

Studying the effect of shading on Solar Panel using MATLAB

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ABSTRACT

Renewable energy sources plays an important role in electricity generation. Various renewable energy sources like wind, solar, geothermal, ocean thermal, and biomass can be used for generation of electricity and for meeting our daily energy needs. Energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness. Solar Photovoltaic (PV) array converts the solar energy into electrical energy. The performance of Photovoltaic array is affected by solar isolation, shading, temperature and this will result in displacement of the Maximum Power Point(MPP). The output characteristics show the multiple maxima point. To get the maximum efficiency from Shaded Photovoltaic (PV) array, it is import to track the GPP from the various local maxima. This paper makes a study on the various Maximum Power Point Tracker (MPPT) for Photovoltaic (PV) array. Also this paper explains the effect of change in solar isolation and temperature and shading effect on solar panel and give the steps to track GPP.

Keywords: Photovoltaic, Maximum Power Point Tracker, Solar Photovoltaic, Maximum Power Point

1. INTRODUCTION

Solar energy is one the most effective, less expensive, harmless and less environmental pollution effect of renewable energy sources. The utilization of solar energy can be categorized in two ways: solar heating/cooling and solar electricity. This energy can be converted into electrical energy through implementation of photovoltaic array[1]. Recently, Photovoltaic (PV) systems application is well recognized and widely used in electric power technologies. Many applications regarding to this technology have been developed such as solar power generation, solar vehicle

construction, battery charging, water pumping, satellite power system and so on.

Unfortunately, PV system has its own drawbacks, which are mainly due to high fabrication cost and low energy conversion. It is caused by their nonlinear, isolation level and temperature-dependent of Current-voltage (I-V) and Power Voltage (P-V) characteristics. To tackle these problems, three essential approaches have been developed.

They are:

- 1) Improving manufacturing process of solar array.
- 2) Controlling the isolation input to PV array; the input of solar energy is maximized using sun-tracking solar collector.
- 3) Utilization of output solar arrays electric power [3].

The nonlinear variations of output voltage and current that depends on solar-radiation levels, operating temperature, and load current to cause in low electrical efficiency. To solve these problems, by utilizing approach, the maximum power point of the PV system (at given condition), is tracked using offline or online algorithms where the system operating point is forced toward optimal condition. To obtain the maximum power from PV array, a Maximum Power Point Tracker (MPPT) is applied. Thus, there are some techniques used to track the maximum power point, which is known as "look-up table" methods; "Perturbation and Observation (P%O)", "Modified P & O"& "Estimate perturb-perturb" methods [1][2].

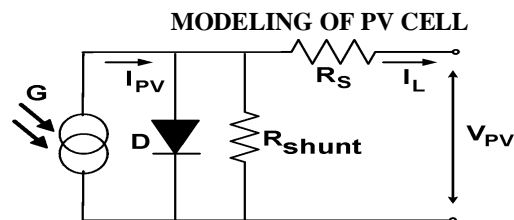


Figure1: Equivalent circuit of a solar cell

The solar cell can be represented by the electrical model shown in Figure 1. Its current voltage characteristic is expressed by the following equation (1):

$$I = I_L - I_0 \left[e^{\frac{q(V-IR_S)}{AKT}} - 1 \right] - \frac{V - IR_S}{R_{SH}} \quad (1)$$

where I and V are the solar cell output current and voltage respectively, I_0 is the dark saturation current, q is the charge of an electron, A is the diode quality (ideality) factor, k is the Boltzmann constant, T is the absolute temperature and R_S and R_{SH} are the series and shunt resistances of the solar cell. R_S is the resistance offered by the contacts and the bulk semiconductor material of the solar cell. The origin of the shunt resistance R_{SH} is more difficult to explain. It is related to the non ideal nature of the p-n junction and the presence of impurities near the edges of the cell that provide a short-circuit path around the junction [1]. In an ideal case R_S would be zero and R_{SH} infinite. However, this ideal scenario is not possible and manufacturers try to minimize the effect of both resistances to improve their products [2].

2. PHOTOVOLTAIC ARRAY

PV cells are made of semiconductor materials, such as silicon. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current - that is, electricity. This electricity can then be used to power a load.

Due to the low voltage generated in a PV cell (around 0.5V), several PV cells are connected in series (for high voltage) and in parallel (for high current) to form a PV module for desired output, as shown in Figure 2 [1].

The power that one module can produce is not sufficient to meet the requirements of home or business. Most PV arrays use an inverter to convert the DC power into alternating current that can power the motors, loads, lights etc. The modules in a PV array are usually first connected in series to obtain the desired voltages; the individual modules are then connected in parallel to allow the system to produce more current [2].

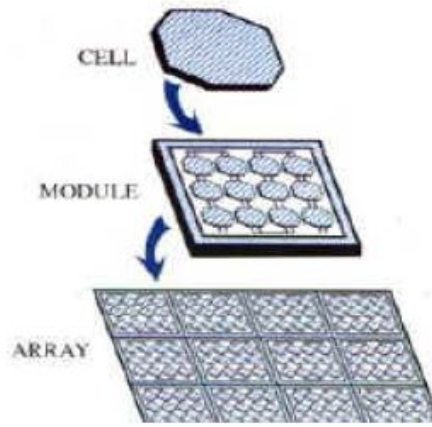


Figure 2: Photovoltaic system

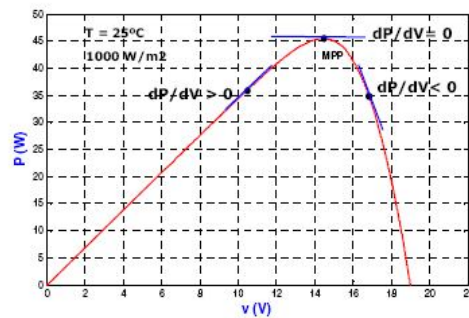


Figure 3: Important points in the characteristic curves of a solar panel

2.1 Efficiency of PV Cell

The efficiency of a PV cell is defined as the ratio of peak power to input solar power.

$$n = \frac{V_{mp} I_{mp}}{I \left(\frac{KW}{m^2} \right) \cdot A \left(m^2 \right)} \quad (2)$$

where, V_{mp} is the voltage at peak power, I_{mp} is the current at peak power, as shown in Figure 3, I is the solar intensity per square metre, A is the area on which solar radiation fall.

The efficiency will be maximum if we track the maximum power from the PV system at different environmental condition such as solar irradiance and temperature by using different methods for maximum power point tracking.

3. EFFECT OF IRRADIANCE & TEMPERATURE EFFECT ON VI CHARACTERISTICS

Two important factors that have to be taken into account are the irradiation and the temperature. They strongly affect the characteristics of solar modules. As a result, the MPP varies

during the day and that is the main reason why the MPP must constantly be tracked and ensure that the maximum available power is obtained from the panel. The effect of the irradiance on the voltage-current (V-I) and voltage-power (V-P) characteristics is depicted in Figure 4, where the curves are shown in per unit, i.e. the voltage and current are normalized using the V_{OC} and the I_{SC} respectively, in order to illustrate better the effects of the irradiance on the V-I and V-P curves.

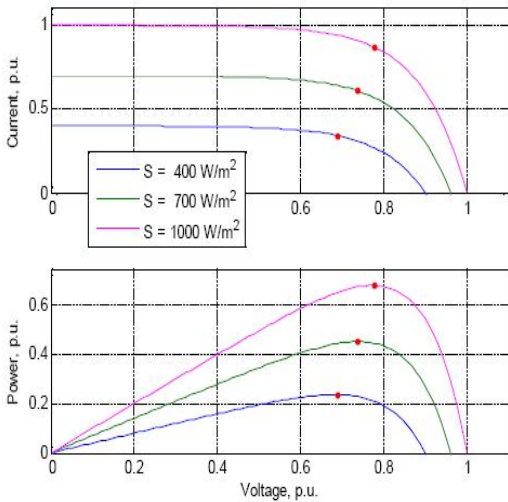


Figure 4: V-I and V-P curves at constant temperature (25°C) and three different insolation values

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4. MAXIMUM POWER POINT TRACKER

As we have seen in the above section, the operating point at maximum power in systems based on PV modules depends on solar-radiation level, operating temperature and load current. So that’s the reason to develop control algorithms in order to ensure that operating point achieves its optimal value. MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

4.1 Perturb & Observe technique

P&O technique has been selected to implement a MPPT control algorithm due to its simplicity and the possibility to introduce improvements. As it can be seen in Fig and Fig. the point of maximum power (MPP) depends on the radiation level and temperature, so the system is not linear and time-variable. That’s the reason to implement the control based on the achievement of $dP/dV = 0$ that always is related to the MPP [5][8]

In this control algorithm PV-output voltage (V_k) and PV output current (i_k) are sensed. Then power is calculated (p_k) and compared with the power value calculated in the previous sample (p_{k-1}) in order to get Δp_k . If the result of Δp_k is zero the system is working in MPP. Otherwise and according to the sign of Δp_k and to the sign of Δv_k the command voltage to control the duty cycle (δ) of the converter (let’s say the perturbation), will be decreased or increased in order to force the working point of the PV module towards the MPP. The algorithm is illustrated in the flowchart shown in Figure 5 and summary of the steps are given in Table 1.

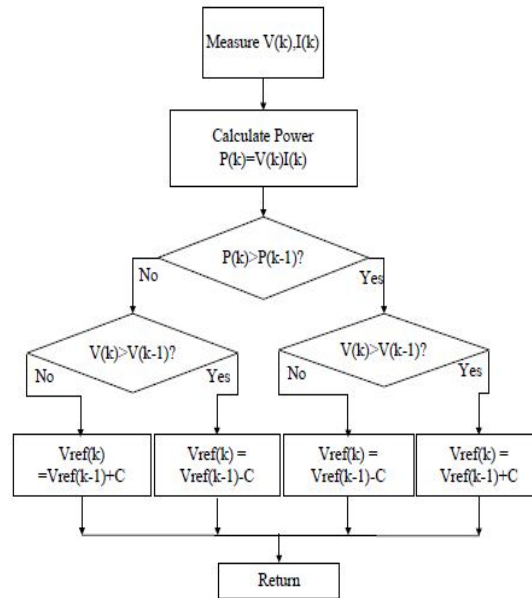


Figure 5: P&O algorithm flowchart

Table 1: Summary of P&O Algorithm Cases

Case	Conditions	Position	Control action
1	$\Delta p_k > 0, v_k > 0$	Left of MPP	Increase δ
2	$\Delta p_k > 0, v_k < 0$	Right of MPP	Decrease δ
3	$\Delta p_k < 0, v_k > 0$	Right of MPP	Decrease δ
4	$\Delta p_k < 0, v_k < 0$	Left of MPP	Increase δ

4.2 MPP Tracking using P&O method

Using the steps shown in the Table 1 , following Matlab code is developed for δ ,which will decide the step size of Vref.

Matlab routine used to set Vref using δ is given below-

```

if deltaPa > 0
    if Va_new > Va
        Vref_new = Va_new + C;
    else
        Vref_new = Va_new - C;
    end
else
    if deltaPa < 0
        if Va_new > Va
            Vref_new = Va_new - C;
        else
            Vref_new = Va_new + C;
        end
    else
        Vref_new = Va_new; % No change
    end
End
    
```

Insolation level used for this program varies from 0.2 to 1Mw/m² with the step size 0.2. The red mark show the MPPT tracked using the P& O algorithm. If the variation in the insolation (G) is very fast then this algorithm fails to track the MPPT. This is shown in Figure 6.

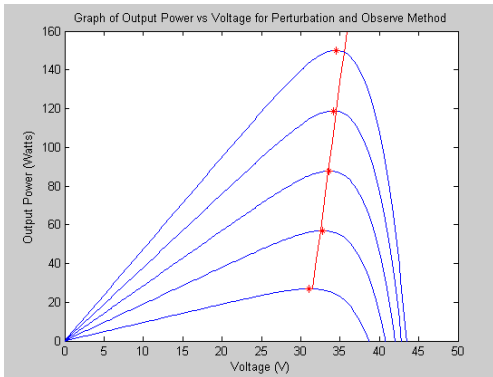


Figure 6: Matlab output of P&O Algorithm

4.3 Incremental Conductance Algorithm

This method uses the source incremental conductance method as its MPP search algorithm. It is more efficient than Perturb and Observe method and independent on device physics. The output voltage and current from the source are monitored upon which the MPPT controller relies to calculate the conductance and incremental conductance, and to make its decision (to increase or decrease duty ratio output).

Mathematical of the Incremental Conductance algorithm is discussed below-

The output power from the source can be expressed as

$$P = V \cdot I$$

The fact that $P = V \cdot I$ and the chain rule for the derivative of products yields[5][8]

$$\begin{aligned} dP/dV &= d(V I) / dV \\ &= I dV / dV + V dI / dV \\ &= I + V dI / dV \end{aligned}$$

$$(1/V) dP/dV = (I/V) + dI/dV$$

Let's define the source conductance:

$$G = I/V$$

And the source incremental conductance:

$$\Delta G = dI/dV$$

In general output voltage from a source is positive. The operating voltage is below the voltage at the maximum power point if the conductance is larger than the incremental conductance, and vice versa. The job of this algorithm is therefore to search the voltage operating point at which the conductance is equal to the incremental conductance. From the Figure 7, the steps of this algorithm is-

- $dP/dV > 0$, if $G > \Delta G$
- $dP/dV = 0$, if $G = \Delta G$
- $dP/dV < 0$, if $G < \Delta G$

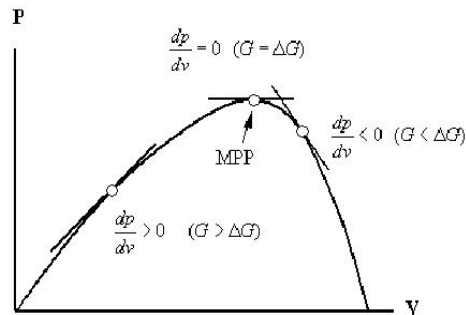


Figure 7: Tracking of MPP using IncConductance Algorithm

Algorithm is implemented using the Matlab code the different level of insolation is used in this program. The output is shown below in Figure 8-

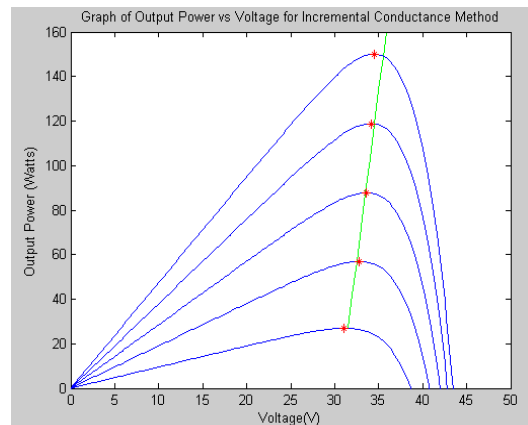


Figure 8: Matlab output of Inc. Conductance Algorithm

5. SHADING ON SOLAR PANEL

The solar cell is the semiconductor device that directly converts the light energy to the electrical energy. A solar cell has nearly the same behavior as a diode. Specifically, the output power of a solar array strongly depends on the irradiance level of sunlight and ambient temperature. The most conventional model of a solar cell is the one diode model.

In uniform solar insolation, the output power of the array is equal the total output power of all solar cells. But in non uniform insolation condition, as shown in Figure 9, i.e. shadow on the solar panel, the shaded solar module starts working as a load, which can be avoided by using the bypass and blocking diode. The cause of non-uniform insolation may be shadows from trees, a neighbor's houses, or even a shadow of one solar array to the other one. These sources of shadow can be separated as soft and hard sources, depending upon their distance from solar panel [9][10].

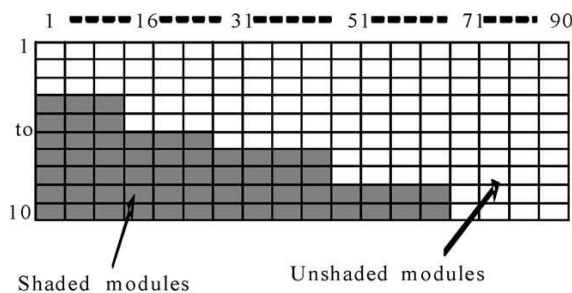


Figure 9: Shading on the Solar Panel[11]

If a tree branch, roof vent, chimney or other item is shading from a distance, the shadow is diffuse or dispersed. These soft sources significantly reduce the amount of light reaching the cell(s) of a module [11].

Hard sources are defined as those that stop light from reaching the cell(s), such as a blanket, tree branch, bird dropping or the like, sitting directly on top of the glass.

5.1 Effect of Shading on Solar Panel

If even one full cell is hard shaded, the voltage of that module will drop to half of its un-shaded value in order to protect itself. If enough cells are hard shaded, the module will not convert any energy and will in fact become a tiny drain of energy on the entire system. 80% power losses is recorded because of shading [10].

The effect of shading is occurrence of multiple local maxima points (MPPT), as shown in Figure 10. The algorithm which were discussed used before cannot be applied, the algorithm stops when they get first local maximum point, but we have

to track the Global Power Point (GPP), which requires the differ approach. The GPP is shown in red star in the Figure 9.

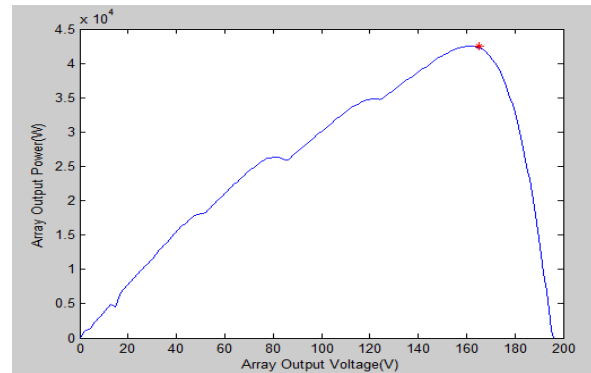


Figure 10: Matlab output showing the effect of Shading on Solar Panel

6. STEPS USED TO TRACK THE GPPT

Step1: Set the Verf at 80% of Voc

Step2: Call the P&O routine to search for first Local Maxima.

Step3: Store the value Pmpp and Vmpp and set the flag=1

Step4: Calculate ΔP .

Step5: If $\Delta P > \Delta P_{crit}$ then call the GPP tracking subroutine ($\Delta P_{crit}=0.01$, to note the change of power and existence of another local maxima)

Step6: Check the flag, if ==1, then left side of the curve is traced fro local maxima else the right side.

Step7: Call the p & O subroutine to track the next local maxima.

Step8: Store the value Pmpp and Vmpp and compare it with the last value.

Step9: If the value is less, then the last maxima is at higher level than the current, store the last value and set the flag=1

Step10: If the difference is large, then this will be considered as the new maxima and flag=-1 is set, to search the right hand side [12].

This algorithm will track the GPP and will use the flag to scan the curve is less time and track the GPP.

7. CONCLUSION

This paper discussed the Photovoltaic modeling and its characteristics at uniform insolation. And shows the effect of different insolation condition on V-I and V-P curves at constant temperature. The two Maximum Power Point Tracking algorithms where discussed, whose Matlab output is also given. The Power_Voltage curves show multiple peaks under partially shaded conditions. To track the Global Power Point, from the multiple maxima the steps are given. From these steps algorithm can be developed using SIMULINK.

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