MATLAB based modelling and maximum power point tracking (MPPT) method for photovoltaic system under partial shading conditions

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Abstract *- photovoltaic (PV) system essential to always track maximum power. Failure to track the maximum power (GMP) point under partial shaded conditions is one of the major reasons that lead to significant power losses. Many maximum power point {MPP} tracking methods have been proposed the deal with this problem. Partial shading, PV system there are multiple peaks on PV array's, output power-voltage (P-V) characteristic curve. Conventional maximum power point tracking {CMPP} methods are effective for single peak P-V characteristic & adaptive maximum power {AMPP} methods use in partial shading.*

MPP under different partial shading condition with and without bypass diodes Simulation and comparison results verify that the with bypass diodes MPP accurately, quickly and smoothly for complex multi-peak P-V characteristics. Comparison analysis results shading photovoltaic (PV) system is more effective for most shade types with bypass diodes.

Key Words: Maximum power point tracing (MPPT), DC to DC converter, Photovoltaic system, partial shaded conditions solar cell model.

1. INTRODUCTION

Photovoltaic (PV) power generation of infinite energy resources and no carbon dioxide (CO_2) emission [2].Photo-voltaic (PV) energy conversion systems maximum power point to increase the output efficiency of photovoltaic [3]. The output powers of PV system are mainly depending of the two variable factors, which are the solar irradiances and cell temperatures. Hence, different tracking control technique have been developed & implemented. The most common techniques that has been used such as Perturb and Observe (P&O), constant voltage , neural network and fuzzy logic [4]-[5]. At the same time, these techniques have some drawback such as fail performance due to partially shaded irradiance conditions, complexity and costly. The primary purpose of this project is to design the PV system to tracking the maximum power during shading condition.

During the cloudy day, the non-uniform insolation's lead to more complicate current-voltage (*I -V*) & power voltage (*P - V*) with multiples local maximum power point (MPP). Accordingly, the output power of PV modules dropped because of the mismatching of current-voltage (I-V) characteristic of PV modules[1]. The controller also is hard to look for the maximum power point (MPP) due to multiple MPP appear during partially shaded conditions. Consequently, it is essentially to develop a suitable MPPT controller to solve this issue. To achieve the objective of this paper, MATLAB/SIMULINK software is used to analysis the MPPT for photovoltaic system. This paper is to analyze and compares the simulation result of two intelligent systems with and without bypass diode.

Fig.1.1: Partially shaded Solar panels

2. Mathematical model of PV array

The PV array is composed of PV system connected in series and parallel in order to obtain the desired voltage and current. A PV array configuration is shown in Fig.2.1, which is described as m* n PV array. To protect system from the hot-spot problem, a bypass diode (Ds) is connected in parallel with each PV module. Meanwhile, a blocking diode (Dp) is connected in series with each string to protect the system from the effect of potential difference between series-connected strings. Compared with open circuit voltage V_{oc} and short circuit current I_{sc} (several A) of ordinary PV module, the small break over voltage and leakage current of bypass/blocking diodes are neglectable[6]. Therefore, the ideal diode characteristic is adopted in following analysis. A mathematical model of each string of PV modules can be described as follows:

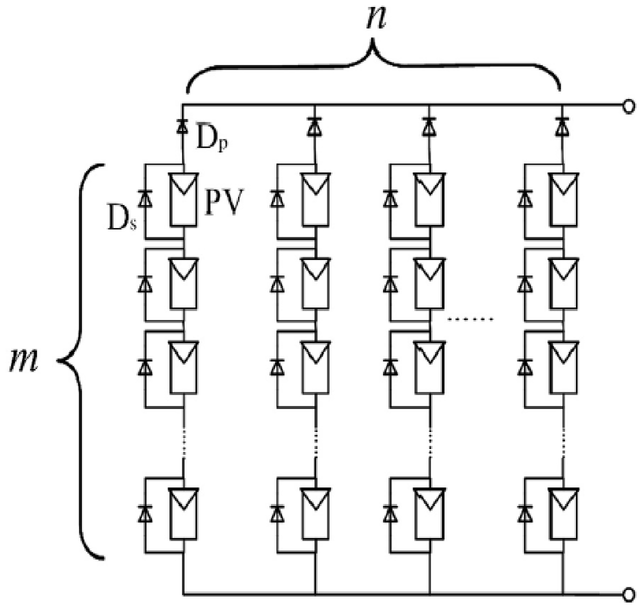


Fig.2.1: Configuration of the PV array with bypass diodes (Ds) and blocking diodes (Dp).

Diode PV cell is shown in Fig.2.2.Equation (4) shows the output current-voltage characteristic of an ideal PV cell in a single diode model[7].

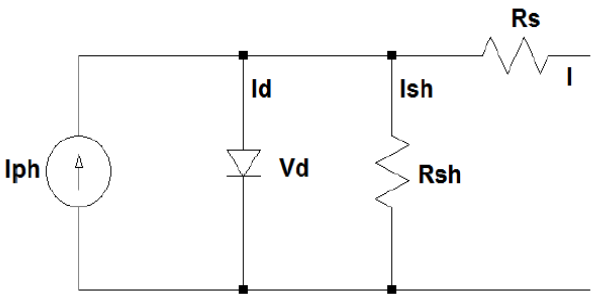


Fig.2.2: Solar cell equivalent circuit

The equation is solved by designing a program in MATLAB, taking into account the number of solar cells which has the photovoltaic panel. The main equation is shown as in equation.

$$I_{ph} = (G/G_{ref})\,[I_{sc} + Ki\,(T-25)] \quad (1)$$

$$Ir = I_{rT1}\,(Ta/Tref1)^{3/A} \times e^{\left[-b\left(\frac{1}{Tref}-\frac{1}{T}\right)\right]} \quad (2)$$

The photocurrent Iph is directly proportional to solar radiation IRA which taking into account a constant of proportionality ,according to the eqn 2. The terms of reference are solar radiation (IRA= 1 sun = 1000 W/m^2) and temp (T=25 C)

$$Ir_{-T1} = I_{SCT1}/\left(\frac{Voc}{_{e}AVt_1}\right) \quad (3)$$

$$I_{pv} = I_{ph} - I_r[\exp\{q\,(V_{pv}+I_{pv}Ra)/AkT\}]-1]-(V_{pv}+IR_a)/Rsh \quad (4)$$

Where b= Vg*q/ (A*k)

Vg is the diode voltage which is equal to 1.12 V for crystalline silicon < 1.75 V for amorphous silicon.

3. Maximum power point tracking

Maximum power point tracking, frequently referred to as MPPT is a electronic system that operates the photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different[6].

To understand how MPPT works, let's first consider the operation of a conventional (non- MPPT) charge controller. When a conventional controller is charging a discharged battery, it simply connects the modules directly to the battery. This forces the modules to operate at battery voltage, typically not the ideal.

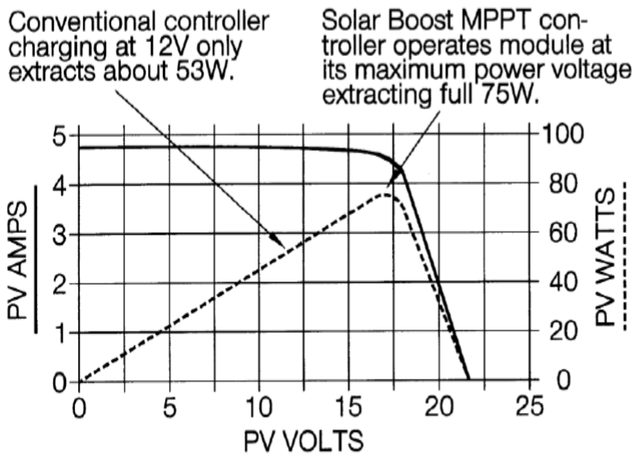


Fig. 3.1: I-V curve & power output for a PV module.

3.1 Incremental conductance method

The main principle of the IncCond method is that the derivative of the output power, P, in terms of voltage, V, at

the peak power point is equal to zero (dP/dV= 0). Therefore, from the equation P=IV, the following equation is obtained: [12]
(at the MPP).

$$\frac{dP}{dV} = V\frac{dI}{dV} + I = 0 \quad \text{(at the MPP)} \qquad 3.1$$

Therefore, within one sampling period, Eq. can be rewritten as:

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \qquad 3.2$$

Eq. (3.2) means that, at the MPP, the opposite of the instantaneous conductance of PV array on the left side of the equation equals the incremental conductance on the right hand side. Thus, the derivative of the points should be greater than zero on the left of the MPP (point G as shown in Fig. 2.7), while, less than zero on the right side. It is illustrated as follows:

$$\text{If } \frac{dP}{dV} = 0 \ \left(\frac{dI}{dV} = -\frac{I}{V}\right), \text{then MPP is reached.} \qquad 3.3$$

$$\text{If } \frac{dP}{dV} < 0 \ \left(\frac{dI}{dV} < -\frac{I}{V}\right), \text{then decrease Vref.} \qquad 3.4$$

$$\text{If } \frac{dP}{dV} > 0 \ \left(\frac{dI}{dV} > -\frac{I}{V}\right), \text{then increase Vref.} \qquad 3.5$$

By comparing the incremental conductance ($\Delta I/\Delta V$) with the instantaneous conductance (I/V), the MPP can be tracked. The basic flowchart of IncCond is shown in Fig.3.3. The algorithm starts with the sensed voltage and current values and calculates the voltage and current changes compared to the previous step. The direction of the voltage movement in the next step depends on the comparison between the result of incremental conductance ($\Delta I/\Delta V$) and the instantaneous conductance (I/V). If the voltage and current changes are both measured to be zero, then keep the present voltage and current values for the calculation in the next step. If the voltage change value is measured to be zero and the current change is non-zero, then the voltage change direction in the next step is to increase the voltage when ΔI is larger than zero or reduce the voltage when ΔI is less than zero. Otherwise, the voltage direction is changed according to Eqs. (3.4) and (3.5).

Some studies have compared the efficiency of the IncCond and P&O algorithms, [and shown that IncCond has a better efficiency than that of P&O. Even though the efficiency of these two methods are similar, the main disadvantage of both methods is the power loss due to oscillations around the MPP, the slow tracking speed when choosing a small perturbation step, and the failure to track the global MPP on the P-V characteristic curve under partially shaded conditions. Although these two MPPT methods are not so efficient under partially shaded and rapidly changing irradiance conditions, they act as good basic algorithms for comparison purposes when investigating global MPP tracking[1].

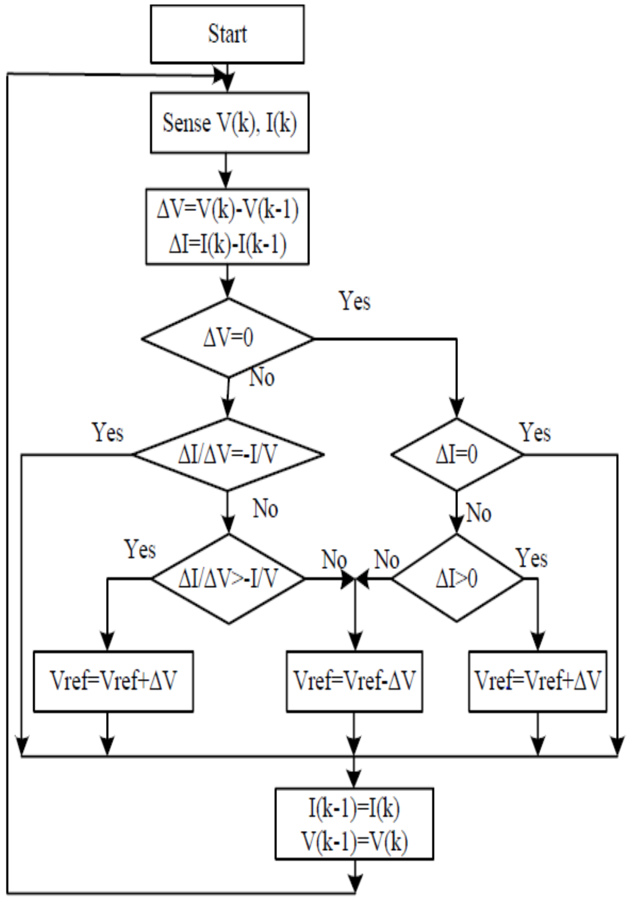


Fig.3.3:The flow chart of the incCond algorithm

4. DC-DC (Buck/Boost) Converter

4.1. Buck Converter

The buck converter is also known as the step down converter. It can be used in the cases where the output voltage (battery) required is less than or equal the input voltage (solar array voltage), and output current is larger than the input current, the power flow is controlled by adjusting the on/off duty cycle of the switching where the relation between input and output voltage are accounted by the conversion ratio $\mu = Vo/Vi$,

$$\mu = \frac{Vo}{Vi} = \frac{t_{on}}{T} = D \qquad 4.1$$

Where t_{on} refer to the duration that the switch is active and T is the switching period where it's constant. In PV applications, the buck type converter is usually used for charging batteries, and for water pumping systems.

4.2. Boost Converter

The boost converter is also known as the step-up converter. It can be used in the cases where the output voltage greater than the input voltage, essentially functioning like are versed buck converter. The practical applications which use a boost type converter appear in grid systems.

$$\mu = \frac{Vo}{Vi} = T/T_{off} = \frac{1}{1-D} \qquad 4.2$$

Where t_{off} is the duration that the switch is not active.

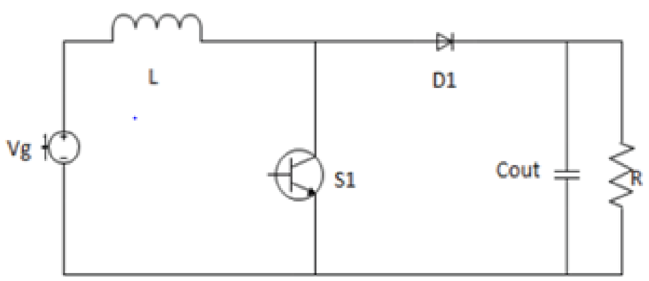


Fig 4.1: Boost converter

4.2.1 Mode of operation

There are two modes of operation of a boost converter. Those are based on the closing and opening of the switch.the first mode is when the switch is closed. This is known as the charging mode, second mode is when the switch is open known as discharging mode.

➢ **Charging mode of the Boost converter**

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.

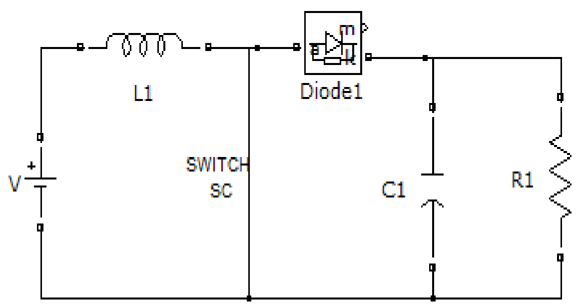


Fig 4.2: Mode-1 Boost converter when switch is closed

➢ **Discharging mode of the Boost Converter**

When the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation.

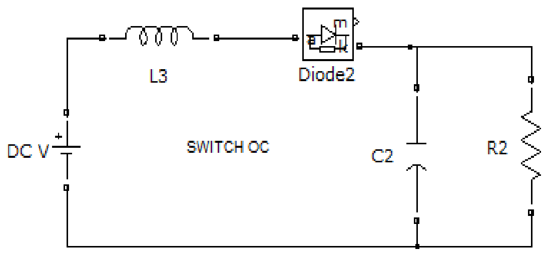


Fig.4.3: Mode-2 Boost converter when switch is open

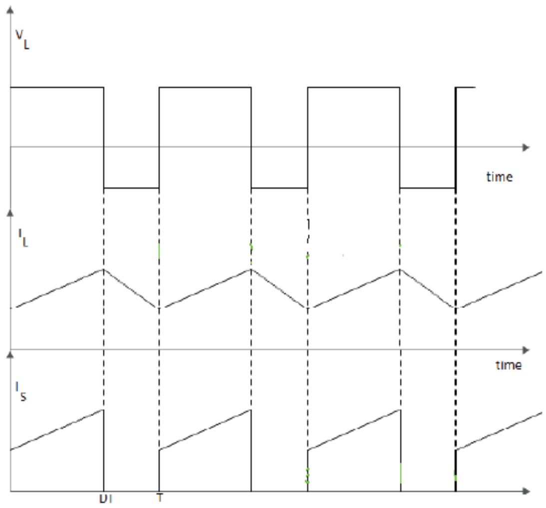


Fig.4.4: Waveform of Boost converter

5. Result & analysis

5.1 Simulink Mathematical model

Figure.4 shows the PV module implement using Matlab program, the model parameter are evaluated using equation above, the I-V characteristics and P-V characteristics curves obtained from the simulation for PV panel.

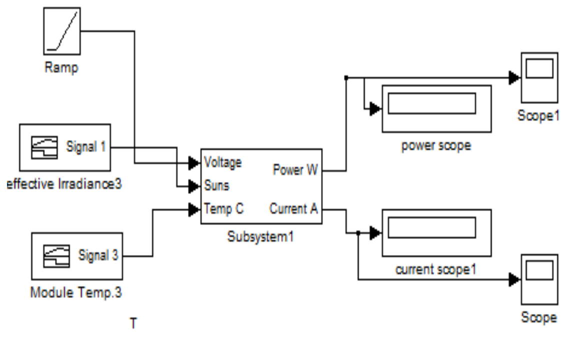


Fig 5.1: PV panel output current equations

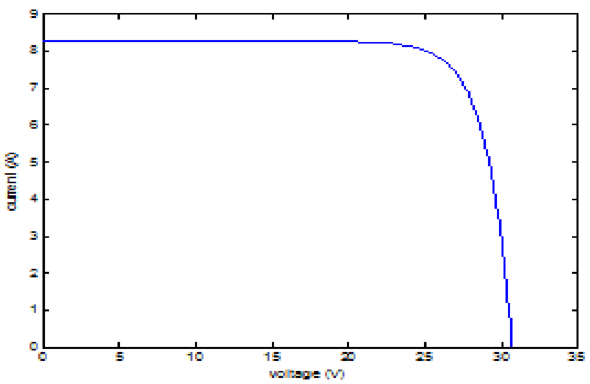


Fig.5.2: I-V curve in PV cell

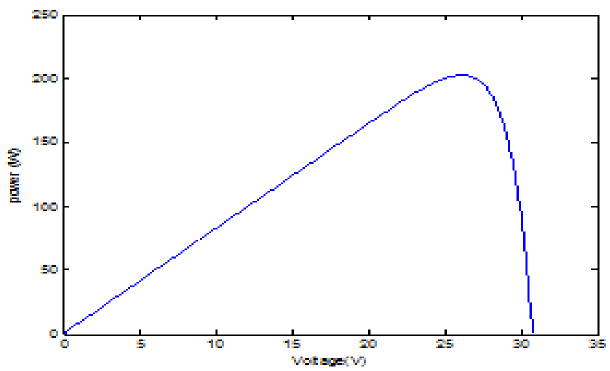


Fig.5.3: P-V curve in PV cell

5.2. Simulation of *PV* module with partial shading

A partially shaded module can be represented by, two groups of *PV* cells in series. Both groups receive different levels of irradiance. Fig.6.9 illustrates built diagram of *PV* array when, one of the *PV* modules under shading, condition equal to 50%. The output parameter for the solar panel with and without bypass diodes under different shading condition are summarized in Table 1.

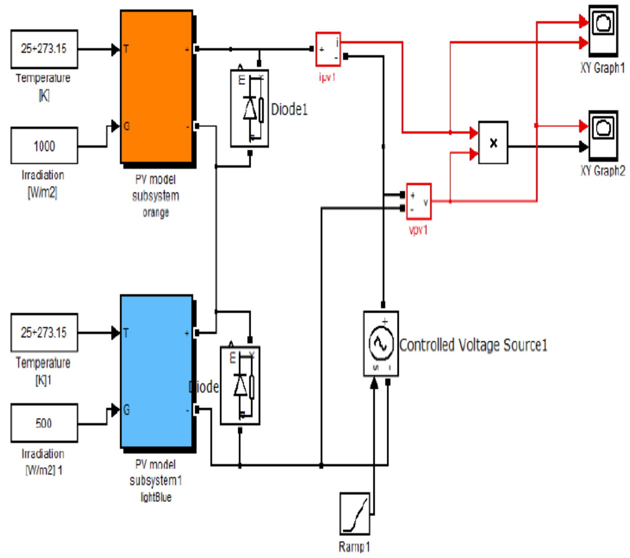


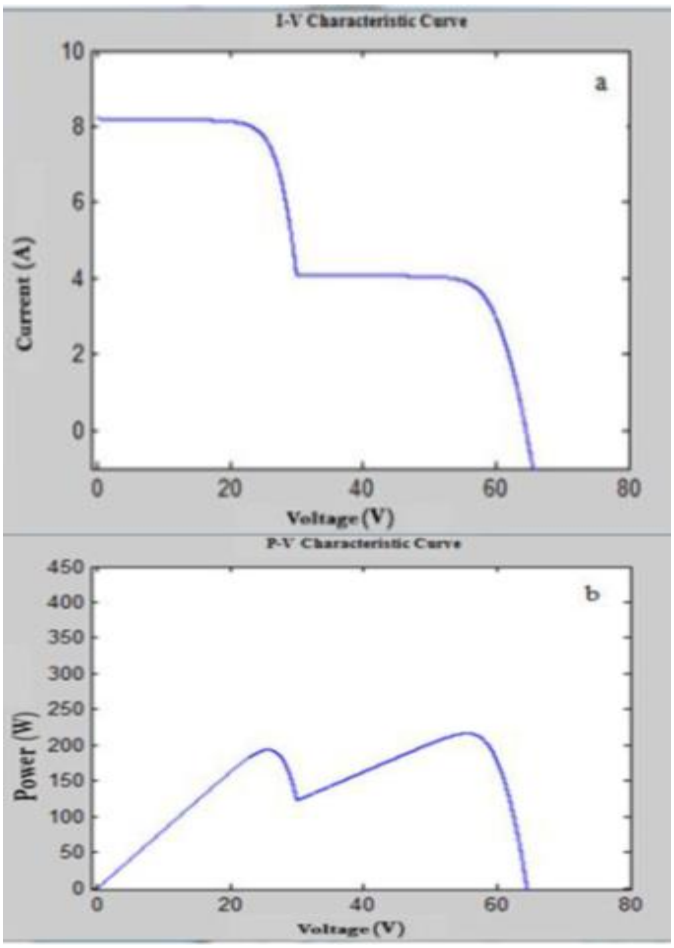
Fig.5.4: Simulation of two modules in series

Case	Cell-1 Irrad.	Cell-2 Irrad.	MPP W	V at MPP	I at MPP
1.	1000	500 With Bypass diode	217.5	55.4	3.93
2.	1000	500 Without Bypass diode	217.6	55.6	3.91
3.	1000	0 With Bypass diode	193.8	25.47	7.62
4.	1000	0 Without Bypass diode	0.45	16.63	.021
5.	500	0 With Bypass diode	94.88	24.77	3.83
6.	500	0 Without Bypass diode	0.415	15.6	.021

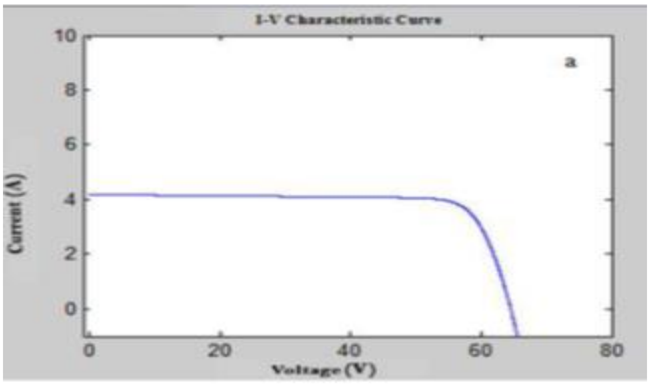
Table.1: MPP under different Partial shading condition with and without bypass diode

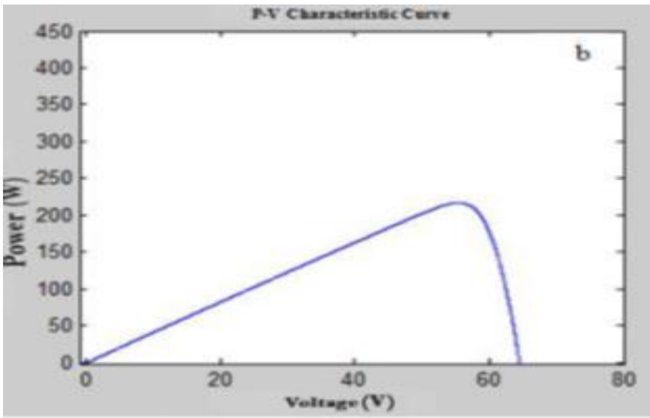
Analysis of all case in table.1 MATLAB/Simulink

Case.1. Partial irradiance (one cell with partial shading effect) and with bypass diode

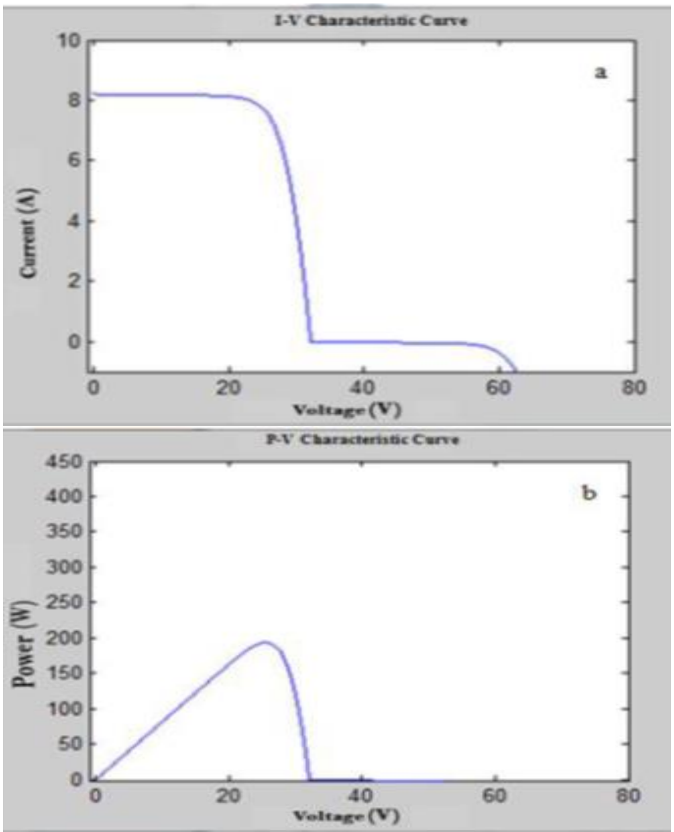


Case.2. Partial irradiance (one cell with partial shading effect) and without bypass diode

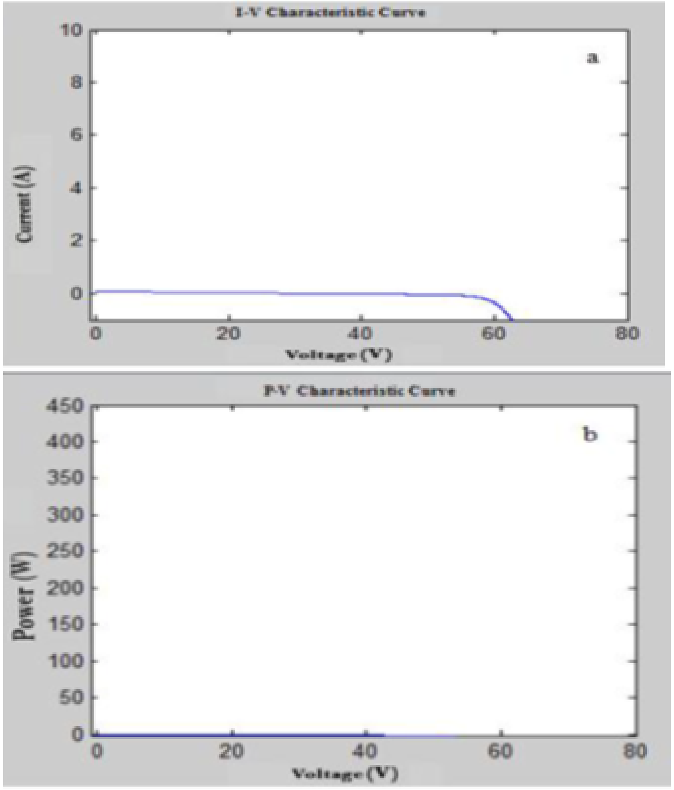




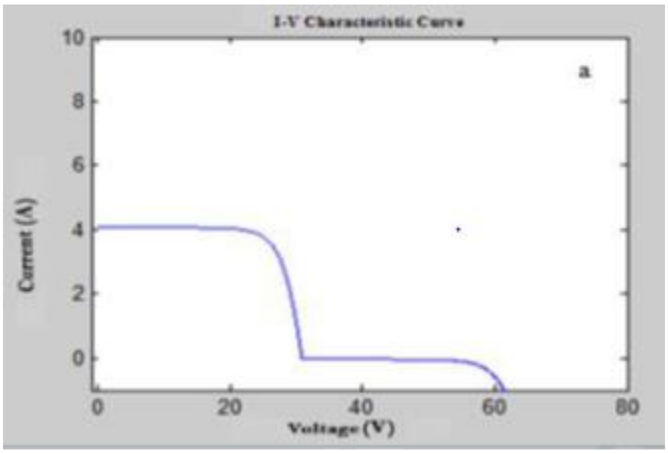
Case.3. Partial irradiance (one cell with full shading effect and second with full irradiance) and with bypass diode

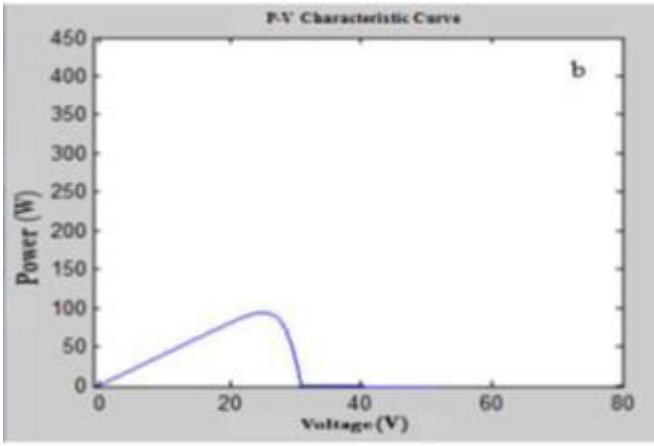


Case.4. Partial irradiance (one cell with full shading effect and second with full irradiance) and without bypass diode

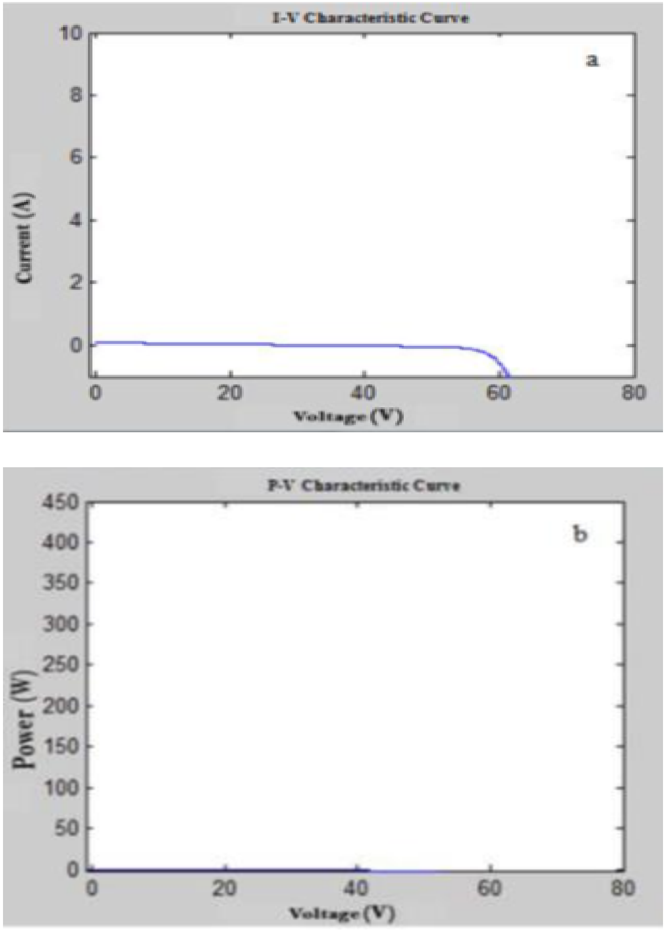


Case.5. Partial irradiance (one cell with partial shading effect and second with full shading) and with bypass diode





Case.6. Partial irradiance (one cell with partial shading effect & second with full shading) & without bypass diode



6. Conclusion

In this project we have considered two the series connection of two PV cells and by varying the irradiances of each cell partial and full shading can be demonstrated . The MPPT algorithm developed is implemented on this series

connection. On varying the Irradiances on the cells we can mimic the phenomena of partial shading. For no shading condition we have taken 1000 W/m^2 as the irradiance. Initially we consider that both the cells are under complete sun. In this case the maximum power obtained is found to be 400.2 W. After that when partial shading on one of the cells was provided in the form of 500 W/m^2 irradiance then the maximum power dropped down to 217 W. On increasing the shading on both the cells there was a further drop in the maximum power output. The obtained maximum power and their corresponding voltages are indicated in the table 1.
However the main drawback of the designed algorithm is that when the irradiance of one cell is made zero indicating that the cell is in complete darkness then the power output also goes to zero. This is due to the series connected nature of the cells. A bypass diode is connected across each PV cell which cuts off the cell under full shading and the MPPT algorithm is then executed for the remaining cells.

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