A Review on Maximum Power Point Tracking of PV Array

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ABSTRACT

A solar cell or photovoltaic cell is a device which generates electricity directly from visible light. However, their efficiency is fairly low. So, the solar cell costs expensive according to other energy resources products. Several factors affect solar cell efficiency. This paper proposes a review of the maximum power point tracking (MPPT) of a photovoltaic system under variable temperature and insolation conditions. This paper presents the most important factors that affecting efficiency of solar cells.

I Introduction

As the conventional energy sources are rapidly depleting, the importance of solar photovoltaic (PV) energy has been emerging as replaceable energy resources to human being. Since it is clean, pollution-free, and inexhaustible, researches on the PV power generation system have received much attention, particularly, on many terrestrial applications. Furthermore, due to the continuing decrease in PV arrays cost and the increase in their efficiency, PV power generation system could be one of comparable candidates as energy sources for mankind in near future. As is well known, the maximum power point (MPP) of a PV power generation system depends on array temperature and solar insolation, so it is necessary to constantly track the MPP of the solar array. In order to increase this efficiency, MPPT controllers are used. Such controllers are becoming an essential element in PV systems. A significant number of MPPT control schemes have been elaborated since the seventies, starting with simple techniques such as voltage and current feedback based MPPT to more improved power feedback based MPPT.[1-3]

II Simulation model of the PV cell

The Fig. 2 shows the I-V and P-V characteristics of PV cell. As we can see from the figure that at Pmax , Vmax and Imax can be obtained.
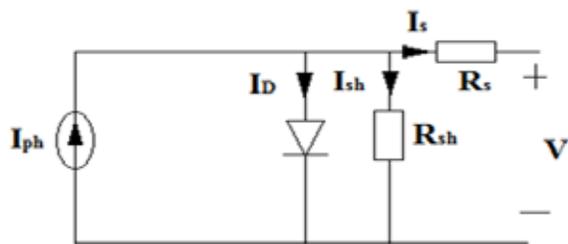

Fig.1 Equivalent circuit for PV cell

According to [4, 14] and based on the equivalent circuit (Fig1) of a photovoltaic panel its characteristic equation is deduced

$$I = I_L – I_D – I_{sh} \qquad (1.1)$$

Being IL, Id and Ish: (1.2)

$$I_D = I_s.(\quad -1) \; e^{\left(\frac{V+I.R_s}{n.V_t.N_s}\right)} \qquad (1.3)$$

$$I_s = I_{sc}.(\quad -1) \; e^{\left(\frac{V_{oc}}{n.V_t}\right)} \qquad (1.4)$$

$$V_t = \qquad (1.5)$$

This expression describes the electrical behavior and determines the relationship between voltage and current supplied by a photovoltaic module. It is a non-linear mathematical equation whose parameters are, Ns is number of cells in series, IL is the current produced by the photoelectric effect, IS is the reverse saturation current. RS and Rsh are inherent resistances in series and parallel associated with the cell. Q is the electron charge, k Boltzmann's constant and a, the ideality factor modified [6].

Characteristics of Solar Cell:

Solar cells naturally exhibit a nonlinear I-V and P-V characteristics which vary with the solar irradiation and cell temperature. The typical I-V and P-V characteristics of solar cell are shown in Fig.2
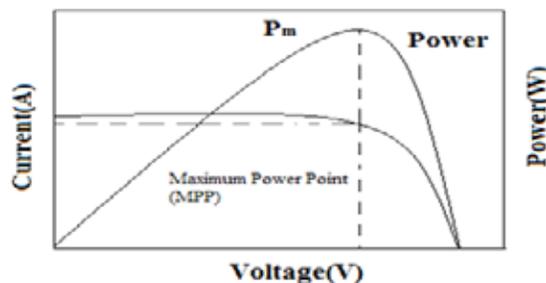

Fig.2 General I-V and P-V Characteristics of PV cell

III Factors affecting efficiency of solar panel
1 Cell Temperature

As temperature increases, the band gap of the intrinsic semiconductor shrinks, and the open circuit voltage (*V OC*) decreases following the p-n junction voltage temperature dependency of seen in the diode factor q/kT . Solar cells therefore have a negative temperature coefficient of *V OC* (β). Moreover, a lower output power results given the same photocurrent because the charge carriers are liberated at a lower potential. Using the convention introduced with the Fill Factor calculation, a reduction in *V OC* results in a smaller theoretical maximum power *max P = I SC * V OC* given the same short-circuit current *I SC* [8]. As temperature increases, again the band gap of the intrinsic semiconductor shrinks meaning more incident energy is absorbed because a greater percentage of the incident light has enough energy to raise charge carriers from the valence band to the conduction band. A larger photocurrent results; therefore, Isc increases for a given insolation, and solar cells have a positive temperature coefficient of *I SC* (α) [8].

Temperature effects are the result of an inherent characteristic of crystalline silicon cell-based modules. They tend to produce higher voltage as the temperature drops and, conversely, to lose voltage in high temperatures. Any solar panel or system derating calculation must include adjustment for this temperature effect [10].

2 Energy Conversion Efficiency
A solar cell's energy conversion efficiency (η, "eta"), is the percentage of power converted (from absorbed light to electrical energy) and collected, when a solar cell is connected to an electrical circuit. This term is calculated using the ratio of the maximum power point, Pm, divided by the input light irradiance (E, in W/m2) under standard test conditions and the surface area of the solar cell (Ac in m2) [11].

$\eta = Pm/ExA$

The efficiency of energy conversion is still low, thus requiring large areas for sufficient insulation and raising concern about unfavorable ratios of energies required for cell production versus energy collected [12]. In order to increase the energy conversion efficiency of the solar cell by reducing the reflection of incident light, two methods are widely used. One is reduction of the reflection of incident light with an antireflection coating, and the other is optical confinements of incident light with textured surfaces. They showed that the transformation of the wavelength of light could significantly enhance the spectral sensitivity of a silicon photodiode from the deep UV and through most of the visible region. [13].

The solar module has a different spectral response depending on the kind of the module. Therefore, the change of the spectral irradiance influences the solar power generation [14]. The solar spectrum can be approximated by a black body of 5900 K which results in a very broad spectrum ranging from the ultraviolet to the near infrared. A semiconductor, on the other hand can only convert photons with the energy of the band gap with good efficiency.

Photons with lower energy are not absorbed and those with higher energy are reduced to gap energy by thermalization of the photo generated carriers.

IV Control Algorithm for MPPT
A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the solar panel. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence our problem of tracking the maximum power point reduces to an impedance matching problem.

In the source side we are using a boost convertor connected to a solar panel in order to enhance the output voltage so that it can be used for different applications like motor load. By changing the duty cycle of the boost converter appropriately we can match the source impedance with that of the load impedance.

Different MPPT techniques
There are different techniques used to track the maximum power point. Few of the most popular techniques are:

1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method

3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic

The choice of the algorithm depends on the time complexity the algorithm takes to track the MPP, implementation cost and the ease of implementation.

1 Perturb & Observe
Perturb & Observe (P&O) is the simplest method. In this we use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPP. To avoid this problem we can use incremental conductance method.

2 Incremental Conductance
Incremental conductance method uses two voltage and current sensors to sense the output voltage and current of the PV array. At MPP the slope of the PV curve is 0.

$(dP/dV)MPP = d(VI)/dV$

$0 = I + VdI/dVMPP$

$dI/dVMPP = - I/V$ $\qquad$ (1.6)

The left hand side is the instantaneous conductance of the solar panel. When this instantaneous conductance equals the conductance of the solar then MPP is reached.

Here we are sensing both the voltage and current simultaneously. Hence the error due to change in irradiance is eliminated. However the complexity and the cost of implementation increases. As we go down the list of algorithms the complexity and the cost of implementation goes on increasing which may be suitable for a highly complicated system. This is the reason that Perturb and Observe and Incremental Conductance method are the most widely used algorithms. Owing to its simplicity of implementation we have chosen the Perturb & Observe algorithm for our study among the two.

3 Fractional open circuit voltage
The near linear relationship between VMPP and VOC of the PV array, under varying irradiance and temperature levels, has given rise to the fractional VOC method.

$VMPP = k1 Voc$ $\qquad$ (1.7)

where k1 is a constant of proportionality. Since k1 is dependent on the characteristics of the PV array being used, it usually has to be computed beforehand by empirically determining VMPP and VOC for the specific PV array at different irradiance and temperature levels. The factor k1 has been reported to be between 0.71 and 0.78. Once k1 is known, VMPP can be computed with VOC measured periodically by momentarily shutting down the power converter. However, this incurs some disadvantages, including temporary loss of power. [15].

4 Fractional short circuit current

Fractional ISC results from the fact that, under varying atmospheric conditions, IMPP is approximately linearly related to the ISC of the PV array.

$$IMPP = k2 \; Isc \qquad (1.8)$$

where k2 is a proportionality constant. Just like in the fractional VOC technique, k2 has to be determined according to the PV array in use. The constant k2 is generally found to be between 0.78 and 0.92. Measuring ISC during operation is problematic. An additional switch usually has to be added to the power converter to periodically short the PV array so that ISC can be measured using a current sensor[15].

5 Fuzzy Logic Control

Microcontrollers have made using fuzzy logic control popular for MPPT over last decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity [15].

6 Neural Network

Another technique of implementing MPPT which are also well adapted for microcontrollers is neural networks. Neural networks commonly have three layers: input, hidden, and output layers. The number nodes in each layer vary and are user-dependent. The input variables can be PV array parameters like VOC and ISC, atmospheric data like irradiance and temperature, or any combination of these. The output is usually one or several reference signals like a duty cycle signal used to drive the power converter to operate at or close to the MPP [15].

V Conclusion

This paper examine factors that affecting efficiency of solar cells. Temperature effects are the result of an inherent characteristic of solar cells. They tend to produce higher voltage as the temperature drops and, conversely, to lose voltage in high temperatures. The function of the maximum power tracker is to change the equivalent load take by the solar cell array, and adjust the working point of the array, in order to improve the efficiency. So different MPPT techniques also discussed in this paper. The optimum factors make it possible to get the great benefits of solar electricity at a much lower cost.

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