PV voltage to high voltage necessary for the inverter.

Fig. 3 shows the Boost converter. The DC input voltage is in series with an inductor L that acts as a current source. A switch T is in parallel with the current source that turns on and off periodically, providing energy from the inductor and the source to increase the average output voltage.

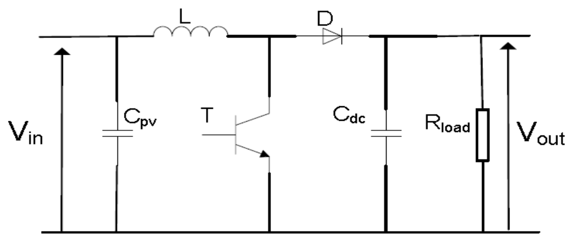

Figure 3: Topology of Boost converter

The voltage ratio for a boost converter is derived based on the time integral of the inductor voltage equal to zero over switching period. The voltage ratio is equivalent to the ratio of the switching period to the off time of the switch.

$$\frac{Vo}{Vin} = \frac{T}{toff} = \frac{1}{1-D}$$

The capacitor C_{dc} is large enough to keep a constant output voltage, and the inductor provides energy when the switch is open, boosting the voltage across the load. The duty cycle from the MPPT controller is to control the switch of the boost converter. It is a gate signal to turn on and off the switches by pulse width modulation.

4. Six Step Inverter

The six-step inverter is used to obtain a three-phase voltage output from DC source. Three-phase voltage source inverter is a combination of three single-phase bridge circuits. A simplified diagram of a basic three-phase inverter bridge is shown in Fig. 5. There are diodes in antiparallel in addition to the main power devices. These diodes are called the return current or feedback diodes. It provides an alternate path for the inductive current.

The magnitude of the harmonic depends of the angle α. Fig. 4 shows an example of voltage output harmonic spectrum when α is 10.

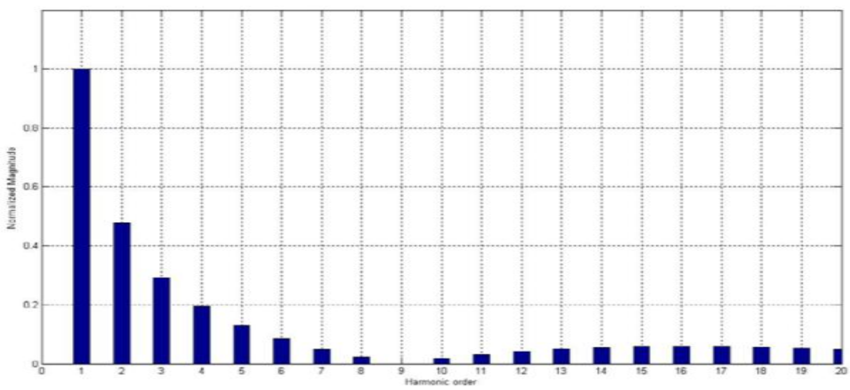

Figure 4: Harmonic of output voltage when α is 10.

The PWM techniques provide control scheme to reduce harmonics. The techniques can reduce the number of filter in high frequencies.

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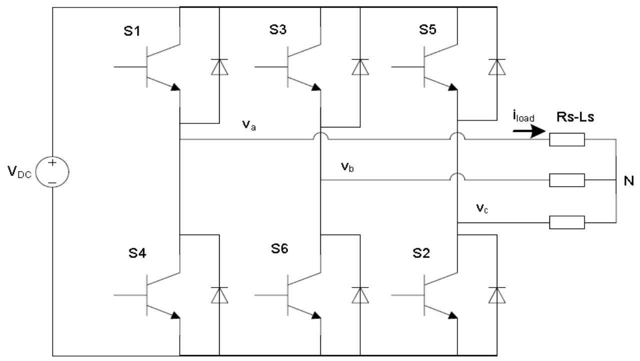


Figure 5: Three-phase six-step inverter

To obtain the three-phase AC current in six-step inverter, six gating signals need to be applied to the six switches of the inverter.

In grid connected PV, the current output of the voltage source inverter will be injected to the grid. The output of the inverter should be in phase and have an identical frequency to the voltage of the grid.

5. Maximum Power Point Techniques for PV

From the characteristic I-V and P-V curves of photovoltaic modules, it is shown that there was a unique point for the maximum power (MPP). This point is defined as the maximum power point (MPP) with the optimal voltage V_{mpp} and the optimal current I_{mpp}. At this point, the entire PV system should operate with the maximum efficiency and produce its maximum output power. The solar cell I-V characteristic is nonlinear and changes with irradiation and temperature. The location of the MPP is not known but need to be located. Different MPPT methods have been realized. They vary in "complexity, sensors required for the voltage or current, convergence speed, and cost, range of effectiveness and implementation hardware".

The three main categories of MPPT algorithms are model-based algorithms, training based algorithms and searching algorithms [17].

Model-based MPPT algorithm

MPPT with Fractional short-circuit current method

This method is based on the measurement periodically of the PV short circuit current, which is approximately linear to the current maximum power point as shown in

$I_{MPP} \approx k_2 I_{sc}$

Experimentally, k_2 is a constant between 0.78 and 0.92. Once the constant k_2 is known, I_{MPP} is computed. The PV array needs to be shorted periodically to measure I_{sc}.

Fractional open circuit voltage

Similarly, the Fractional open-circuit voltage is based on the linear dependence between array voltages at maximum power V_{MPP} with its open circuit voltage V_{oc}

$V_{MPP} \approx k_1 V_{oc}$

k_1 is a constant between 0.71 and 0.78. Voc is measured by shortly shutting down the power converter.

The implementations of those methods are simple and cheap but here is excessive power loss and the efficiency of the PV is very low due to the inaccurate determination of the constant k_1 and k_2. The power loss is caused by the necessity to open and close the circuit for measurement [18].

Perturb & Observe P&O/ Hill Climbing

P&O and Hill climbing use the same fundamental strategy. The duty ratio is the perturbation in hill climbing, while the voltage of the PV module is the perturbation for the P&O. Changing the value of the duty cycle causes a change to the current and as consequence, perturbs the voltage array. In Fig. 6, the voltage and current are measured and the MPPT controller determines the voltage reference. The input for the regulator PI is the difference of the V_{ref} and V_{pv}. The voltage regulated generates the PWM for the converter.

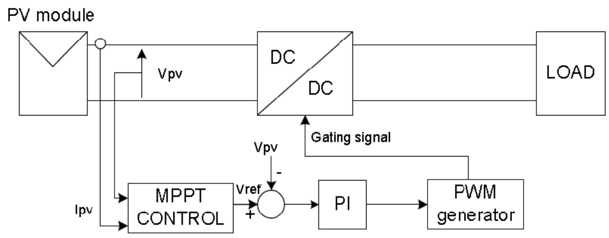


Figure 6: Block diagrams of MPPT with P&O

For Hill climbing, there is no regulator, only the duty ratio controls the converter directly as shown in Fig. 7.

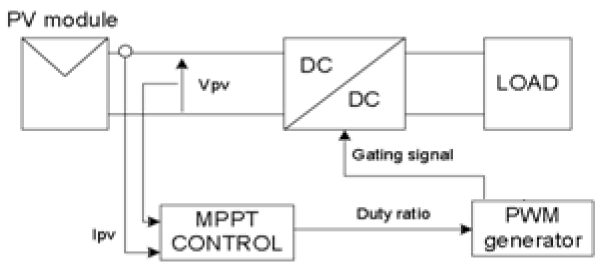


Figure 7: Block diagrams of MPPT with Hill Climbing

In Fig. 8, it can be observed that incrementing the PV voltage increases the power of the PV and decrementing the PV voltage decreases the power of the PV when operating on the left of the MPP. On the right of MPP, incrementing the voltage decreases the power and decrementing the voltage increases the power [19]. This process will be implemented in the MPPT controller to extract the maximum power from the PV module.

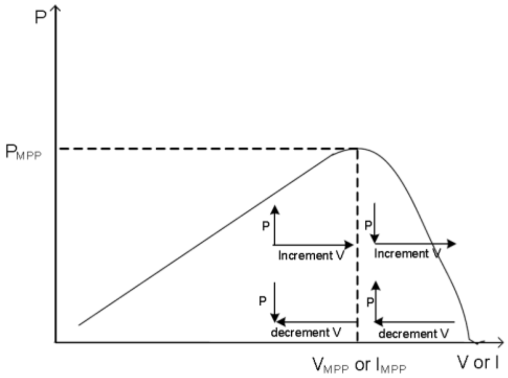


Figure 8: Principle of P&O

6. Simulation Results

Simulink model of Grid connected Photovoltaic system

The simulation model of Grid connected Photovoltaic system is shown in Fig. 9. The three-phase inverter has three-phase inductance filter and resistance load. An inverter block from Simulink is the three-phase inverter [22]. The PV, boost and MPPT, remain the same. The pulse generator produces the gating signal for the inverter block. The output voltage from the boost converter is the DC voltage for the three-phase inverter.

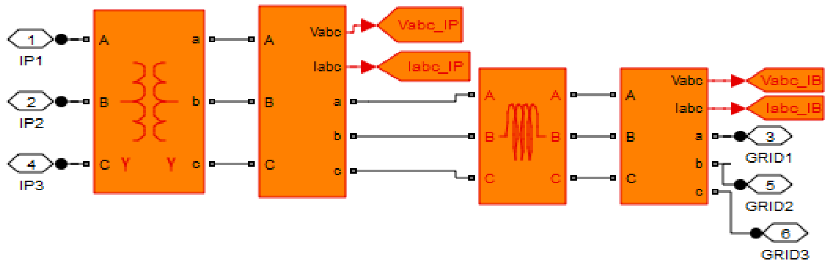


Figure 9: Interconnection between grid and inverter

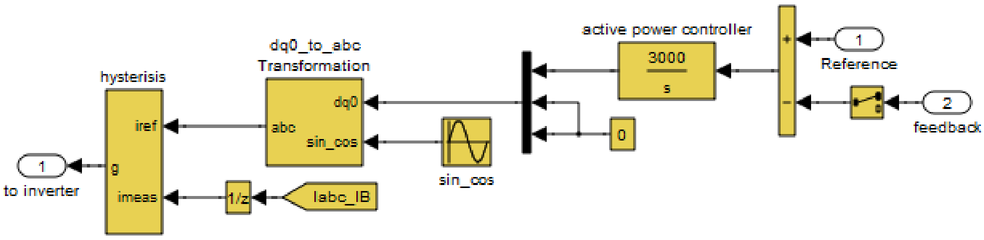


Figure 10: Grid synchronizing

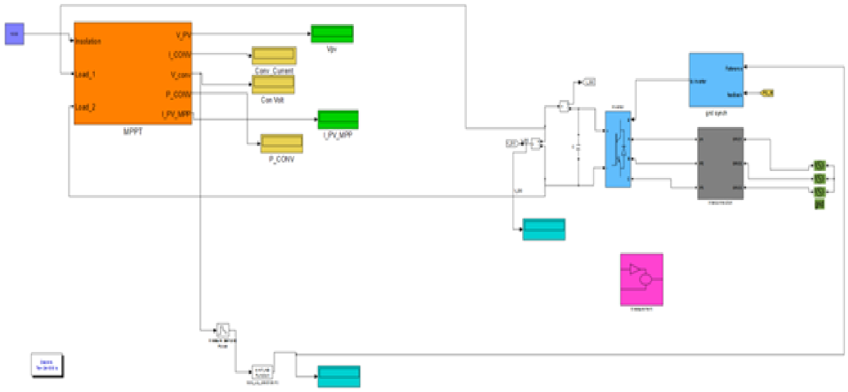


Figure 11: Simulation of Grid connected Photovoltaic system

Grid connected PV system

The simulation model of grid connected PV system. The result of simulation is shown below.

Table 1: Reading of grid connected system at different insolation

Insolation	V_{PV}	Converter Current	Converter Volt	Converter Power	I_{PV} MPP	V_{dc}
1000	856.4	66.72	955.3	6.68*10000	78	955.3
800	849.4	58.48	881	5.351*10000	63	881
500	846.8	38.57	618.1	3.269*10000	38.6	618.3

Now the waveform shows the voltage, current, active and reactive power, terminal voltage and V_{abc} at input side and infinity bus, I_{abc} at infinite bus.

Insolation at 1000 W/m^2

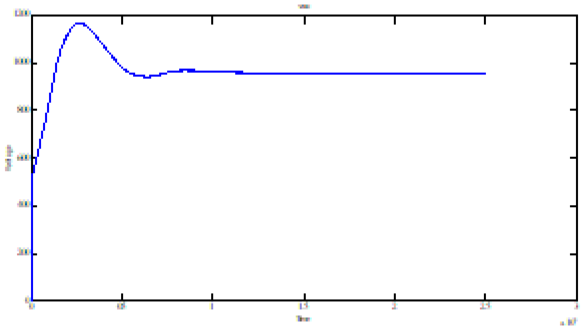


Figure 12: Vdc

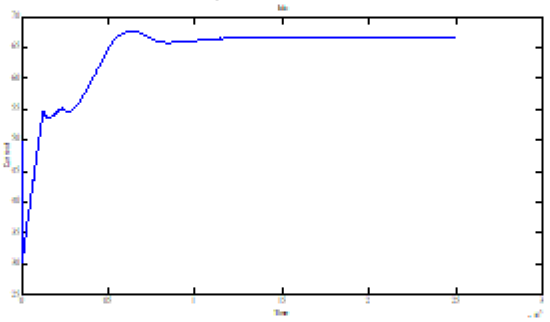
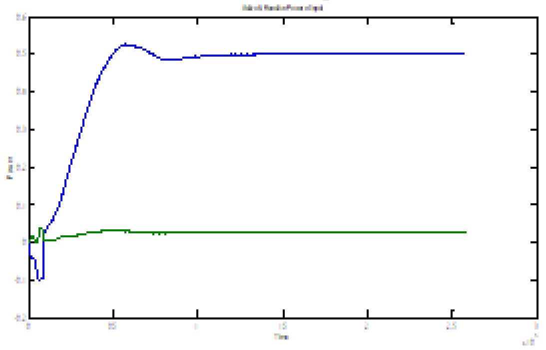


Figure 13: waveform of DC bus I dc

Active & Reactive power (I/P)



Active & Reactive power (I/B)

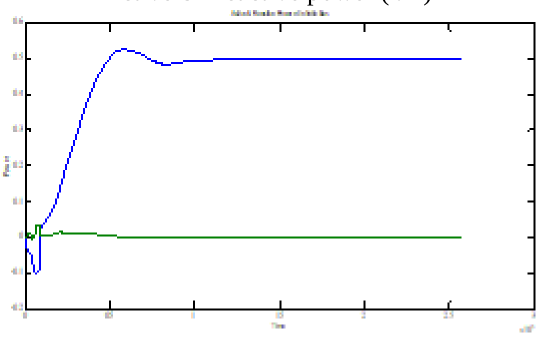
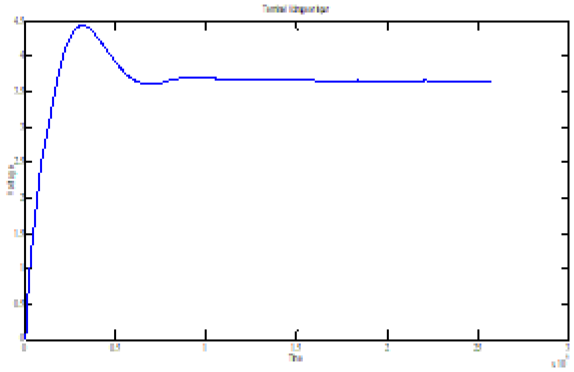


Figure 14: Waveform of active and reactive power

Terminal Voltage (I/P)



Terminal Voltage (I/B)

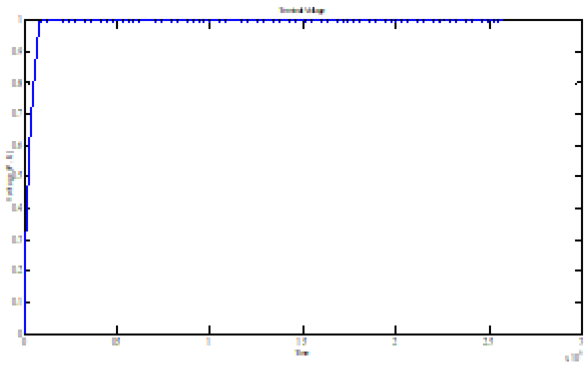
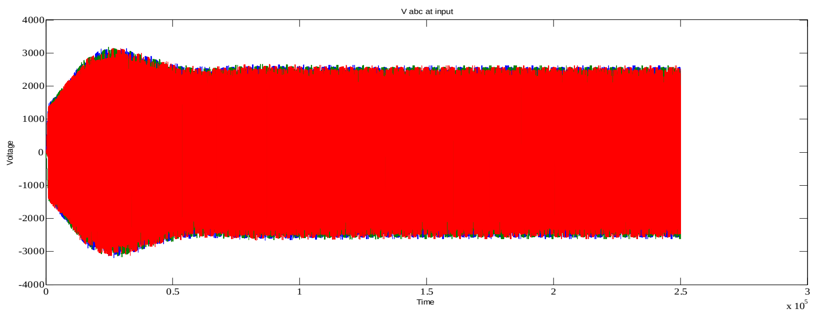
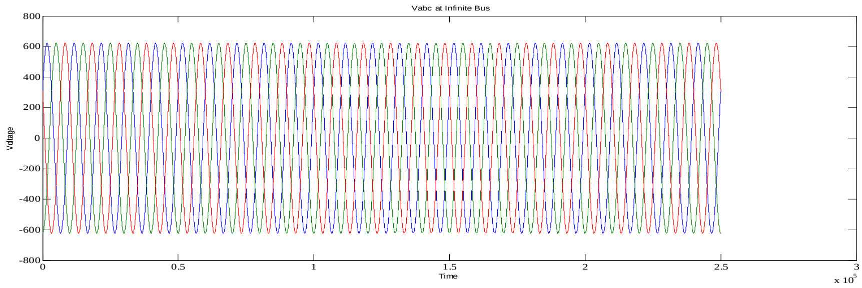


Figure 15: Waveform of terminal voltage Vabc (I/P)



Vabc (I/B)



Iabc (I/B)

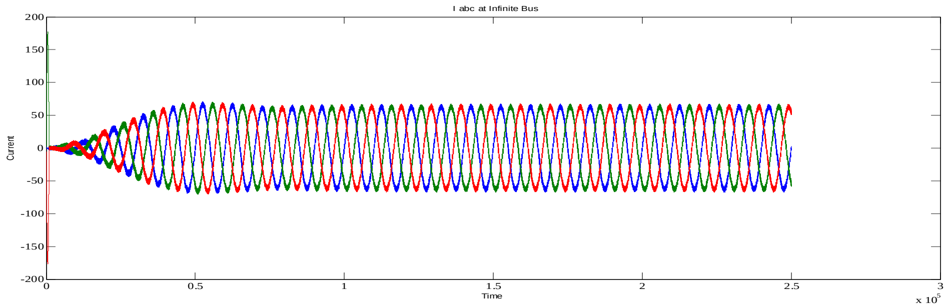


Figure 16: waveform of V_{abc} and I_{abc}

Insolation at 800 W/m^2

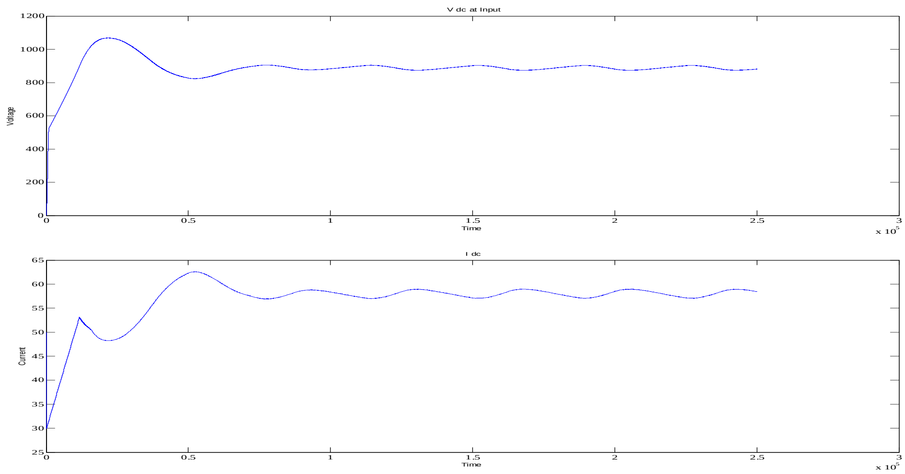
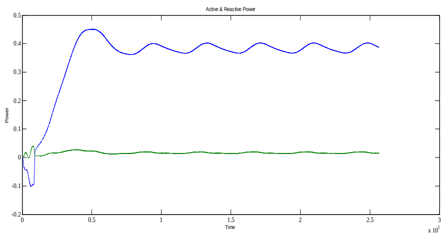


Figure 17: Waveform of DC bus Vdc & Idc

Active & Reactive power (I/P)



Active & Reactive power (I/B)

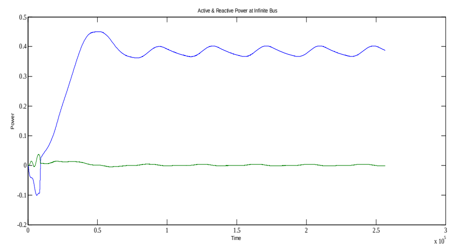
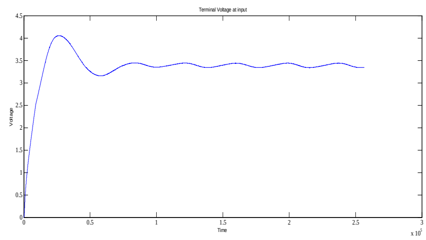


Figure 18: Waveform of active and reactive power

Terminal Voltage (I/P)



Terminal Voltage (I/B)

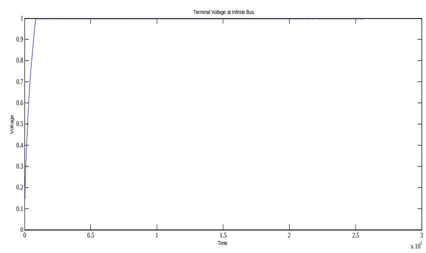
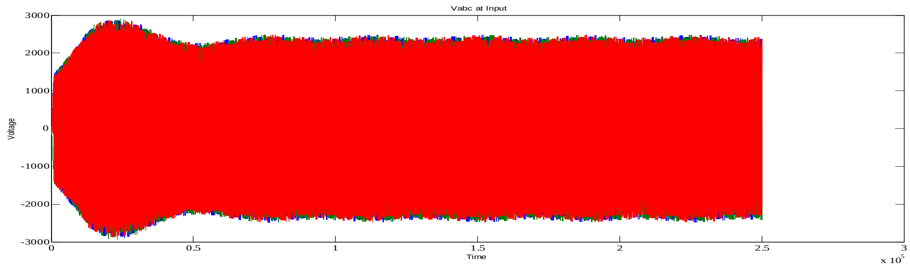
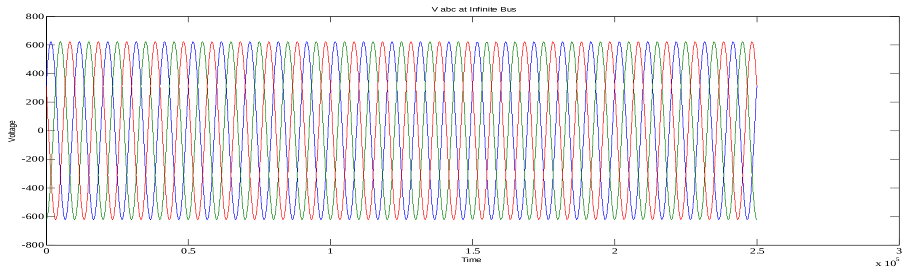


Figure 19: waveform of terminal voltage

Vabc (I/P)



Vabc (I/B)



Iabc (I/B)

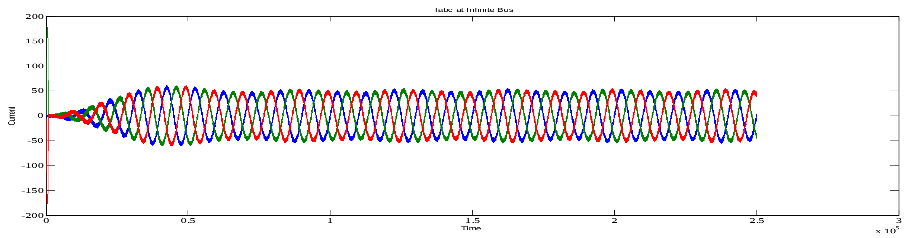
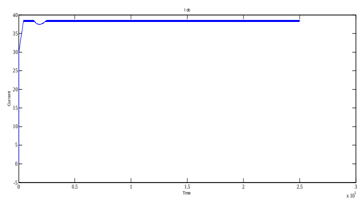


Figure 20: Waveform of V_{abc} and I_{abc}

Insolation at 500 W/m^2

I dc



Vdc

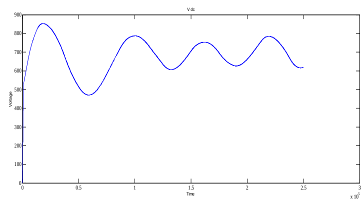
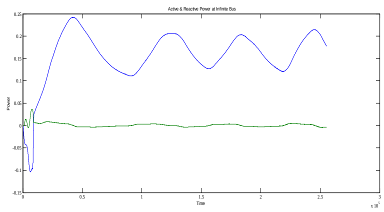


Figure 21: waveform of DC bus

Active & Reactive power (I/B)



Active & Reactive power (I/P)

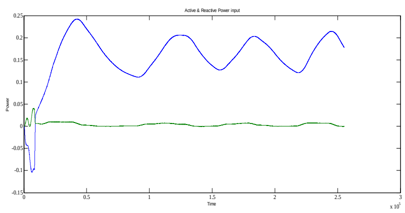
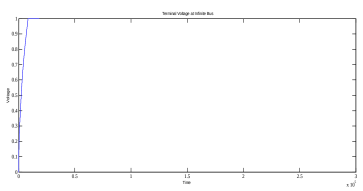


Figure 22: Waveform of active and reactive power



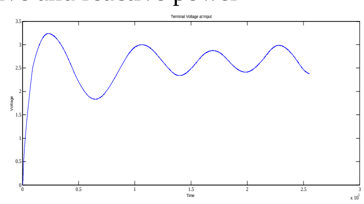
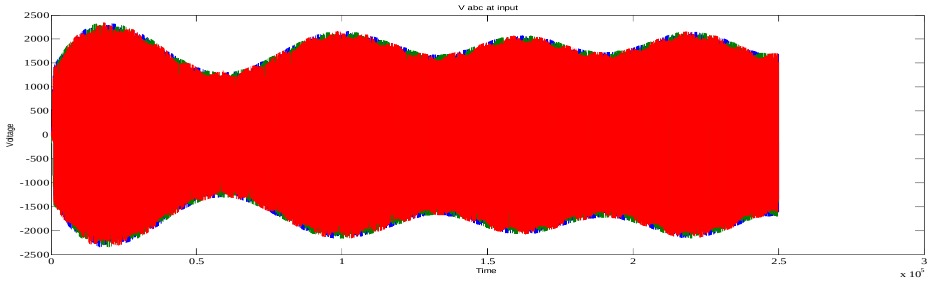
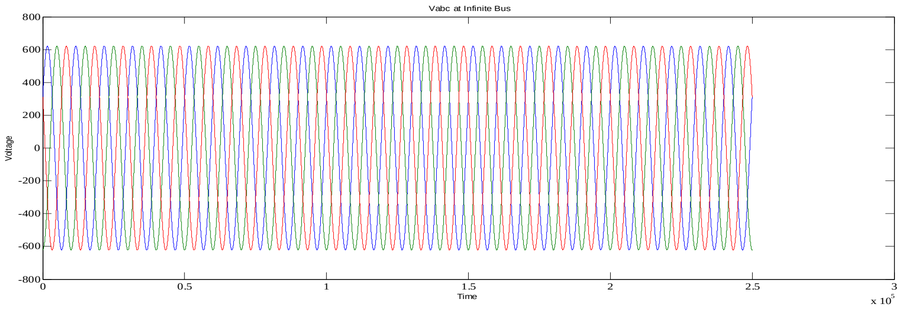


Figure 23: waveform of terminal voltage



Vabc (I/B)



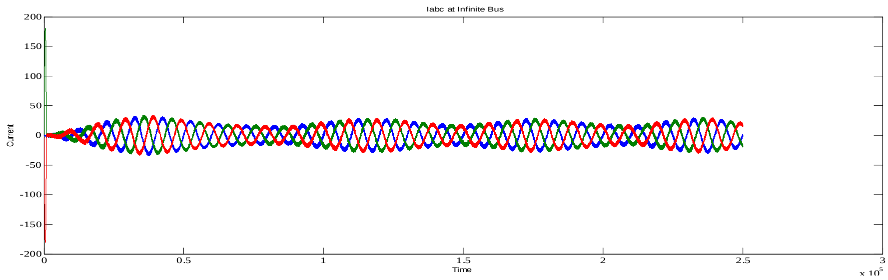


Figure 24: Waveform of V_{abc} and I_{abc}

7. Conclusion

The simulations of the PV panels showed that the simulated models were accurate to determine the characteristics voltage current because the current voltage characteristics are the same as the characteristics given from the data sheet. In addition, when the irradiance or temperature varies, the PV models output voltage current change. Then, the simulation showed that Perturb and observe algorithm can track the maximum power point of the PV, it always runs at maximum power no matter what the operation condition is. The results showed that the Perturb and observe algorithm delivered an efficiency close to 100% in steady state.

The simulations of the PV with maximum power point, boost converter and resistive load were performed by varying the load, the irradiance.

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] M.G.Villalva, J.R. Gazoli, E. Ruppert F.Modelling and Circuit Based Simulation of Photovoltaic Arrays University of Campinas-Brazil.

[3] Huan-Liang Tsai "Development of Generalized Photovoltaic Model using Matlab/Simulink, 2008.

[4] I.H. Altas "A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment" Dept of Electrical and Electronics Engineering, Karadeniz Technical University, Trabzon, Turkey.

[5] Hasaneen, B.M. and Elbaset Mohammed, A.A., "Design and simulation of DC/DC converter," *Power System Conference, 2008. MEPCON 2008. 12th International Middle-East*, July 2008, pp. 335 - 340.

[6] Weiping Luo and Gujing Han, "Tracking and controlling of maximum power point application in grid-connected photovoltaic generation system," *Second International Symposium on Knowledge Acquisition and Modeling 2009, KAM '09,* vol. 3, December 2009, pp. 237 - 240.

[7] Antunes, F.L.M., Santos, J.L., "Maximum Power Point Tracker for PV Systems," World Climate & Energy Event, December 2003.

[8] R.Faranada, S.Leva and V.Maugeri MPPT techniques for PV System; energetic & cost comparison, Member IEEE.

[9] Grid-connected photovoltaic (PV) systems with batteries storage as solution to electrical grid outages in Burkina Faso D Abdoulaye, Z Koalaga, F Zougmore, 1st InternationalSymposiumonElectricalArcandThermalPlasmasinAfrica(ISAPA), IOP Conf. Series: Materials Science and Engineering 29 (2012) 012015.

[10] Zhou Dejia, Zhao Zhengming, Eltawil, M. and Yuan Liqiang; "Design and control of a Three-phase Grid connected Photovoltaic system with developed Maximum power point tracking,"*Applied Power*

Electronics Conference and Exposition, 2008. APEC 2008. Twenty-Third Annual IEEE, May 2008, pp. 973 - 979.

[11] Liang Ma, Wang Ran and Zheng, T.Q., “Modeling and Control of 100 kW Three-phase grid-connected Photovoltaic inverter,” *Industrial Electronics and Applications (ICIEA), 2010 the 5th IEEE Conference*, July 2010, pp. 825 - 830.

[12] http://www.mbipv.net.my (Pusat Tenaga Malaysia).

[13] http://www.met.gov.my (J abatan Meterologi).

[14] http://www.ieeexplorer.com

[15] *ecee.colorado.edu/~ecen2060/materials/lecture.../Grid PVsystem.pdf* iopscience.iop.org

[16] Power electronics circuits, devices, and applications, third edition, Muhammad H. Rashid, electrical and computer engineering university of west Florida, PHI Learning Private Limited New Delhi, 2009.

[17] Solar Photovoltaics Fundamentals, Technologies and applications, second edition, Chetan Singh Solanki, Associate Professor, Department of energy science and engineering, Indian Institute of Technology Bombay. PHI Learning Private Limited New Delhi, 2011.

[18] R.W.Erickson, D.Maksimovic, *Fundamentals of PowerElectronics*

[19] Gwinyai Dzimanu “Modelling of Photovoltaic System” The Ohio State University 2008.

[20] Study of Photovoltaic System By Falinirina F. Rakotomananandro, B.Sc. Graduate Program in Electrical and Computer Science The Ohio State University 2011.

[21] MODELING AND SIMULATION OF GRID CONNECTED PHOTOVOLTAIC SYSTEM USING MATLAB / SIMULINK by “SURESH A/L THANAKODI” Faculty of Electrical Engineering University Technology Malaysia, NOVEMBER 2009.

[22] Maximum Power Point Tracking Algorithms for Photovoltaic Applications, Date: 14.12.2010, David Sanz Morales, Faculty of Electronics, Communications and Automation Department of Electrical Engineering, aalto university school of science and technology

[23] Akihiro Oi, “Design and simulation of photovoltaic water pumping system”, *California Polytechnic State University*, San Luis Obispo. September 2005