International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Modeling and Performance Enhancement of 100kw solar PV Array Power plant situated at village Jaitpurkalan Rajgarh (M.P) India by MPPT Algorithm with Reference to rural electrification

Rakesh Pal [1], Dr. V. K Sethi [2], Anurag Gour[3]

1. M.Tech Scholar School of Energy Technology UIT, RGPV Bhopal, INDIA

2. Professor School of Energy Technology UIT, RGPV Bhopal, INDIA

3. Assistant Professor School of Energy Technology UIT, RGPV Bhopal INDIA

ABSTRACT

This paper proposes modeling and simulation of photovoltaic model. Taking in to account the temperature and sun's irradiance, the PV array is modeled and its voltage current characteristics and the power and voltage characteristics are simulated. This enables the dynamics of PV system to be easily simulated and optimized. It is noticed that the output characteristics of a PV array are influenced by the environmental factors and the conversion efficiency is low. Therefore a maximum power tracking (MPPT) technique is needed to track the peak power to maximize the produced energy. The maximum power point in the power–voltage graph is identified by an algorithm called perturbation & observation P&O) method or Hill climbing. This algorithm will identify the suitable duty ratio in which the DC/DC converter should be operated to maximize the power output. The results confirm that the photo voltaic array with proposed MPPT controller can operate in the maximum power point for the whole range of assumed solar data (irradiance and temperature).

Keywords: Maximum power point tracking, photovoltaic, Solar, P&O, Buck/Boost converter.

1. ABOUT THE POWER PLANT

India lies in the sunny regions of the world. Most parts of India receive 4–7 kWh (kilowatt-hour) of solar radiation per square meter per day with 250–300 sunny days in a year. The highest annual radiation energy is received in western Rajasthan while the north-eastern region of the country receives the lowest annual radiation. Solar energy, experienced by us as heat and light, can be used through two routes the thermal route uses the heat for water heating, cooking, drying, water purification, power generation, and other applications; the photovoltaic route converts the light in solar energy into electricity, which can then be used for a number of purposes such as lighting, pumping, communications, and power supply in un electrified areas. some of the solar PV plant installed across country listed below in table no 1.

2. SITE DESCRIPTION

Rajgarh is located at western part of Madhya Pradesh. It borders the state of Rajasthan, and the districts of Shajapur, Sehore, and Bhopal. Rajgarh District extends between the parallels of latitude 23^0 27' 12" North and 24^0 17' 20" North and between the meridians of longitude 76^0 11' 15" and 77^0 14' East. The total geographical area of the District is 6,154 sq.km. with a population of 15,46, 541 according to census 2011. It is 145 KMs from the state capital Bhopal.24.03°N 76.88°E

- Project Site Incharge: - Mr R.S.Gupta

- Project location:-Village Jaitpurakalan, Vikas Khand Khilchipur, Rajgarh District, Madhya Pradesh, India.

•Plant established: - July, 1998

•Electricity generation: From October, 1999

•Design company: - Tata BP Solar India Ltd. Bangalore.

•Plant capacity: - 100 kW peak at standard test condition.

•Land area: - 1 acre

•Total project cost: Rs 370 lac (Central Govt: Rs 200 lac & State Govt: Rs 170 lac)

•Nominal peak power: - 75W
•Nominal peak voltage: - 12V
•Peak operating voltage:- 17V
•Highest generation duration: -Month of Feb, March & April.

Table 1. Solar PV plant installed across country

239 kW	**India, Dewas, Indore**	Co.Steel Tubes of India, private owned standalone system	Madhya Pradesh Urja Vikas Nigam
150 kW	**India**	Standalone plant ordered by Lakshadweep Administration	BHEL
110 kW	**India, Rakalpur, Sagar Islands**	Rural standalone PV system in Rakalpur, Sagar Islands	BHEL
105 kW	**India, Mousuni Island**	Rural standalone PV system at Mousuni Island	BHEL
100 kW	**India, Jaitpur Kalan, Rajgarh district (Madhya Pradesh)**	Rural standalone PV system in village Jaitpur Kalan of Rajgarh district in Madhya Pradesh	Madhya Pradesh Urja Vikas Nigam

3. INTRODUCTION

Solar energy is one of the most important renewable energy sources. Compared to conventional non renewable resources such as gasoline, coal, etc, solar energy is clean, Inexhaustible and free. In tropical countries like India, as well as other places where solar energy is available in abundance, photovoltaic (PV) has emerged as major candidate for meeting the energy demand. It offers an option for clean (pollution free) energy offers an option for clean (pollution free) energy source, with almost no running and maintenance cost.

In the recent past years, PV power generation System has attracted more attention due to the Energy crisis and environment pollution. Photovoltaic (PV) power generation systems can mitigate effectively environmental issues such as the green house effect and air pollution. PV power generation systems have one big problem that the amount of electric power generated by PV module is always changing with weather conditions, i.e., irradiation. Therefore, a maximum power point tracking

(MPPT) control method to achieve maximum power (MP) output at real time becomes indispensable in PV generation systems. The amount of power generated by a PV depends on the operating voltage of the array. A PV‟s maximum power point (MPP) varies with solar insulation and temperature. It's V-I and V-P characteristic curves specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV operates at its highest efficiency. Therefore, many methods have been developed to determine MPPT for a particular isolation value.

In the photovoltaic field, manufacturers provide ratings for PV modules for conditions referred to as standard test conditions (STC). However, these conditions rarely occur outdoors, so the usefulness and applicability of the indoors' characterization in standard test conditions of PV modules area divisive issue. Therefore, to carry out photovoltaic engineering well, a suitable characterization of PV module electrical behavior (V–I curves) is necessary. Since solar cells convert light to electricity it might seem odd to measure the photovoltaic cells in the dark. However, dark I-V measurements are in valuable in examining the cell properties. Under illumination, small fluctuations in the light intensity add considerable amounts of noise to the system making it difficult to measure. Dark I-V measurements use injects carriers into the circuit with electrical means rather than with light generated carriers. In most cases the two are equivalent and the Dark I-V measurements give extra information about the cell for diagnostic purposes. Even in the absence of noise there is a wealth of information in comparing the illuminated and dark I-V curves. The solar cell characteristics are handled in many references. Alternatively, the static parameters and characteristics of solar cells are normally determined from their illuminated current-voltage characteristics under standard solar simulators, based on flash lamps or distributed light sources, or outdoor conditions. They are used in assessing solar cell efficiency and fill factors. On the other hand, dynamic parameters are required in designing circuits containing solar cells and switching devices as well as providing important diagnostic tools.

The conventional MPPT methods are generally categorized into the following groups:

1) Perturbation and observation (P&O) methods.
2) Incremental conductance methods.
3) Constant current or constant voltage
4) Miscellaneous (e.g., fuzzy control and voltage based scheme

Among them P & O method has drawn much attention due to its simplicity. But the oscillation problem is unavoidable

4. SIMULATION MODEL OF PV CELL

The basic structure of a cell model or solar cell is similar to that of a photodiode, generally of silicon, designed to maximize the absorption of photons from the light and minimize reflection. When it receives an incident light behaves as a current generator whose value increases in inverse function of the amount of light incident upon it.

The building block of PV array is the solar cell, which is basically a p-n junction semiconductor junction that directly converts light energy into electricity. The physical structure and equivalent circuit are shown below in fig no 1.

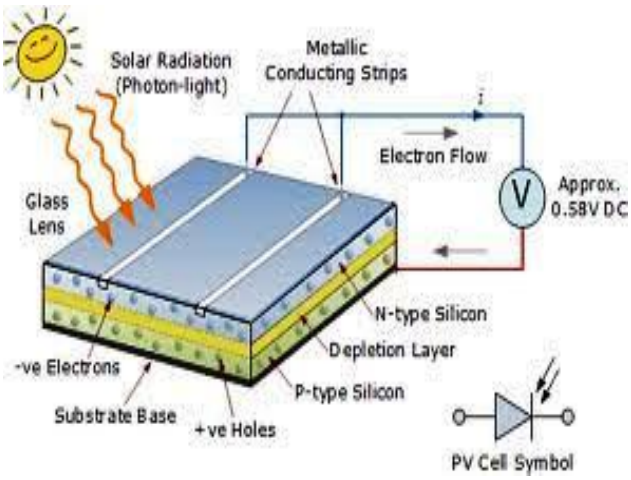

Figure.1 Structure of a PV cell

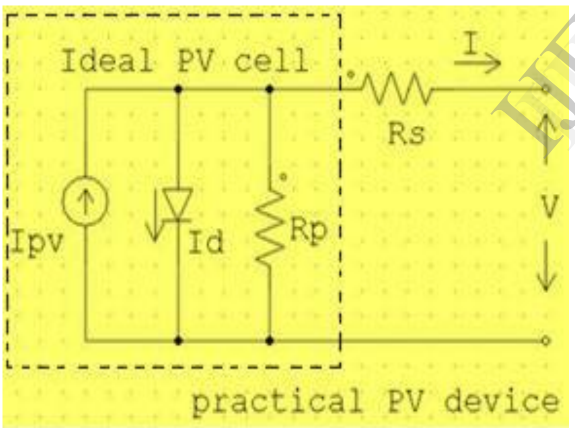

Figure.2 Equivalent circuit of the PV cell

The simplest equivalent circuit of a solar cell is a current source in anti-parallel with a diode. The output of the current source is directly proportional to the light falling on the cell photocurrent (I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current Id, called diode (D) current or dark current. The diode determines the I-V characteristics of the cell. Graph shown in fig no 3.

$$I = I_{pd} - I_d$$

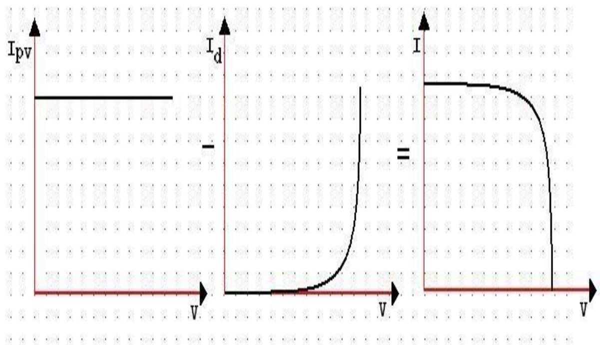

Figure. 3 simulated I-V graph for PV cell

In an ideal cell Rs = Rsh = 0, which is a relatively common assumption. For this paper, a model of moderate complexity was used. The net current of the cell is the difference of the photocurrent, I and the normal diode current Id:

To simulate PV array, a PV mathematical model is used following set of equations from [3].

$$I = I_{pv} - I_o\left(e^{\frac{q(V+IR_S)}{nkT}} - 1\right) \ldots\ldots\ldots\ldots\ldots \text{(i)}$$

$$I_{pv} = I_{pv}(T_1) + K_0(T - T_1) \ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

$$I_{pv}(T_1) = I_{SC}(T_{1,nom})\frac{G}{G_{nom}} \ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

$$K_o = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{(T_2 - T_1)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

$$I_o = I_o(T_1) \times \left(\frac{T}{T_1}\right)^{\frac{3}{n}} e^{\frac{qV_q(T_1)}{nk}\left(\frac{1}{T} - \frac{1}{T_1}\right)} \ldots\ldots\ldots\ldots \text{(v)}$$

$$I_o(T_1) = \frac{I_{SC}(T_1)}{e^{\left(\frac{qV_{OC}(T_1)}{nkT_1}-1\right)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

The model includes the temperature dependence of photocurrent I and saturation current of the diode Io.

Terms used in equations are-

I - Current from solar cell
G - Isolation in W/m2.
T - Temp for which VI characteristics have to be found.
T1- Temprature for which characteristics is Known.
Isc - short circuit current
K_o - Increase in Amps/ Degree increase in Temp
q - Charge of an electron
Voc- Open circuit voltage

4.1 Determination of total load current and operational time

Before starting determining the current requirements of loads of a PV system, one has to decide the nominal operational voltage of the PV system. Usually, one can choose between 12V or 24V nominal voltage. When knowing the voltage, the next step is to express the daily energy requirements of loads in terms of current and average operational time expressed in Ampere-hours [Ah].

In case of DC loads the daily energy [Wh] requirement is calculated by multiplying the power rating [W] of an individual appliance with the average daily operational time [h]. Dividing the Wh by the nominal PV system operational voltage, the required Ah of the appliance is obtained.

EXAMPLE: A 12 V PV system has two DC appliances A and B requiring 15 and 20 W respectively. The average operational time per day is 6 hours for device A and 3 hours for device B. The daily energy requirements of the devices expressed in Ah are calculated as follows:

Device A: 15W×6h = 90Wh

Device B: 20W×3h = 60Wh

Total: 90Wh+60Wh = 150Wh

150Wh/12V = 12.5 Ah

In case of AC loads the energy use has to be expressed in the DC energy requirement since PV modules generate DC electricity. The DC equivalent of the energy use of an AC load is determined by dividing the AC load energy use by the efficiency of an inverter, which is typically 85%. By dividing the DC energy requirement by the nominal PV system voltage the Ah is determined.

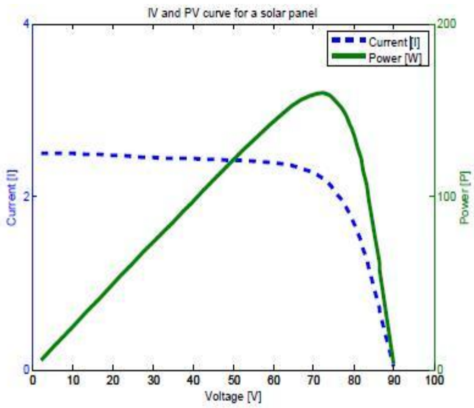

Figure 4 Typical V-I & P-V characteristics of solar array

5. CONTROL ALGORITHM FOR MPPT PERTUBATION & OBSERVATION (P&O) TECHNIQUE:

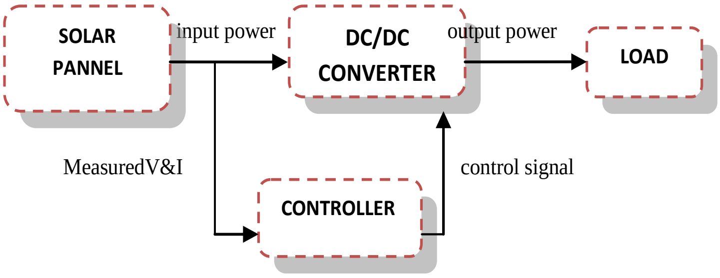

Figure 5 MPPT block scheme

MPPT Controller

The MPPT controller executes the algorithm to find the MPP.The input of the controller is the measured output voltage and current of the solar panel. This value is not the actual value of the output voltage and current, but the actual value has been converted to a value between 0 and 5 V. Based on these inputs, the algorithm performs its calculations. Practical MPPT block scheme shown in figure 5. The output of the controller is the adjusted duty cycle of the PWM, which drives the DC-DC converter's switching device. A different duty cycle causes a different operating point. In addition to these calculations, the controller also has to send the measured output voltage and current to the operating system. These values are used to track how much energy is generated and to spot any failures or errors in the system.

5.1 Perturb & Observe

The most widely used algorithm is the Perturb & Observe (P&O) algorithm. The P&O algorithm perturbs the duty cycle which controls the power con-verter, in this way it takes steps over the p-v characteristic to find the MPP .This perturbation causes a new operating point with a different output power. In case this output power is larger than the previous output power, this point is set as the new operating point. In case it is lower, the same power point is adjusted to a lower or higher working voltage, depending on the previous step direction. A Flowchart of the P&O algorithm is found in figure 5.1. In several studies, it has been shown that P&O has led to frequencies as high as 96.5%, and 99.5% in.

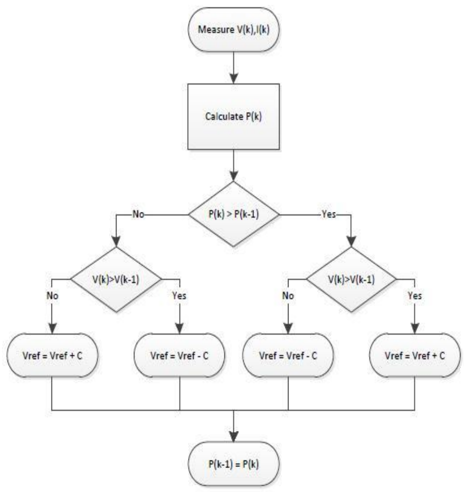

Figure 5.1 Flowchart of the P&O algorithm

5.2 DC/DC converter

A Boost-type dc/dc converter shown in fig 5.2 is used to interface the PV output to the battery and to track the maximum power point of the PV array. The converter power switch consists of one or more parallel-connected power MOSFET' s. The fly back diode is of a fast switching type. The parameters of the converter are given in table below.

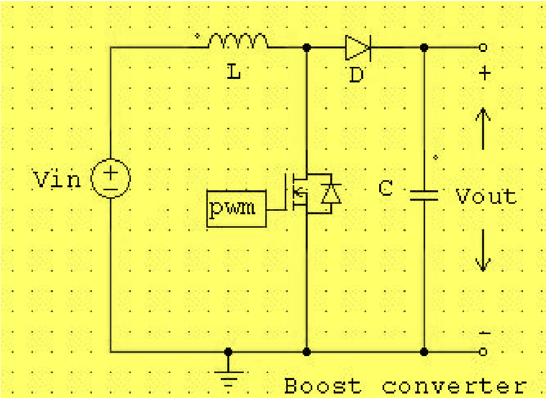

Figure 5.2 Boost converter topology

Table of listed component used for Boost converter Technology

Parameter	**Values**
Inductance L	1e- 2H
Capacitance C	1e- 2F
Switching frequency	1Khz

Table 2 shows specification of components

6. EXPERIMENTAL SETUP

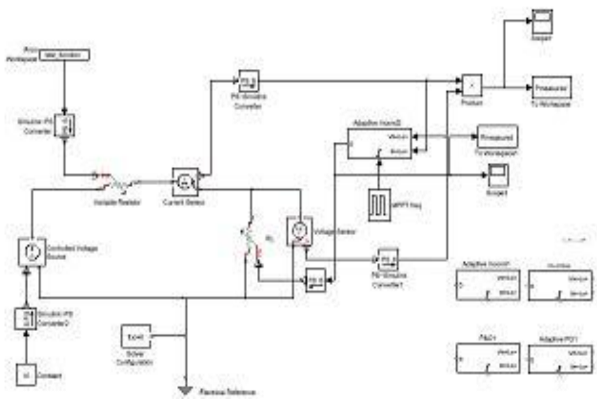

Figure 5.3 Matlab model for PV Module

6.1 MATLAB MODEL OF THE PV MODULE

The MATLAB model of the PV module shown in fig 5.4 was implemented using a Matlab program. The model parameters are evaluated during execution using the equations listed above in this paper. The program calculates the current *I*, using typical electrical parameter of the module (*Isc*, *Voc*). The characteristics for PV module is simulated using the matlab program shown in figure 5.5, 5.6, 5.7, 5.8, 5.9, 5.10

Simulink/Matlab Simulation Block Scheme

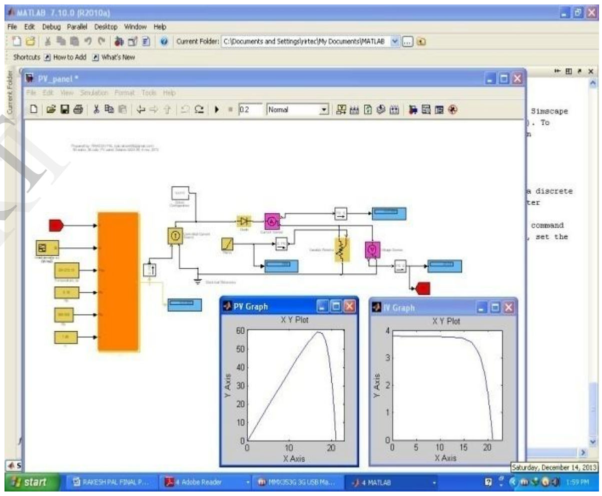

Figure 5.4 Actual PV model simulated on Matlab

6.2 SIMULATION RESULTS

Let us consider photovoltaic cell with Irradiance is 1000w/m2 And Temperature is 25oc and Simulated the Circuit without maximum power point tracking controller and with maximum power point tracking and the results are show in the below graphs viz.,5.5,5.6,5.7,5.8,5.9,5.10, respectively

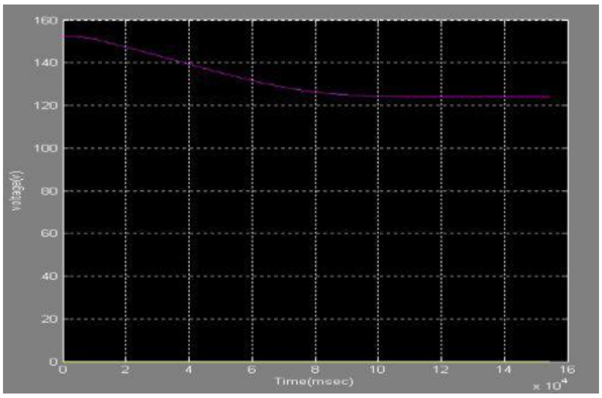

Fig 5.5 Output voltage without MPPT controller

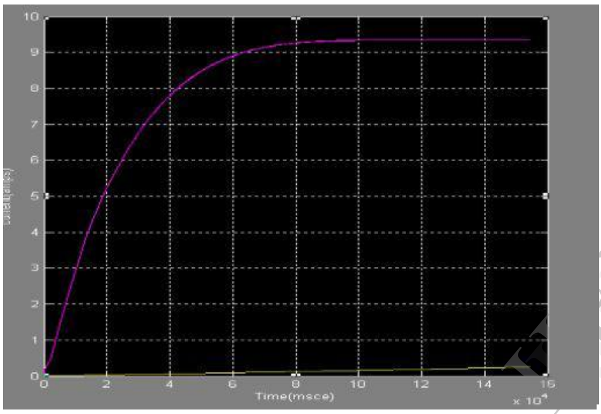

Fig 5.6 Output voltage with MPPT controller

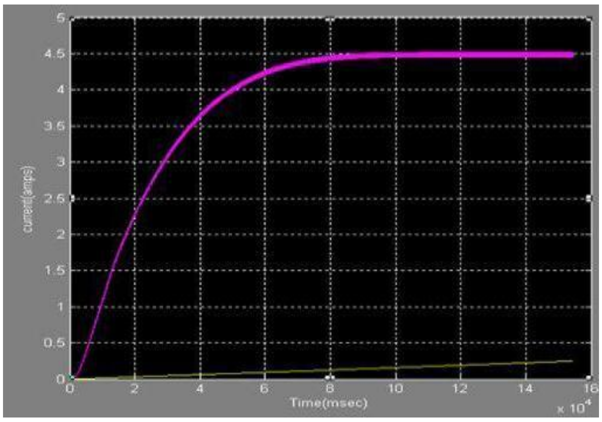

Fig 5.7 Output current without MPPT controller

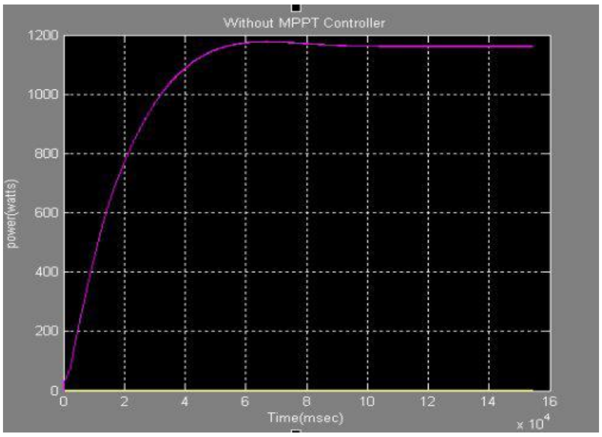

Fig 5.8 Output current with MPPT controller

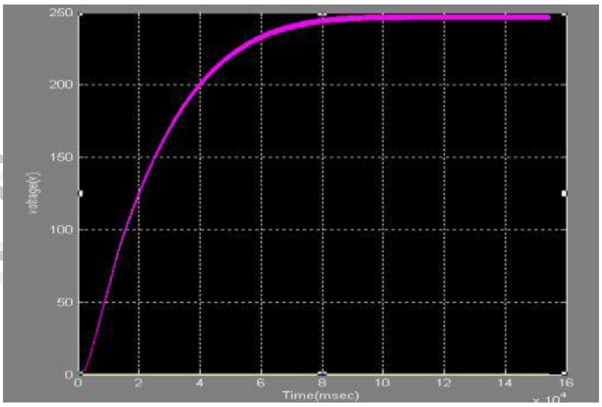

Fig 5.8 Output power without MPPT controller

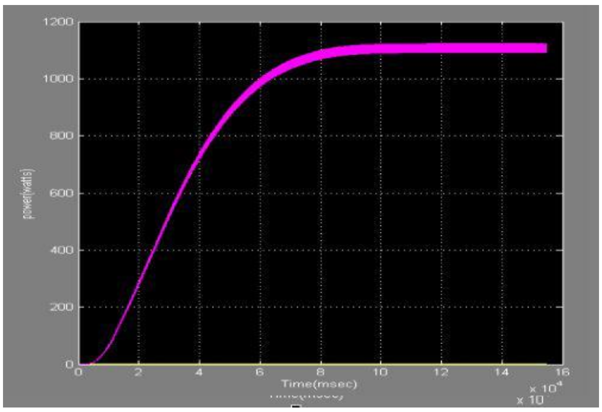

Fig 5.9 Output power with MPPT controller

CONCLUSION

The paper proposes a simple MPPT method by using this MPPT method we have increased efficiency by 19.25%. 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. This paper discussed the modeling and simulation of PV array and also the implementation of an MPPT algorithm. The simulation results show the voltage and current characteristics and power and voltage characteristics of the modeled PV array. Also from the simulation it is inferred how the maximum power point is tracked using P&O algorithm to maximize the power output of the PV array.

REFRENCES

[1] S. Premrudeepreechachain and N Patanapirom, „Solar Array Modeling and Maximum Power Tracking Using Neural Networks‟, IEEE Power Tech Conference, Bologna, Italy, PP. 53 – 68, 23-26 June 2003.

[2] B. Amrouche, M. Belhamel and A. Guessoum, Maximum Power Point Tracking Acceleration by Using Modified P&O Method for Photovoltaic Systems‟, Second International Congress on Environment and Renewable Energies, Mahdia, Tunisia, 6-8 November 2006.

[3] R.Sridhar,Dr.Jeevananathan N.Thamizh Selvan "Modeling of PV Array and Performance Enhancement by MPPT Algorithm" International Journal of Computer Applications (0975 – 8887) Volume 7– No.5, September 2010

[4] J. Youngseok, S. Junghun, Y. Gwonjong and C. Jaeho, „Improved Perturbation and Observation Method (IP&O) of MPPT Control for Photovoltaic Power Systems‟, The 31st Photovoltaic Specialists Conference, Lake Buena Vista, Florida, pp. 1788 – 1791, 3-7 January 2005.

[5] Mikel Santamaría, Sindia Casado*‡, Mónica Aguado "Adjustment and Validation of a 25 kW Photovoltaic System Matlab/Simulink Model' INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH Sindia Casado et al., Vol.3, No.3*

[6] RChenni, M. Makhlouf, T. Kerbache, A.bouzid. A detailed modeling method for photovoltaic cells. Energy 32 (2007) 1724 1730

[7] Huan liang Tsai. Insolation- oriented model of photovoltaic module using Matlab / Simulink. 2010. Solar energy 84 (2010) 1318-1326

[8] Vicent Brown-Gella, F.Escobar Ibañez. Study and simulation systems using photovoltaic generation Matlab/ Simulink. 2010.

[9] ECR Solar. Photovoltaic Energy Book. Chapter 4: The Photovoltaic Panel, pp 27-35

[10] Anca D. Hansen, Poul Sørensen, Lars H. Hansen and Henrik Bindner. Models for a Stand-Alone PV System Risø National Laboratory, Roskilde December 2000.
[11] J.F Jimenez Ortiz, D. Biel Solé. Study and simulation of photovoltaic systems-electrical conversion using Matlab / Simulink. 2009.

[12] Maximum Power Point Tracking Algorithms for Photovoltaic Applications Faculty of Electronics, Communications and Automation Thesis submitted for examination for the degree of Master of Science in Technology.2010.

[13] Suntech Power STP280-24/Vd Product Information Sheet.
[14] E. Skoplaki, J.A. Palyvos. Operating temperature of photovoltaic modules: A survey of pertinent correlations. Renewable Energy 34 (2009), Issue 1,pp 23–29

[15] Issam Houssamo, Fabrice Locment, Manuela Sechilariu, Maximum power tracking for photovoltaic power system: Development andexperimental comparison of two algorithms. Renewable Energy 35 (2010), pp 2381-2387

[16]Burri Ankala R.Sharadha jalakanuru nageswararao implementation of mppt algorithm for solar photovoltaic cell bycomparing short-circuit and incremental conductance method

[17] T. Noguchi, S. Togashi, and R. Nakamoto, "Shortcurrent pulse-based Maximum Power Point Tracking Method for Multiple Photovoltaic-and-Converter Module System", IEEE Trans on Ind. Elec., Vol. 49, 2002.

[18] E. Solodovnik, S. Liu and R. Dougal, "Power Controller Design for Maximum Power Tracking in Solar Installations", IEEE Transactions on Power Electronics, Vol. 19, No. 5, pp.1295-1304, 2004.

[19] Hussein, K.H., Murta,I., Hoshino,T., Osakada,M., "Maximumphotovoltaic power tracking: an algorithm for rapidly changingatmospheric conditions", IEEE Proceedings of Generation, Transmission and Distribution, vol. 142, No.1, 1995.

[20]www.shell.com/home/Framework?siteId=shellsolar

[21]www.pv.kaneka.co.jp/about/index.html

[22]www.firstsolar.com/index.html

[23] *www.mathworks.in/**matlab**central/.../43606-simplified-pv-module-simulatiom*]