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Maximum Power Point Tracker Using Perturb and Observe Algorithm for PV System

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A B S T R A C T

Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to extract maximum power from the PV module. Perturb and observe (P&O) method is widely used because of its low-cost and ease of implementation. The P&O method oscillates close to maximum power point (MPP), when atmospheric conditions are constant or slowly varying. However, when irradiance and temperature are changing rapidly, this method fails to track MPP with rapid speed. This paper presents characteristics of the PV device, which are affected by the atmospheric factors like irradiation and temperature etc. Basic Perturb & Observe MPPT algorithm to track the maximum power available in the solar panel. The MPPT method Perturb & Observe is implemented in MATLAB/M-files.

Keywords: Solar Photovoltaic (PV); Modeling; Maximum power point tracking (MPPT); Perturb and Observe (P&O).

1. Introduction

Alternate energy sources gained a lot of importance in power generation due to their abundant availability in nature and eco-friendly nature. Growing demand for energy and the increasing concern about the environmental impact from excessive use of fossil Fuels have progressively increased the interest in renewable Energy research. Among the alternative sources, solar power generation is currently considered as a natural energy source that is more useful, as it is pollution free, maintenance free, distributed over the earth, fast technological progress and Continuous cost reduction. The fundamental element in solar power generation system is the solar cell or photovoltaic (PV) cell that converts sunlight into direct current (DC) electricity. The basic device of a PV system is the PV cell. Cells may be grouped to form panels or arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors. Applications that are more sophisticated require electronic converters to process the electricity from the PV device. In general, the larger the area of a module or array, the more electricity that it can produce [1]. The biggest disadvantage of solar energy production revolves around the fact that power Generation is not constant throughout the day; it is always changing with weather conditions, i.e., irradiation and temperature. Furthermore, the efficiency of solar energy conversion to electrical energy is very low which is only in the range of 9-17% [2]. Therefore, it is important to track maximum power point of solar photovoltaic system. There are many MPP tracking methods have been developed and implemented. The MPPT methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness and in other aspects. Among the different MPPT methods perturb and observe (Hill climbing method), Incremental conductance, fractional short circuit current, fractional open circuit voltage and Ripple correlation control these are some well-known methods. The P&O method is commonly used because of ease of implementation and this method compares output power of PV array with last one to determine increase or decrease the output voltage of the PV array for achieving MPPT. Incremental conductance method is effective while working with long time partial shading condition by varying duty ratios of boost converter. Ripple correlation control uses ripple that exists in all switching power converters to extract information about the operating point of the solar panel [3].

2. Solar PV Modeling

Solar Photovoltaic (PV) system studies need a reliable and accurate mathematical model to predict energy production from the PV resource under various irradiance and temperature conditions. In order to study the electronic converters for PV systems, it is necessary to know how to model the PV device, which is attached to the converters. The Mathematical model of the PV device useful in the study of the dynamic analysis of converters, especially in the study of maximum power point tracking algorithms. Modeling of the PV models can be categorized into two main types, single diode models and double diode models. The double diode model is characterized by its high accuracy; however, it is relatively complex and suffers from low computational speed. The second type, single diode model, is the most commonly used model in power electronics simulation studies, because it offers a reasonable tradeoff between simplicity and accuracy. Another advantage of using single diode model is the possibility to parameterize it based only on provided information by datasheet of solar PV panel. PV manufacturing datasheets provide only four information about the output electrical characteristics of their PV modules at standard test conditions (STC), which are short-circuit current I_{sc}, open circuit voltage V_{oc}, operating voltage and current at maximum power point(V_m,I_m), and the implicit information that the peak of P–V curve occurs at the voltage point(V_m). Thus, only four equations can be written accurately relying on datasheet information. However, single diode PV models have five unknown parameters, which need to be estimated. To compensate, the parameterization in starts with one predefined parameter, the ideality factor, and then derives the rest four parameters accordingly. [4].

There are more than sixteen equations available for the modeling of the PV device. Out of which some important equations are as follows, From equivalent circuit, Output current of the PV device (I) in ampere is given as,

$$I = Ip - Is\left(\exp\left(\frac{V + I\,Rs}{aVt}\right) - 1\right) \qquad (1)$$

Where, I_P is the photocurrent; I_S is the reverse saturation current which is affected by the temperature of the PV cell; V is the voltage applied on the diode; a is the ideality factor, which normally varies from 1 to 2 depending on the diode itself, and in this case, it is assumed to be approximately equal to 1.82; V_t is the thermal voltage ($V_t = \frac{k_B T}{q}$) with the Boltzmann constant k_B =1.38 × 10−23 J/K; T is the absolute temperature of the diode in Kelvin; and q = 1.6 × 10−19 C is the charge represented by an electron. Finally, R_s is the equivalent series resistance of the PV array [5-6].

Output voltage of the PV device (V) in volts is given as,

$$V = \frac{akTr}{q}\ln\left[\frac{Ip + Is - I}{Is}\right] - IRs \qquad (2)$$

The photocurrent generated by the light depends linearly on Irradiation of the sun and the temperature of the cell expressed as follows influences it: Photocurrent (I_P) generated when light incident in ampere is given as,

$$Ip = Ipr + ki(T - Tr) \qquad (3)$$

Reverse saturation current (I_s) in ampere is given as,

$$Is = Isr\left(\frac{T}{Tr}\right)^{\frac{3}{a}} exp\left(\frac{-qVg}{ak}\left(\frac{1}{T} - \frac{1}{Tr}\right)\right) \qquad (4)$$

Where, Reference Reverse saturation current (I_{sr}) in ampere is given as,

$$Isr = \frac{Iscr}{\exp\left(\frac{qVocr}{akTr}\right)} \qquad (5)$$

Where,Vg is the band gap voltage of the semi-conductor. It is set at 1.12V in this paper. The series resistance can be determined by, Series resistance (R_s) of the PV device in Ohm and given as,

$$RS = \frac{-dV}{dIVoc} - \frac{1}{Xv} \qquad (6)$$

$$Xv = Iscr\frac{q}{kBTr}\exp\left(\frac{qVocr}{akBTr}\right) \qquad (7)$$

Where, $\frac{dV}{dIVoc}$ can be generated from manufacturers' data.

Table I: KEY SPECIFICATIONS OF KC200 GHT PV Module

Dimensions	**Specifications**
Length	1425(±2.5)mm
Width	990(±2.5)mm

Parameters At 1000 W/m^2 **(STC)**	**Ratings**
Maximum power (P_m)	200W
Maximum Power Voltage (V_{mp})	26.3V
Maximum Power Current (I_{mp})	7.61A
Open Circuit Voltage (V_{oc})	32.9V
Short Circuit Current (I_{sc})	8.21A
Parameters At 800 W/m^2 **(NOCT)**	**Ratings**
Maximum power (P_m)	142.21W
Maximum Power Voltage (V_{mpp})	23.2V
Maximum Power Current (I_{mpp})	6.13A
Open Circuit Voltage (V_{oc})	29.9V
Short Circuit Current (I_{sc})	6.62A

3. Characteristic of PV System

The characteristics of Solar PV panel describes the effective performance of solar PV panel under different environmental conditions such as irradiation, temperature etc. these atmospheric factors affect the output power of the PV panel. To analyze the characteristics of the PV panel the specific solar panel Kyocera KC200 GHT PV module is utilized. Each PV module consists of 54 series connected cells. The key specifications for the PV module from the manufacturers' data sheet are listed in Table I. A model of the PV array is created in MATLAB with M-files.

The characteristics of the PV device is mainly affected by the atmospheric conditions such as,

3.1 Effect of different Irradiation levels

The effect of different Irradiation level can be analysed by keeping the other environmental factors constant. Such as temperature, shading effect of PV panel etc. The effect of different Irradiation levels directly affects the output current of PV device. As the higher the value of Irradiation level higher will be the output current of the PV device and vice-versa. Output voltage of the PV panel is less affected by the variation of irradiation level.

3.2. Effect of different Temperature levels

The effect of different Temperature level (difference between ambient temperature and Nominal temperature) can be analysed by keeping the other environmental factors constant. Such as Irradiation, shading effect of PV panel etc. The effect of different Temperature levels directly affects the output current of PV device. As the higher, the value of Temperature level lower will be the output voltage of the PV device and vice-versa. Output current of the PV panel is less affected by the variation of Temperature level.[7].

4. Purturb and Observed (P&O) MPPT method

The objective of Perturb & Observe MPPT algorithm is to adjust the current (I_{mpp}) and voltage (V_{mpp}) of the PV array at which maximum output power (P_{mpp}) is obtained under a specific irradiation and temperature. Conventional P&O method involves a perturbation in the Operating voltage ΔV of the PV array and observes the impact on the output power ΔP of the PV array. The controller adjusts the voltage by a small amount from the array and measures the power. If the power increases, further adjustments in that direction are tried until power no longer increases. This is called Perturb & Observe method.

Although this method can result in oscillation of power output. It is referred to as a hill climbing method. Because, it depends on the rise of power against voltage below MPP and above MPP.

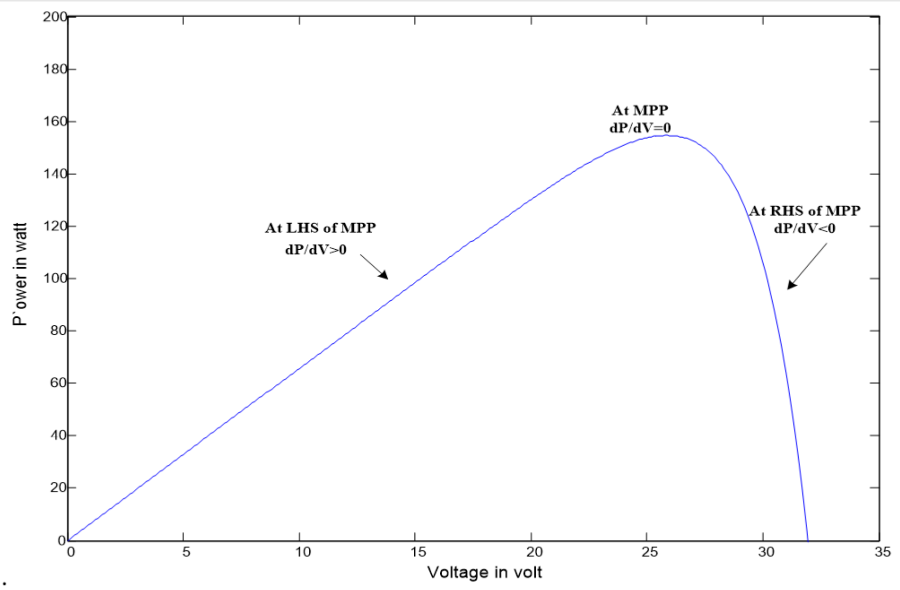


Fig.2 ***Typical P-V curve at 800 W/m^2***

Fig.2. Shows typical P-V curve at 800 W/m^2. On the LHS of the MPP there is linear increase in power with respect to voltage (dP/dV>0). But on RHS of the MPP there is increase voltage with decrease in power (dP/dV<0). So, this P&O algorithm will try to maintain the maximum power point by perturbing voltage with respective power. At MPP change in power with respect to change in voltage is zero (dP/dV=0). Table II shows the direction of perturbation of voltage with respect to power. Table II shows that with same sign of ΔV and ΔP results in direction of step size is positive i.e. + C. and if either sign of ΔV and ΔP results in direction of step size is negative i.e. – C. [8],[9].

Fig.3 shows the flowchart of P&O MPPT algorithm [10]. This algorithm continuously compares the previous voltage sample with present voltage sample. If this change in voltage is greater than zero (dV>0) in that case P&O algorithm continuously perturbs the voltage in the same direction until Maximum power point is reached. If change in voltage is less than zero (dV<0) in that case this algorithm perturbs the voltage in reverse direction so that it reaches back to Maximum power point.

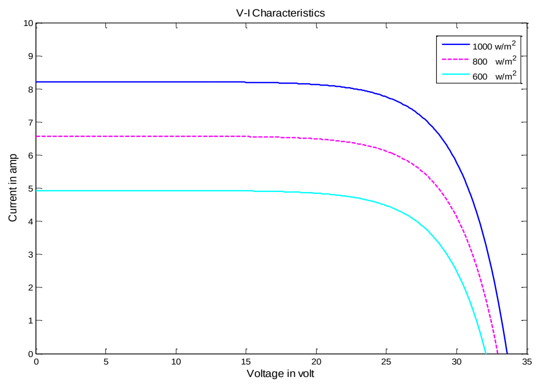
This algorithm has the drawback that after reaching the maximum power point its starts deviating on the maximum power point continuously all the time results in the substantial amount of power loss at maximum power point. Although this algorithm is quite simple to implement and it requires only one voltage sensor so, the cost of implementation of this algorithm is low [11].

Fig.3 ***Flowchart of P&O MPPT Algorithm***

5. Result and Discussion

5.1. Characteristics of PV device

Fig.4 shows V-I and Fig.5 shows V-P Characteristics of solar PV module with different Irradiation levels such as 1000 w/m^2,800 w/m^2 and 600 w/m^2 keeping the temperature level constant. It clearly shows that at low irradiation level the output current of PV device is more affected compared to output voltage. Fig.6 shows V-I and Fig.7 shows V-P Characteristics of solar PV module with different temperature levels such as 25 deg., 50 deg. and 75 deg. keeping the irradiation constant. It also shows that as the temperature increases the output voltage of the PV device is reduces and vice-versa.



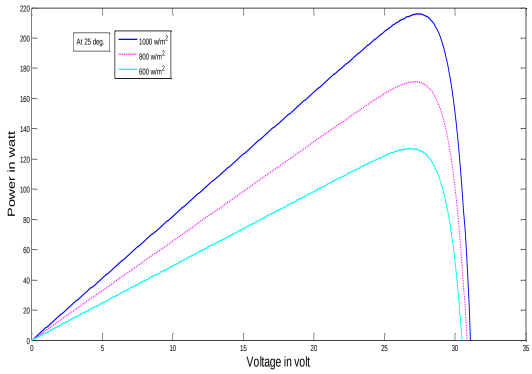
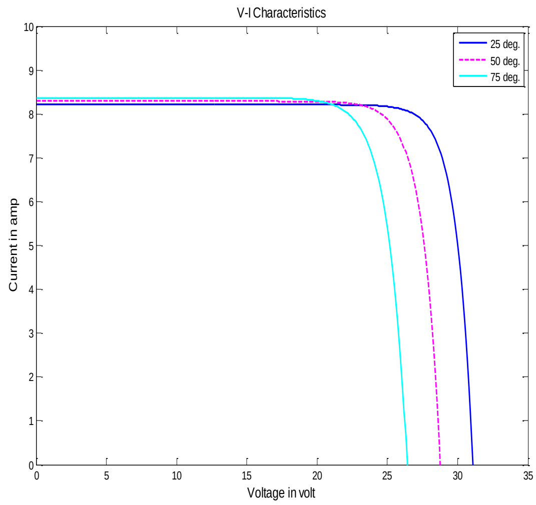


Fig.4 *V-I Characteristics of solar panel with different Irradiation* Fig.5 *V-I Characteristics of solar panel with different Irradiation*



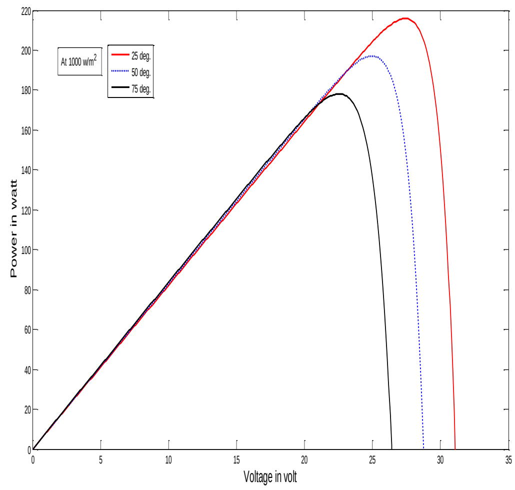
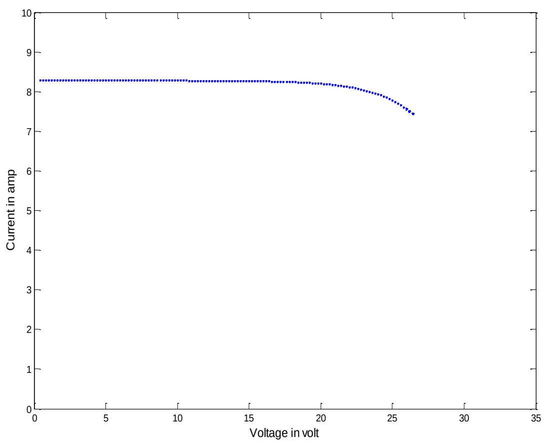


Fig.6 V-I Characteristics of solar panel with different Temp. *Fig.7 V-P Characteristics of solar panel with different Temperature*

5.2. MPPT Results- Perturb & Observe Method

At 1000 w/m²

On LHS of MPP



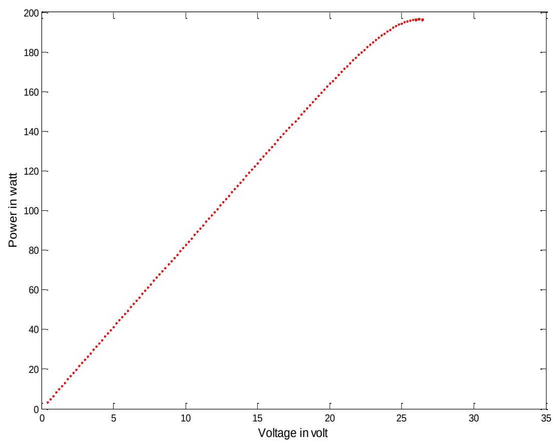
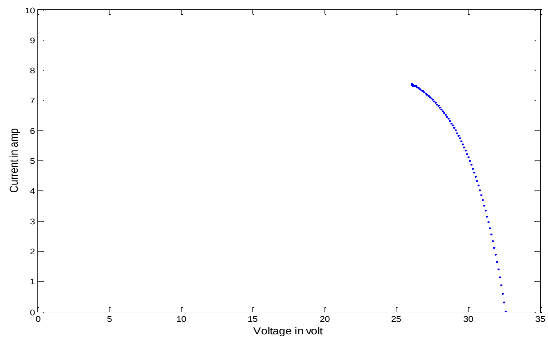


Fig.8 *V-I Characteristics of solar panel* Fig.9 *V-P Characteristics of solar panel*

At 1000 w/m²

On RHS of MPP



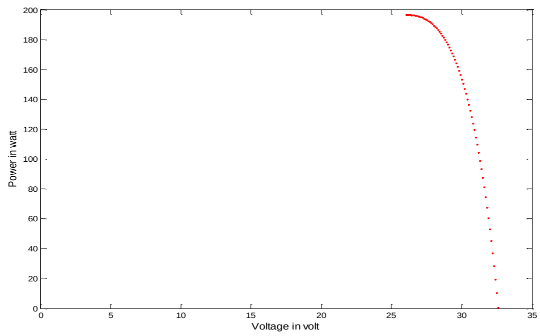


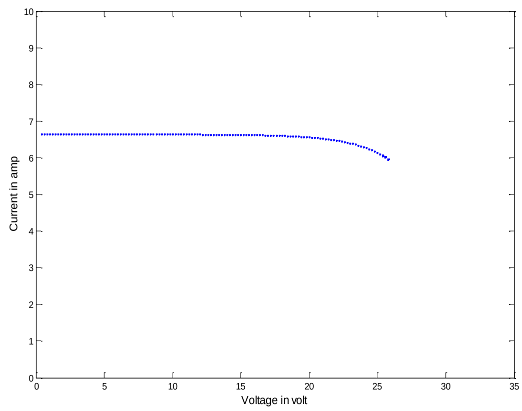
Fig.10 *V-I Characteristics of solar panel*

Fig.11 *V-I Characteristics of solar panel*

Fig. 8 and 9 represents the tracking of maximum power point i.e. At 200 watt corresponding to left hand side i.e. LHS (V-I and V-P plot respectively) and Fig 10 and 11. Represents the tracking of maximum power point i.e. at 200 watt corresponding to right hand side i.e. RHS (V-I and V-P plot respectively) of the maximum power point. It clearly shows that perturb and observe MPPT method tracks the maximum power point at voltage 26.3 volts i.e. V_{mp} and at current 7.61 ampere i.e. I_{mp} as per mentioned in datasheet for 1000 w/m^2 (STC). Observing from the tracking of maximum power point by executing the M-file of Perturb and Observe method shows that the reaching of maximum power point takes more time since it compares the present voltage and power with previous value of voltage and current and correspondingly changes the direction of tracking.

At 800 w/m²

On LHS of MPP



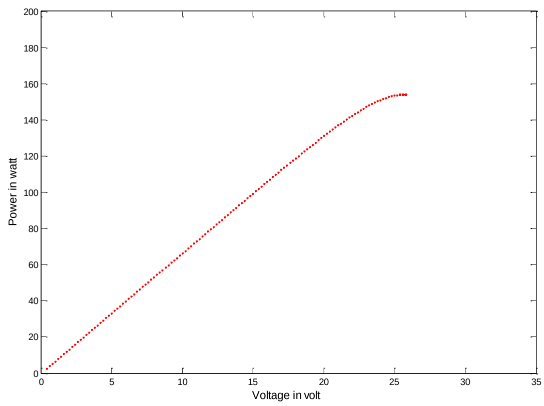


Fig.12 *V-I Characteristics of solar panel*

Fig.13 *V-P Characteristics of solar panel*

At 800 w/m²

On RHS of MPP

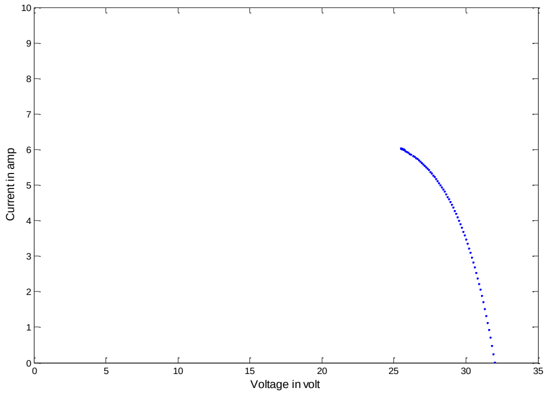


Fig.14 *V-I Characteristics of solar panel*

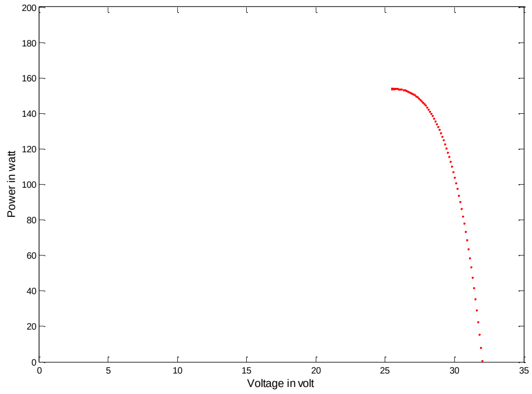


Fig.15 *V-P Characteristics of solar panel*

Fig.12 and 13 represents the tracking of maximum power point i.e. At 141.42 watt corresponding to left hand side i.e. LHS (V-I and V-P plot respectively) and Fig.14 and 15 represents the tracking of maximum power point i.e. At 141.42 watt corresponding to right hand side i.e. RHS (V-I and V-P plot respectively) of the maximum power point. It clearly shows that perturb and observe MPPT method tracks the maximum power point at voltage 23.2 volts i.e. V_{mp} and at current 6.13 ampere i.e. I_{mp} as per mentioned in datasheet for 800 w/m^2 (NOCT).

6. Conclusion

Results demonstrate that Solar PV device characteristics have been greatly affected by the atmospheric factors like different irradiation and temperature levels. Variation in Irradiation has great influence on output current in solar PV panel whereas variation in temperature has adversely affected the output voltage of the PV panel.

The conventional Perturb and Observe MPPT method effectively track the maximum power point by perturbing the voltage of the PV panel. This method has the drawback to continuously varying maximum power around the maximum power point results in power losses.

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