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Detailed Analysis of Three Diode Model of Solar Photovoltaic Cell with Maximum Power Point Tracking Algorithms

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***Abstract*—An innovation that directly changes free sunlight-based energy into electrical energy without making any contamination the climate is named as photovoltaic power generation. For the prediction of the conduct of a genuine solar cell under different ecological conditions and further to acquire its power-voltage and current-voltage characteristics curves, displaying of solar cell is fundamentally required. Numerous models have been proposed for the simulation of a solitary sunlight-based cell or for a total photovoltaic framework at different sun-oriented powers and temperature conditions. Subsequently, demonstrating of solar cell is fundamental for understanding its conduct under different atmospheric conditions. With the assistance of datasheet given by manufactures showing specifications of solar cell module and from set of non-linear conditions, different unknown parameters necessary for demonstrating are assessed and individual qualities have been created. This article presents a detailed analysis of a three diode model with a complete analysis of maximum power point tracking algorithms.**

***Index Terms*— Solar photovoltaic systems, maximum power point tracking algorithm, three diode model.**

Nomenclature:-

- I_{ph} **Photocurrent (A)**
- I_0 **Diode saturation current (A)**
- q **Electron charge, 1.6021 x 10^{-19}C**
- k **Boltzmann constant, 1.3865 x 10^{-23} J/K**
- T **Operating Temperature (Kelvin)**
- n **Diode factor ($1 \leq n \leq 2$)**
- G **Irradiance (W/m^2)**
- R_s **Series Resistance (Ω)**
- R_p. **Shunt Resistance (Ω)**
- n_s **Number of cells in series**
- V_{oc} **Open circuit voltage**
- I_{sc} **Short circuit current**
- V_{mp} **Voltage at the maximal power point**
- I_{mp}. **Current at the maximal power point**
- I_d. **Current through the diode**
- I **PV module current (A)**

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V	**PV module voltage (V)**
$\boldsymbol{E_g}$.	**Silicon gap energy of semiconductor**
$\boldsymbol{v_T}$	**Thermal voltage equivalent (V)**
STC	**Standard temperature condition**

I. INTRODUCTION

The MPPT controller is the device that controls the PV module in such a way that it extracts the maximum amount of power. The efficiency of the PV system is increased if the controller operates at MPP on purpose, regardless of the weather. To achieve optimum power generation, this should be possible by legitimately coordinating PV sources with loads in any climate situation. Mechanical and electrical monitoring are two methods for extracting full power from a PV array. The PV panel orientation varies with the months and seasons during the year in mechanical tracking, while the IV curve is used to locate MPP in electrical tracking. MPPT is a critical component of modern power systems, ensuring that the batteries/load/motors and the power grid receive the maximum power for on-grid and off-grid applications, respectively. The MPPT controller is widely used in PV plants because the conversion rate of solar energy to electrical energy in PV arrays is still poor and solar irradiance is not always uniform. Solar energy is abundantly available in nature. The solar photo voltaic cell (SPV) would capture the light energy from sun to electrical energy. Edmond bequerel was the first person to discover the photovoltaic effect. So he is named as father of PV cell [1-6]. How does a PV cell be made? Sand contains 99.99% pure silicon, when mixed with carbon and heated to 2000oc raw silicon on heating would turn into gaseous silicon. When gaseous silicon is mixed with hydrogen poly crystalline silicon ingots are formed and they are reshaped as thin films known as silicon wafers. The silicon is doped with phosphorous to get n-type layer and boron to form a p-type layer. Together form a P-N junction diode. In order to function a Diode as a PV cell bottom p-type layer is thick and lightly doped and top n-type layer is thin and heavily doped. When solar irradiance fall on the PV cell the valence electron from N (top) layer would flow from top layer to bottom layer and the current is produced in such a way [7-10].
The electrical equivalent of a PV cell as a single diode and two diode model is understood initially and it is later extended to three diode model alone.

A. Single Diode Model

This one is an identical circuit of a single diode PV cell. In numerous writings it is additionally named as a five boundary model. It considers various properties of solar cell as:
• RS is introduced as to consider the voltage drops and internal losses in because of flow of current.
• RP considers the leakage current to the ground when diode is reverse biased. But this model has dismissed recombination impact of diode, which is the reason it is as yet not the most precise model.

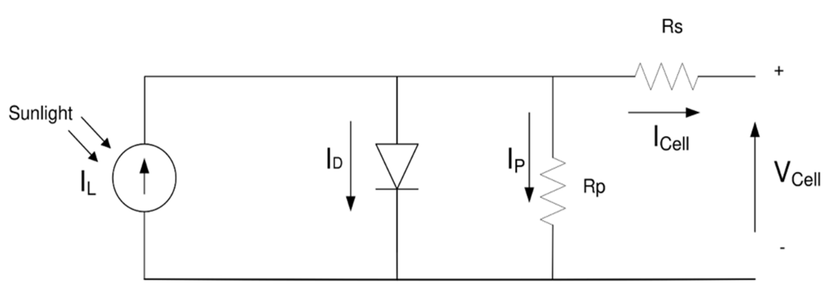

Figure 1. Single diode solar cell

$$V_T = \frac{N_S KT}{q} \quad (1)$$

$$I_{ph} = \left(\frac{G}{Gn}\right)[I_{pvn} + K1(T - T_n)] (2)$$

$$I = I_{ph} - I_0\left(e^{\frac{V+IR_S}{n_S V_T}} - 1\right) - \frac{V + IR_s}{R_p} \quad (3)$$

B. Two Diode Model

This is the advance type of single diode circuit which takes into account the results of recombination by adding another diode in equal. So, there will be two unknown diode quality variables. Consequently no. of conditions increments in this manner making estimations more intricate. At lower estimations of irradiance and low temperatures, two diode model gives significantly more precise curve attributes when compared with single diode model. So contemplating all perspectives, to the extent numerical calculation and number of cycles are concerned, single diode model ends up being quick outcomes because of less perplexing condition and furthermore computational blunders are less dissimilar to if there should be an occurrence of two-diode model. The single diode model can be reasonably utilized for power system planning purposes.

C. Mathematical Equation for Plotting I-V and P-V Curve

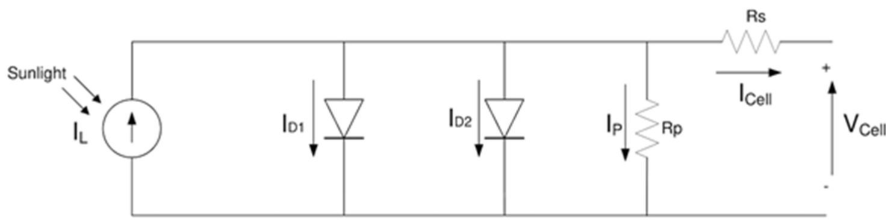

Figure 2. Double diode solar cell

As current through RP is less compared with rest of the currents, estimation of RP has been thought to be irrelevant for purpose of simplifying the calculation. The photocurrent and reverse saturation current are temperature dependent parameters as,

$$I = I_{ph} - I_{01}\left(e^{\frac{V+IR_s}{n_{s1}v_T}} - 1\right) - I_{02}\left(e^{\frac{V+IR_s}{n_{s2}v_T}} - 1\right) - \frac{V + IR_s}{R_p} \quad (4)$$

$$I_{ph} = (I_{ph})_{T1} + K_o(T - T_1) \quad (5)$$

Where, T_1 is a normal standard temperature.

$$(I_{ph})_{T_1} = (I_{sc})_{T_1}\frac{G}{G_{STC}} \quad (6)$$

$$K_O = \frac{(I_{sc})_{T_2} - (I_{sc})_{T_1}}{T_2 - T_1} \quad (7)$$

The cell photocurrent is directly relative to irradiance. Despite the fact that cell execution doesn't degrade significantly yet PV cell effectiveness relies upon incident solar energy.

$$I_o = (I_o)_{T_1} \times (\frac{T}{T_1})^{3/n} \times e^{\frac{q(E_g)_{T_1}}{nk}(\frac{1}{T} - \frac{1}{T1})} \quad (8)$$

$$(I_o)_{t_1} = \frac{(I_{sc})_{T_1}}{\left(e^{\frac{q(V_{OC})_{T_1}}{nkT_1}} - 1\right)} \quad (9)$$

The series resistance can be estimated through,

$$R_s = -(\frac{dV}{dI})_{V_{oc}} - \frac{1}{X_v} \quad (10)$$

$$I_v = (I_0)_{T_1\frac{q}{nkT_1}} e^{\frac{q(V_{OC})_{T_1}}{nkT_1}} - \frac{1}{X_v} \quad (11)$$

The proportion of the maximum power which is passed through the load and the product of ISC, VOC is named as fill factor. It is a measure of the actual I-V characteristics. For fill factor of 0.7 or higher are considered as great cells. FF increments with decline in temperature.

$$FF = \frac{P_{max}}{V_{oc}I_{sc}} = \frac{V_{mp}I_{mp}}{V_{oc}I_{sc}} \quad (12)$$

At open circuit condition,

$$0 = I_{ph} - I_o\left(e^{\frac{V_{oc}+IR_s}{n_s v_T}} - 1\right) - \frac{V_{oc} + IR_s}{R_p} \quad (13)$$

At short circuit condition,

$$I_{sc} = I_{ph} - I_o\left(e^{\frac{I_{sc}R_s}{n_s v_T}} - 1\right) - \frac{I_{sc}R_s}{R_p} \quad (14)$$

At maximum power point condition,

$$I_{mp} = I_{ph} - I_o\left(e^{\frac{V_{mp}+I_{mp}R_s}{n_s v_T}} - 1\right) - \frac{V_{mp} + I_{mp}R_s}{R_p} \quad (15)$$

Solar PV cell characteristics can be produced by using above equations.

II. Three Diode Model

It comprises of a steady current source, in corresponding with a first diode including an ideality factor representing the recombination in the space-charge region. The second diode in the records for the carrier recombination in the space charge region of the intersection and the surface recombination losses. The third diode represents the commitment of added diode current due to recombination in the imperfection areas and grain destinations.

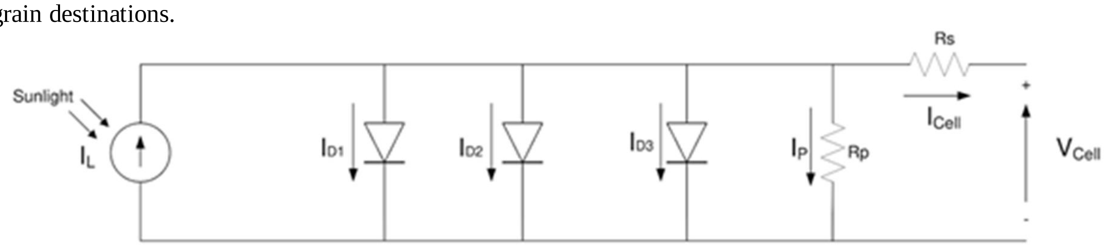

Figure 3. Three diode solar cell

$$I = I_L - I_{D1} - I_{D2} - I_{D3} - I_{SH} \quad (16)$$

$$I = I_L - I_{01}\left[\exp\left(\frac{q(V + IR_s)}{n_1 kT}\right) - 1\right] - I_{02}\left[\exp\left(\frac{q(V + IR_s)}{n_2 kT}\right) - 1\right] - I_{03}\left[\exp\left(\frac{q(V + IR_s)}{n_3 kT}\right) - 1\right] - \frac{V + IR_s}{R_{SH}} \quad (17)$$

$$I_L = \left(\frac{G}{Gn}\right)[I_{L},n + K1(\Delta T)] \quad (18)$$

$$I_{01} = I_{02} = I_{03} = \frac{I_{scn} + K1(\Delta T)}{\left[\exp\left(\frac{Voc,n + Kv(\Delta T)}{\left(\frac{a1 + a2 + a3}{p}\right)V_T}\right) - 1\right]} \quad (19)$$

A. Modelling of PV cell

The parameters of the solar cell is taken as in the Table I.

TABLE I: SOLAR CELL PARAMETERS

Electrical Parameters	Values
I_{sc}	7.6 A
V_{oc}	21.3 V
Number of cells in series	36
Temperature	25^{o} C
Irradiance	1000 W/m^2
a1	1
a2	1.2
a3	1.5
Band Gap	1.12
R_s	0.016 Ohms
R_p	415.405 Ohms

The essential parameters are assessed and suspicions have been made during execution of conditions recorded in previous section. This program takes cell temperature, irradiance and PV module voltage as data sources and with the assistance of conditions it returns yield current value of PV module.

The MPPT controller is the device that controls the PV module in such a way that it extracts the maximum amount of power. The efficiency of the PV system is increased if the controller operates at MPP on purpose, regardless of the weather. To achieve optimum power generation, this should be possible by legitimately coordinating PV sources with loads in any climate situation. Mechanical and electrical monitoring are two methods for extracting full power from a PV array. The PV panel orientation varies with the months and seasons during the year in mechanical tracking, while the IV curve is used to locate MPP in electrical tracking. MPPT is a critical component of modern power systems, ensuring that the batteries/load/motors and the power grid receive the maximum power for on-grid and off-grid applications, respectively. The MPPT controller is widely used in PV plants because the conversion rate of solar energy to electrical energy in PV arrays is still poor and solar irradiance is not always uniform.

B. Need for an MPPT Controller

Any change in the climate necessitates the production of energy from a renewable source. The effect is particularly severe in solar and wind energy systems. Solar and wind systems also face challenges related to (i) grid integration and (ii) shifting climatic conditions. As a result, MPPT procedures are used in solar PV and wind energy conversion systems to ensure optimum power production. As a result, it is important to check for an MPP in the PV and I-V curves for temperature and variable irradiation. When the atmosphere changes, this MPP continuously shifts its location. As a result, MPPT controllers are designed to maintain MPP monitoring and are an essential component of a PV system. The involvement of a controller effectively modifies the panel's resistance and, as a result, encourages the panel to function closer to MPP. MPPT controllers with high efficiency are needed to change the load's operating point when the duty cycle of the converter is changed.

C. Mppt Control Techniques

Perturb and observe (P&O) Algorithms

The conventional P&O scheme is part of a hill climbing (HC) algorithm. When the difference between instant power P(k) and actual power P(k−1) is positive (dP/dV> 0), the direction of an operating point is located toward the MPP and vice versa. To achieve the MPP locus, the perturbation of a PV voltage and current continues in both directions. The algorithm's flaws include tracking deviation from the MPP on rare occasions, slow tracking speed, and steady-state oscillation near the MPP under PSCs. When the frequency of a perturbation is small enough, accelerating the PV system into a steady-state level prior to the next perturbation should improve efficiency. The use of a modified fixed-step P&O algorithm to choose a proper scaling factor reduces the trade-off between steady-state oscillations and tracking speed. A traditional adaptive P&O is implemented to address this trade-off, but it faces the same difficulty due to its reliance on a pre-determined phase size and fluctuating open circuit voltage (V_{oc}) under PSCs. Moreover, to improve tracking efficiency and convergence speed, an adaptive variable step-size P&O is created, in which an adaptive perturbation of a duty cycle change (D) and periods (T) is calculated to observe a load current. Based on the calculation of a fractional short circuit current (I_{SC}), the adaptive perturbation takes an operating point near to MPP, while the variable perturbation decreases power oscillations toward MPP. The efficiency of both traditional and adaptive P&O algorithms is harmed by drift caused by an incorrect duty ratio (D) selection and a significant change in perturbation. Even after detecting MPP, the P&O algorithm looks for an optimum power point consistently toward the front and back of a P-V curve, resulting in many oscillations around the MPP. By choosing the smallest phase size, the oscillations can be minimised, but the tracking speed will be slowed. However, because of the delayed time in perturbation, the transient response is overcome.

To detach a PV array only at PSCs and at the beginning of the steady-state conditions, an offline FSCC is coupled with an online P&O. The online P&O algorithm receives an operating point from FSCC. In PSCs, this approach has a fast tracking speed and less oscillations around the MPP. Furthermore, to achieve the best task ratio decision, a revamped hybrid drift avoidance P&O approach with a fixed and adaptive technique is used. As a result, the PSCs in this system overcome the drift problem by increasing the duty cycle (D) and positive values of dV and dI and shifting an operating point adjacent to the MPP. A particle swarm optimization (PSO) scheme is integrated with P&O to boost tracking performance, convergence speed, and steady-state response, as well as reduce the searching space. The P&O scheme searches for a specific MPP under uniform environmental conditions to track a current Local MPP under non-uniform environmental conditions in this process. The PSO technique is then used to monitor the perturbation size of the P&O system at a PSC moment. Without requiring PIC, an adaptive P&O algorithm is combined with FLC to achieve high tracking precision and reduced computational time. By decreasing the step size of the MPP in an incorrect direction and increasing the step size in the true direction of the MPP, this hybrid technique increases device output in both steady-state and dynamic environments. To ensure rapid convergence, an ant colony optimization (ACO) approach is combined with the P&O process, which detects Global MPP in the form of Local MPPs on rare occasions regardless of duty ratio (D) variations. During the ACO search time, oscillations are detected, but they are removed by the P&O algorithm. The P&O algorithm incorporates an artificial neural network (ANN) method for sampling the location of an operating point by measuring currents and classifying the output reference voltage from partially shaded I-V curves. The ANN algorithm predicts a new region of Global MPP for each shift in irradiance, and the P&O technique measures the tracking location as a voltage value. The P&O algorithm then searches for the Global MPP by perturbing the direct duty cycle into the ANN algorithm's pre-approximated field. To improve monitoring and dynamic outputs with less computational time and complexity, the hybrid model-based (MB) and heuristic P&O algorithms are implemented without direct temperature and irradiance measurements. By reducing the searching space, the offline Gray wolf optimization (GWO) approach brings the operating point closest to the obvious MPP in the hybrid Gray wolf optimization (GWO) and P&O methods. Then, when the wolves are nearest to one another, the online P&O system is used to track the best wolf location. This combined technique will minimise computational load at any transition time of atmospheric conditions, resulting in a faster convergence speed around Global MPP at PSCs. Only three animals were thought to scale down computational complexity in this combined process, despite the fact that a larger number of animals produces a more accurate MPP.

TABLE II: COMPARISON OF THE P&O ALGORITHMS

Parameters/P&O MPPTs	**Adaptive P&O**	**FSCC P&O**	**DA P&O**	**PSO P&O**	**FLC P&O**	**ACO P&O**	**ANN P&O**	**MB P&O**	**GWO P&O**
Input variables	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}
Control variables	I_{ref}	D, I_{ref}	D, ΔI	V_{ref}	D, Load	D	V_{ref}, D	V_{ref}	D
Implementation cost	Low	Low	Low	Low	Low	Low	Low	Low	Low
Controller types	dSPACE	dSPACE	Micro-controller	Micro-controller	dSPACE	PIC	DSP	PIC	dSPACE
Converter types	Boost	Buck-Boost	SEPIC	Boost	Ćuk	Boost	Buck	Boost	Boost
Complexity	Simple	Average	Average	Simple	Simple	Simple	Simple	Simple	Simple
System Independence	Poor	High	High	High	Average	High	High	High	High
Reliability in PSCs	Average	High	High	High	High	High	High	High	High
Convergence speed	Fast	Fast	Fast	Faster	Fast	Very Fast	Fast	Fast	Fast
Oscillation around MPP	Less	Less	Less	Less	Less	No	Less	Less	Less
Periodic tuning	Yes	Yes	No	Yes	No	No	Yes	No	No
Power efficiency	Medium	High	High	High	High	High	High	High	High
Tracking speed	Faster	Fast	Fast	Fast	Fast	Faster	Fast	Faster	Faster

Incremental Conductance Algorithms (INC)

The traditional fixed phase size (FSS) INC algorithm is based on the assumption that the P-V curve's slope, or the sum of the instantaneous and INC, is zero at MPP, positive at MPP's left, and negative at MPP's right. When it comes to detecting MPP during steady-state and transient phases, this algorithm gets confused. By minimising the number of iterations of searching reference voltage, an adaptive phase size INC method is used in the PV system to improve convergence speed and tracking accuracy. Following that, to increase tracking performance, boost transient behaviour, and reduce steady-state oscillations around MPP, a low-cost adaptive algorithm is used to exclude manual perturbation. The variable step size (VSS) INC method optimises a task cycle's broad step size at the MPP's farthest locus. This method produces quick tracking speed, but it also produces more oscillations, and vice versa. To achieve a trade-off between dynamics and steady-state oscillations, a modified variable phase INC scheme is needed. Due to a deviation in the service cycle phase size under PSCs, the VSS-INC algorithm performs worse in dynamics. A current-controlled variable phase size incremental resistance (INR) MPPT algorithm is used to improve the tracking speed in the dynamics while also increasing the precision in the steady-state. Due to the confounding flat-low values of current change (AI) in a PV panel with almost zero I-V slope, the power increment (PI) aided INC MPPT is then applied to increase the slow tracking speed on the left side of the MPP. This approach involves frequency and duty cycle control variables to achieve optimal power transfer from a PV array (VFCD and CFVD).

Let us discuss few number of hybrid INC techniques. To guarantee rapid computation of MPP with limited searching space for a reference voltage during non-uniform weather conditions, a solar tracker (ST) is combined with the improved INC and constant voltage (CV) process. This constrained search space results in less computation when looking for necessary parameters, the best tracking distance, and faster convergence. To prevent an extra control loop and periodic disconnection, the INC technique has been combined with the fractional open circuit voltage (FOCV) and fractional short circuit current (FSSC) algorithms. To operate a PV array at its maximum expected capacity, a duty cycle must be tuned on a regular basis. The permitted error in the duty cycle for operating the PV system at Global MPP with rapid convergence speed is estimated to be about 6%. Under partial shading conditions, this algorithm is used to distinguish between Global MMPs and Local MPPs derived from PV characteristic curves. By that power oscillations during steady-state conditions, a controlled duty cycle improves overall system performance. The primary goal of a hybrid Fuzzy Logic Controller (FLC) with INC system is to precisely and quickly monitor the MPP in dynamic and equilibrium conditions. The system can solve the disadvantages of a traditional fixed INC MPPT. Under PSCs, the FLC has a significant impact on reducing power fluctuations near MPP.

TABLE III: COMPARISON OF THE INC ALGORITHMS

Parameters/P&O MPPTs	**Adaptive INC**	**INR-Based INC**	**ST-Based INC**	**FC-Based INC**	**PI-Based INC**	**FLC-Based INC**
Input variables	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}	V_{pv}, I_{pv}
Control variables	D	I_{ref}	V_{ref}	R_{load}, D	D	R_{load}, D
Implementation cost	Low	Low	Low	Low	Low	Low
Controller types	PIC	Micro controller	Micro Processor	PIC	DSP	dSPACE
Converter types	Boost	Boost	Buck-Boost	SEPIC	Flyback	ĆUK
Complexity	Simple	Simple	Complex	Simple	Complex	Average
System Independence	High	High	High	High	High	High
Reliability in PSCs	Less	High	High	High	High	High
Convergence speed	Average	Fast	Fast	Fast	Medium	Fast
Oscillation around MPP	No	Less	No	No	No	Less
Periodic tuning	Yes	No	Yes	Yes	Yes	Yes
Power efficiency	Average	High	High	High	High	High
Tracking speed	Slow	Faster	Fast	Fast	Fast	Faster

Constant voltage technique

The Constant Voltage (CV) technique is one of the most basic MPPT control methods, assuming that insulation and temperature fluctuations on the array are minor and that the constant reference voltage is a good approximation of the true MPP. As a result, the PV array's operating point is set to fit a specified reference voltage V_{ref}. The Vref value is set to the VMPP of the characteristic PV module or another best voltage value that has been pre-evaluated. In certain cases, an external resistor connected to a current source pin of the control IC is used to programme this value.

As a result, the operating point for the CV approach is never exactly at the MPP, and different data must be used for different geographical regions. There is no input required for the CV method. However, in order to set up and change the duty-cycle of the DC/DC converter by PI regulator, measurement of the PV array voltage VPV at MPP is required. Since the CV technique performs best at low irradiance levels, it is often used in conjunction with other MPPT techniques. It outperforms both the P&O and the INC methods in this regard.

Open voltage technique

The Open Voltage (OV) technique is based on the observation that the voltage of the maximum power point V is always close to a fixed percentage of the open-circuit voltage Voc. Temperature and solar insolation levels change the position of the maximum power point within a 2% tolerance band. This technique uses 76% of V_{ov} value as value of the operating voltage V (at which the maximum output power can be obtained). In general, this value is very close to VMPP of the solar array.

When the circuit is opened, the OV control algorithm involves voltage V measurements. Again, a static switch must be installed in the PV system; for the OV process, the switch must be used to open the circuit. When I_{ov}= 0V, the PV system provides no power, and thus no energy is provided. This approach also necessitates the calculation of the PV array voltage V_{PV}.

III. Results and Discussions

The I-V curves have been created by differing certain parameters each in turn keeping different parameters consistent at STC. Figure. 4 depicts I-V characteristics for Single diode Solar cell (at STC 1000 W/m2). On noticing the curve we see that with increment in irradiance values cell current increases relatively yet cell voltage increments less. Figure. 6 depicts I-V attributes for Double Diode Solar Cell. It is seen that as radiance builds cell current likewise expands somewhat and cell voltage shows critical increase in its value. The reverse saturation current is temperature dependent parameter and furthermore relies upon quality factor of diode. There are two additional plots in Figure. 5, Figure. 7 and Figure. 9 are showing P-V characteristics of solar cell through which we can find its peak for example maximum power point with individual voltages for shifting irradiance. Furthermore, it is being seen that as irradiance increases output power increments and arrives at nominal power point at STC.

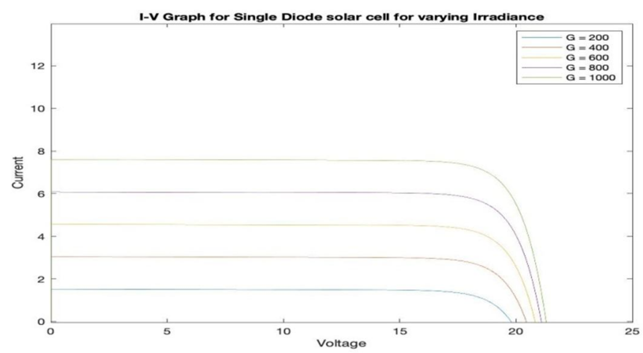

Figure 4. I-V Curve for Single diode Solar cell for Varying Irradiance

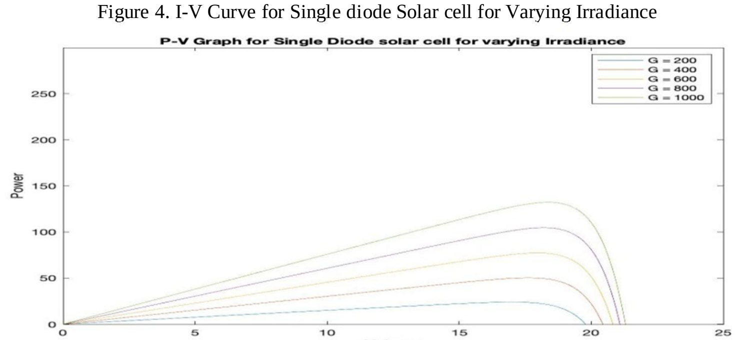

Figure 5. P-V curve for Single diode Solar cell for Varying Irradiance

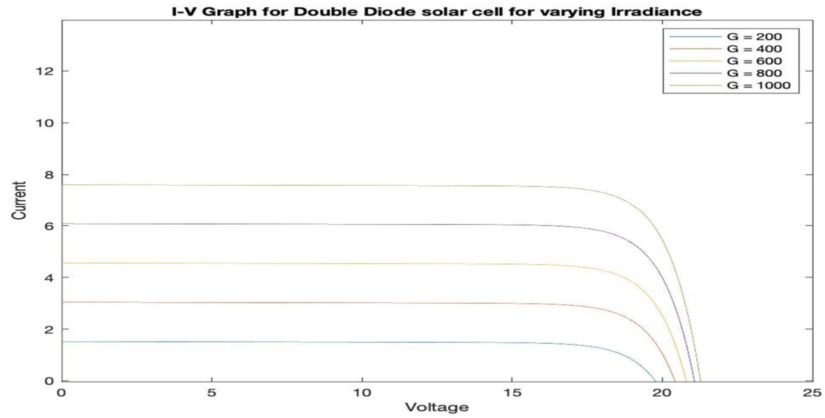

Figure 6. I-V curve for Double diode Solar cell for Varying Irradiance

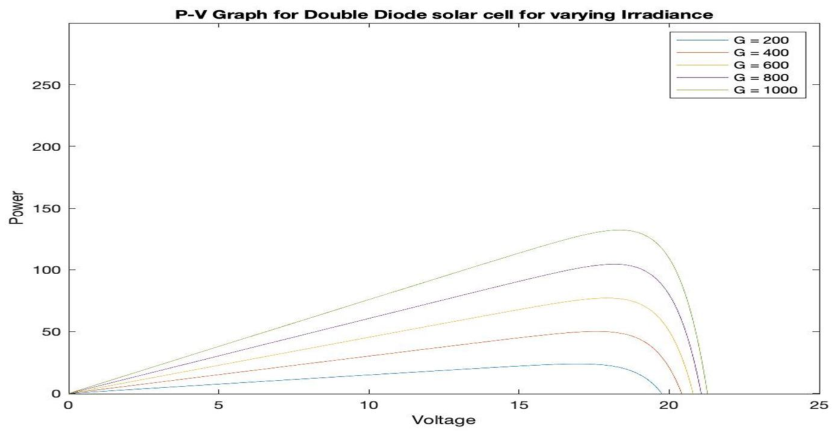

Figure 7. P-V curve for Double diode Solar cell for Varying Irradiance

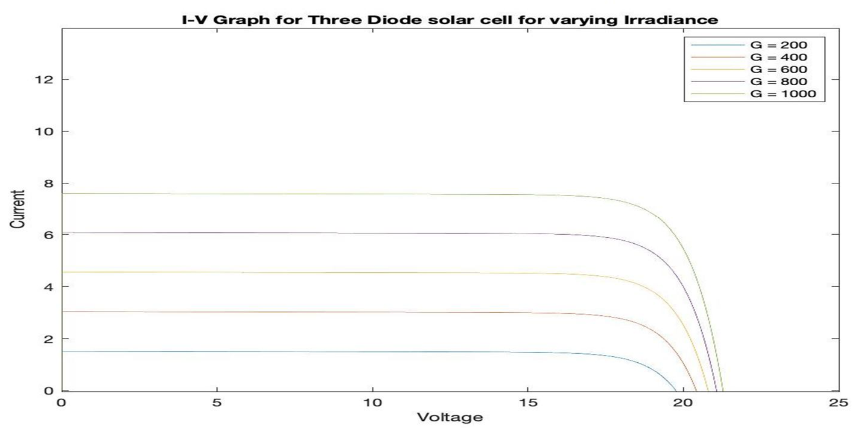

Figure 8. I-V curve for Three diode Solar cell for Varying Irradiance

The single diode model gives a lot of acceptable outcomes in different conditions inside less emphasis. For a given solar temperature and insolation the program assesses the current for a given value of voltages. This model so created was utilized to show impact in I-V attributes of temperature, insolation, obstruction, ideality factor and arrangement protections. The above observations shows that single diode modelling is the most reasonable model which can be utilized for simulating electrical conduct of PV module system for planning purposes in the field of power system.

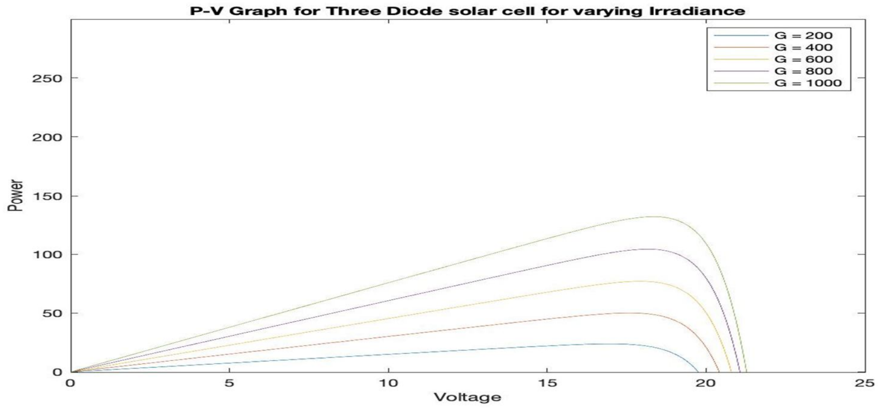

Figure 9. P-V curve for Three diode Solar cell for Varying Irradiance

IV. CONCLUSIONS

Maximum power point trackers (MPPT) are used to increase the efficiency and lower costs of photovoltaic systems by ensuring that the panel's operating parameters are operating at optimal levels. Although, there are many approaches to tracking and finding this power point for PV cells or groups of cells. For many systems, we can use a combination of methods to ensure better results. For example, OV technique can be first used to find the starting point for the algorithm and the iterative methods like INC and P&O are then used to track the algorithm more accurately. Based on the level of irradiance, changing from one method to another is also possible. Methods like OV and CV techniques may be more appropriate at low levels of irradiance, as they can be more resistant to noise. The iterative techniques such as INC and P&O and their modifications have better solution when panels do not have the same angle of incidence, when a portion of the panel is shaded.

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