Design Optimization of Solar PV Power Plant for Improved Efficiency of Solar PV Plant by Maximum Power Point Tracking System

Doulat Pawar[1], Dr. V. K Sethi[2], Anurag Gour[3]

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

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

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

Abstract

Maximum power point tracking (MPPT) is a method that grid connected inverters, solar battery chargers and similar devices use to get the maximum potential power from one or more photovoltaic devices, normally solar panels. P-V and I-V curve for MPPT [fig 1]This paper presents a relative study of widely-adopted MPPT algorithms; their performance is calculated on the basis of energy generation capability in most effective way, by using the simulation tool Matlab/Simulink, taking into account different solar irradiance variations. PV cells have a relationship between, temperature solar irradiation, and total resistance which generate non-linear production efficiency which can be studied for optimum power generation which is based on the V-I characteristic curve of PV module.

It is the purpose of the MPPT system to model the output of the cells and apply the appropriate load resistance to obtain maximum power for any given ecological conditions. solar radiation energy is most Viable & eco friendly source of energy. It shows ways to Integrate solar design into multi-units of small household PV plant, and provides calculations and examples to show how better design optimization decisions can increase the useable solar energy. The improvement in overall system efficiency of integrated PV modules embedded in power plant increased power generation is achieved by minimizing and capturing energy losses.

Keywords: P&O Algorithm, Solar Photovoltaic cell, buck converter, MPPT, Simulink model, solar tracking

1. Introduction

The MATLAB/SIMULINK model consists of PV module proposed model of plant, buck/boost converter [fig 2], and MPPT controller. The role of the present work is in the modeling of buck converter using standard equation model approach moderately than circuit model. The buck/boost converter model is developed using model based on governing equation [2.1] that allowing the input voltage of the converter, i.e. output voltage of particular PV module is altered by varying the duty cycle, so that the maximum power point could be tracked when the ecological conditions changes. This paper is focused on the famous Perturb and Observe (P&O) method [fig 10] and is compare to predefined system.

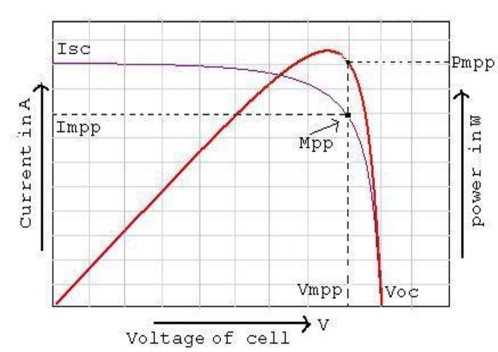

Fig –1 P-V & I-V curve for MPPT

The model work with MPPT controller, a DC/DC, buck/boost converter feeding a load is achieved. The simulation results proposed that the MPPT algorithm used in the solar PV system is applicable. For particular power plant to work efficiently the BOS (Balance of system) [fig 3] must satisfy the basic condition to laid down the plant. The BOS typically includes grid inverters, mounting system, cable and connectors. The life expectancy of the PV module support Structures are assumed 50 years. Inverters, transformers, cable and connector are considered to last for 30 years, but spare must be replaced every 10 years based on data provided by the power industry on transformers and electronic components. The life-cycle record includes the energy use by running authority and regular maintenance of system is required for proper generation of electric power through the solar PV plant

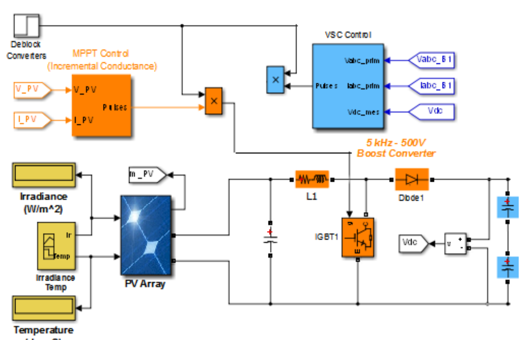

Fig:-2 Proposed model of PV Array plant (MPPT controller using "Incremental Conductance" Technique)

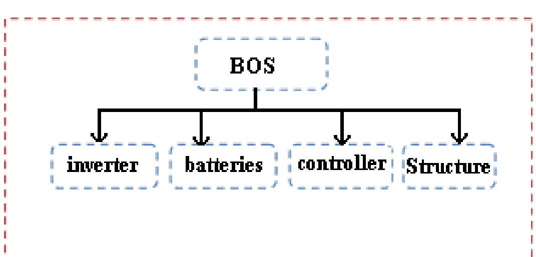

Fig: - 3 Balance of system for PV plant

1.1 Boost Converter Technology

A Boost-type dc/dc converter [fig 4] is used to interface the PV output to the battery and to trail the maximum power point of the solar PV array. The boost converter power switch consists of one or more parallel-connected power MOSFET's. The fly back diode is of a high-speed switching type. The parameters of the converter are given in table below.

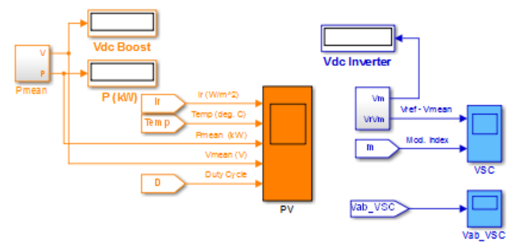

Fig: -4 DC/DC Boost converter technologies

A maximum power point tracker system (MPPT) can be used to keep the PV module's operating point at the MPP. By using MPPT, we can extract more than 97% of the PV power when accurately optimized. We require a DC–DC converter [fig 5] that converts produced DC voltage by the PV module to a load voltage demand. Suitable Digital controller that drives the converter operation with MPPT capability.

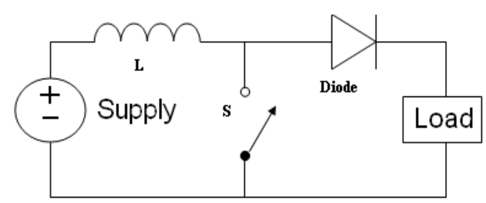

Fig: - 5 Schematic of Boost Converter

Parameter	values
Inductor (L)	$200\mu H$
Capacitor (c)	1.25 mF
Mosfet switch	30A 500V
Diode (D)	60A 600V
Switching freq.	100 KHz
Duty cycle	25 ms

Table: - 1 DC/DC converter parameters

2. Basics of solar PV cell

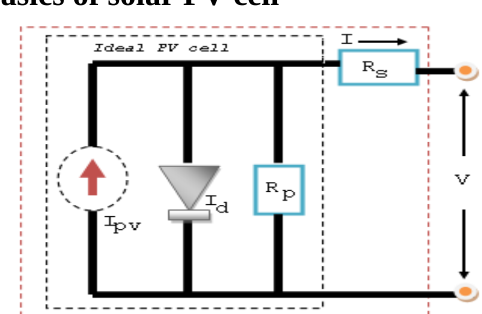

Fig: - 6 Equivalent circuit of the PV cell

2.1 Typical Rating of a PV module

Electrical parameter	PM80
Maximum power rating P_{max} (Wp)	80.5
Minimum power rating P_{min}(Wp)	75.0
Rated current I_{mpp} (A)	4.6
Rated voltage V_{mpp} (V)	17.5
Short - circuit current I_{sc} (A)	5.0
Open – circuit current V_{oc} (V)	21.5

Table: - 2 Solar cell parameter for PM80

Study of P-V, V-I curve of a cell module with manufacturer specification is taken into consideration when design optimization of power plant was done. [Table 2]

2.2 Physical Parameter

• Number of series-connected cells: 36
• Physical dimension (mm): 1200 x550x35
• Weight (Kg) : 7.5

The basic creation solar cell is analogous to photodiode, usually of semiconductor like silicon, designed to maximize the absorption of photons from the sun light and minimize reflection through the surface of PV module. When it receives an incident light, it behaves as a current initiator whose value increases in inverse function of the quantity of light incident upon it. The PV array block menu allows us to plot the V-I and P-V characteristics for one cell module and for the whole array.

2.3 Governing Equation for Solar PV Cell

In a PV cell, the Itotal (i.e. total current) is the same as the current IL (load current) produced by the photoelectric effect of PV cell minus the ID, (diode current) .Basic equations are:

$$I = I_L - I_D \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$I = I_L - I_o\left(e^{\frac{qV}{kT}} - 1\right) \ldots\ldots\ (2)$$

Where,
V- Measured cell voltage
Io - Saturation current of the diode,
q - Elementary charge1.6x10-19 Coulombs,
k - Constant of value 1.38x10-23J/K,
T - Cell temperature in Kelvin,

$$I = I_{pv} - I_o\left(e^{\frac{q(V+IR_S)}{nkT}} - 1\right) \ldots\ldots\ (3)$$

$$I_{pv} = I_{pv}(T_1) + K_0(T - T_1) \ldots\ldots\ (4)$$

$$I_{pv}(T_1) = I_{SC}(T_{1,nom})\frac{G}{G_{nom}} \ldots\ldots\ (5)$$

$$K_o = \frac{I_{SC}(T_2) - I_{SC}(T_1)}{(T_2 - T_1)} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$I_o = I_o(T_1) \times \left(\frac{T}{T_1}\right)^{\frac{3}{n}} e^{\frac{qV_q(T_1)}{nk\left(\frac{1}{T} - \frac{1}{T_1}\right)}} \ldots. (7)$$

$$I_o(T_1) = \frac{I_{SC}(T_1)}{e^{\left(\frac{qV_{OC}(T_1)}{nkT_1} - 1\right)}} \ldots\ldots\ldots\ldots\ (8)$$

The parameters that are determined from the VI curve of PV cell are very important like short-circuit current (I_{SC}) of cell its, open-circuit voltage (V_{OC}), the fill factor (FF) and efficiency. The model includes the temperature dependence of photocurrent I and saturation current of the diode Io shown in [fig 7.]

2.4 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- Temperature 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

Above equation provides the basic circuit model shown above and the following related equation, where n is the diode ideality factor.

3. I-V curve

The array V-I & P-V characteristics are changed at different value of cell temperature [fig 7] (Voc, Isc, Vmp, Imp) under standard test conditions (25 deg. C, 1000 W/m^2). The array V-I and P-V characteristics at 1000 W/m^2 are displayed for different cell temperatures [fig 7].PV module or solar cell shows different behavior when exposed to different value of solar irradiance [fig 8]

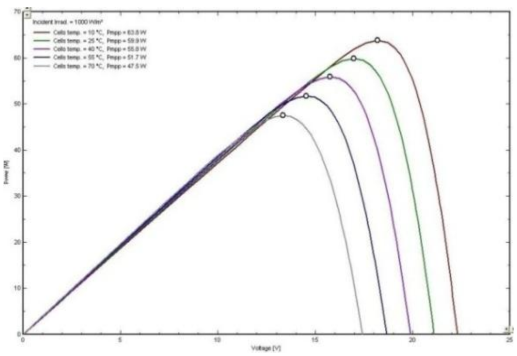

Fig -7 P-V graph with respect module temperature

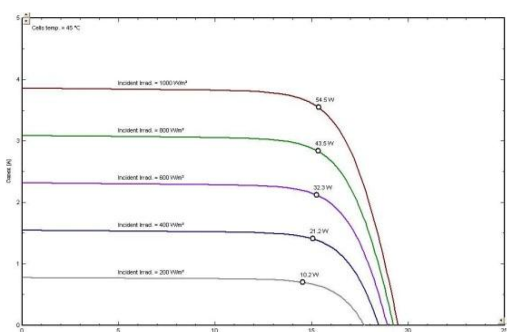

Fig: - 8 V -I graph with respect to irradiance

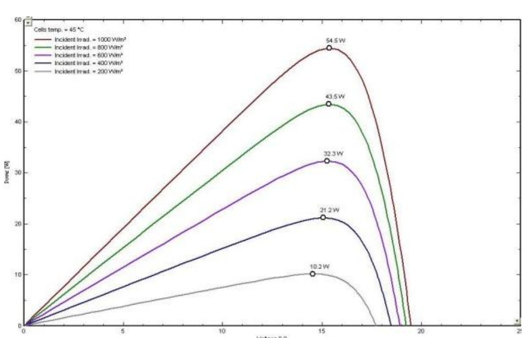

Fig: - 9 P-V graph with respect to incident irradiance

[Fig. 9] shows the characteristic power curve for a PV array for different values of incident irradiance. The problem measured by MPPT techniques is to automatically find the voltage VMPP (Voltage at maximum power point) or IMPP (Current at maximum power point) at which a PV array should operate to obtain the output PMPP (Power at maximum power point) under a given temperature and irradiance. It is considered that under partial shading conditions, it is possible to have multiple local maxima, but we get only one MPP. Most techniques respond to changes in both irradiance and temperature, but few are more useful if approximate constant temperature is found. Many techniques were repeatedly react to alteration in the PV array, though few are open loop and require periodic tuning with respect to sun. In this case, the PV array will usually be coupled to a power converter that can change the current imminent from the PV array.

4. Classification

MPPT Controllers typically trail one method to optimize the generated power output of a solar array out of the three. Maximum power point trackers use different algorithms and switch among them based on the working conditions of the array & they are -

- Perturb and observe
- Incremental conductance Method
- Current drag/sweep Method

4.1 Comparison of methods for MPP

The perturb-and-observe and incremental conductance is examples of “hill rising” method, also known as perturbation method, is the most commonly used MPPT algorithm in commercial PV product. This is a “trial and error” method. The PV controller increases the reference for the inverter output power by a small amount, and then detects the actual output power. If the output power is indeed increased, it will increase again until the output power starts to decrease, at which the controller decreases the reference to avoid collapse of the PV output due to the non-linear PV characteristic. The enhanced perturbation-observation method can eliminate the oscillation near the maximum power point. The P&O method can generate oscillations of output power around the MPP even under balanced state solar illumination.

P&O method is the most common. In this method very less number of sensors are utilized the operating voltage is sampled and the algorithm changes the operating voltage in the required direction and samples dP/dV. If dP/dV is positive, then the algorithm increases the voltage value towards the MPP until $dP/dV$is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point (MPP).

The main task of the incremental conductance algorithm is to find the derivative of PV output power with respect to its output voltage, that is dP/dV Perturb and observe method can find out the maximum power point without swings around this value. It finds maximum power point tracking under rapid changing environmental conditions with greater accuracy than the basic perturb and observe method. The calculation time for MPP is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method. However, efficiencies of some systems may reach above 95%.MPPT placement.

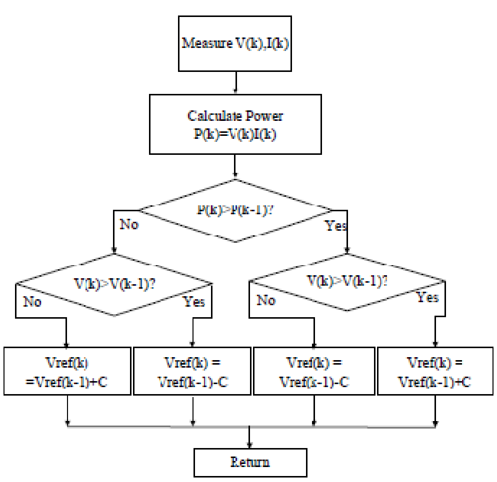

Figure 10 Flow chart of P&O algorithm.

5. Effect of variation of solar irradiation

The output P-V and V-I curves of a PV cell are directly dependent on the solar irradiation values. Due to ecological variation the solar irradiation keeps on fluctuating, but MPPT control method are available which find this variation and can change the power generating efficiency of the PV cell to congregate the required power load demands. Solar irradiation falling on PV module has direct relationship with power generating capability of PV cell. Greater the Solar irradiation greater the solar input to the solar cell and hence power generation level would increase for the identical voltage value. As solar irradiation, increase the open circuit voltage (I_{OC}) increases. This is because, when more sunlight falls on to the solar cell, the more electrons are supplied with higher excitation energy, thereby increasing the electron mobility and thus more power is generated. We can see that these two kinds of method can make PV cells operate at the maximum power point from the simulating figure. However, there is obvious oscillating near the maximum power point through comparing.

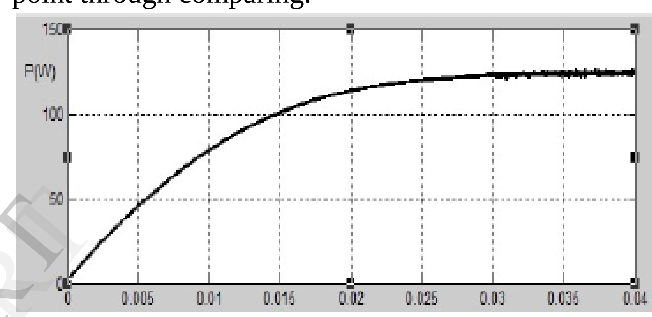

Fig 11simulation waveform of traditional P&O method

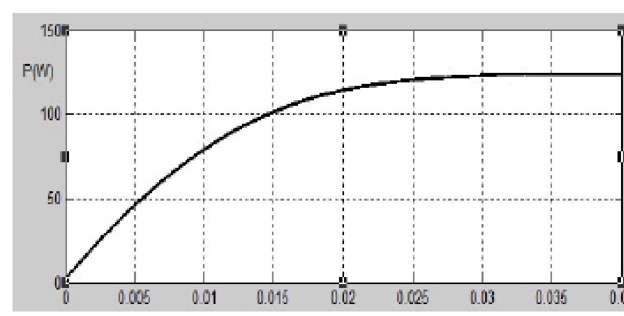

Fig 12 simulation waveform of improved P&O method

6. Conclusion

This paper suggest an improved P&O, MPPT method by using it we increased generation efficiency by 25% from same value of irradiance. This method calculates the maximum power and controls directly the produced power from the PV solar cell. The proposed method offers various advantages, whose response is high and well control for the extracted power, good tracking efficiency. This paper discussed the modeling and simulation of PV array and the implementation of an MPPT algorithm for tracking systems from the simulation; it inferred how the maximum power point is tracked using P&O algorithm to maximize the power output of the PV array.

The work focused on the well known Perturb and Observe (P&O) algorithm and compared to a designed proposed system. A simulation work dealing with MPPT controller, a DC/DC Ćuk converter feeding a load is achieved. The results [fig 11, 12] showed the validity of the proposed MPPT in the PV system.

References

[1] T. Tafticht and K. Agbossou, "Development of a MPPT method for photovoltaic systems," In Canadian Conf. Elect. Computer. Eng., 2004, pp. 1123–1126

[2] 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*

[3]Arun KumarVerma, Bhim Singh and S.C Kaushik, " An Isolated Solar Power Generation using Boost Converter and Boost Inverter," in Proc. National Conference on Recent Advances in Computational Technique in Electrical Engineering, SLITE, Longowal (India), 19-20 March, 2010, paper 3011, pp.1-8.

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

[5]L. L. Buciarelli, B. L. Grossman, E. F. Lyon, and N. E. Rasmussen, "The energy balance associated with the use of a MPPT in a 100 kW peak power system," in IEEE Photovoltaic Spec. Conf., 1980, pp. 523–527.

[6] 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

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

[8] 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*

[9]R Chenni, M. Makhlouf, T. Kerbache, A.bouzid. A detailed modeling method for photovoltaic cells. Energy 32 (2007) 17241730

[10]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

[11] www.ni.com