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Modelling and Simulation of Double Diode Model of PV Cell by Using LtSpice

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Abstract: This research provides a systematic analysis of the PV cell modeling for simulation studies. The primary aim of this analysis is to examine the findings and compare them under normal test conditions. In order to extract the maximum possible power, PV model parameters are find using mathematical analysis and manufacturer's datasheet. Therefore, it is vitally important to determine maximum power point (MPP) location for the implemented model. Other criteria for finding the right model for use in simulation should also be considered. Choosing the right model based on the application is very critical. Double-diode model was used to study the characteristic of the PV cell and to simulate the model, LtSpice software has been chosen. Under various temperature and irradiance conditions, several work tests have been carried out to investigate the performance of the PV model. The double diode model is known to have better accuracy at low irradiance levels, allowing the performance of the PV model to be predicted more accurately.

Keywords: Photovoltaic (PV) Cell, Double Diode Model, LtSpice

1.0 INTRODUCTION

Renewable energy, also referred to as clean energy, comes from the continually replenishing natural sources or processes. Sunlight, water, or wind that keeps shining and flowing, even if its availability depends on weather and time. These sources are unrestricted so we can be used without harming the environment unlike non-renewable sources such as fossils fuel. In this globalization, more energy resources are needed to keep fulfil humanity development stable. The usage of eco-friendly energy has been suggested by global community as it to maintain our green environment.

A better way has been considered which is to use solar energy. The reason why the solar energy is chosen because the increasing of cost to find and process the conventional energy as the mineral sources take time to be create. Meanwhile, the solar energy can easily be found because it is available all around the earth. To make it as higher voltages, currents and power levels, photovoltaic cells are usually connected in series and based on their maximum DC power output the performance of Photovoltaic (PV) modules and arrays are generally rated [1]. PV arrays will generate electrical power depending on the surrounding temperature.

Photovoltaic system uses solar panels to convert sunlight into electricity. As for data processing we will use maximum power point tracking (MPPT) algorithm. For a certain condition, the MPPT algorithm can find out the maximum power from the PV module by using charge controller. The MPPT algorithm system will pinpoint the peak voltage of the output power for the solar panel and can observe the data to know the efficiency of the system. Solar radiation, ambient temperature and solar cell temperature will be the factors that can affect the maximum power of the PV arrays [2].

The most used techniques apply for tracking the MPP of PV cell are "Incremental Conductance" and "Perturb and Observe" (P & O). To predict the position of maximum power point, the voltage and current of the PV array can be used. Due to its fast change, it becomes hard for tracker to predict maximum power point correctly as the atmospheric conditions play an important role in the tracking [3].

2.0 LITERATURE REVIEW

A PV cell is made from purified silicon, liquefied and afterward crystalized. Most of the cell is equipped with a marginally certain electrical charge, with a slender layer, at the top, having a somewhat negative charge. A slight framework of metal is set on the head of the cell which permits satisfactory measures of sunlight to be conceded yet in addition had the capacity to convey electrical energy [4]. The stage of light and the temperature accessible to the cell influences the measure of current and voltage created separately, which directly effect on the power output [5].

The voltage and current produce in one PV cell are smaller. So, in a series-parallel combination, solar cells are interconnected to attain the desired power. By sequentially linking the solar cells, the required voltage and necessary current is created by the parallel combination of the cells. The combination of current source (I_{ph}) connected in anti-parallel to a diode 'D', series resistance (R_s) and parallel resistance (R_p) is example of the ideal PV model [6].

There are non-linear I-V and P-V properties of the PV cell. Temperature and irradiation levels are the two key factors affecting the performance of the PV device. The change in temperature and degree of irradiation results in the voltage and current changes caused by the PV cell. The solar cell's nominal operating condition is 25^{o}C temperature, 1000 W-m2 (G=1) irradiation at AM of 1.5.

The highest voltage a cell can have is open circuit voltage (V_{OC}) which is generate at I=0 under open circuit position and short circuit current (I_{SC}) circumstance corresponds to the current of the short circuit at V= 0. The PV cell produces maximum power at just single point throughout the process, and this point is called MPP. In the graph, I_m, V_m and P_m are the maximum current, maximum voltage, and maximum power respectively of the PV cell.

a) Temperature

The temperature acted as important role in deciding the performance of the solar cell. The primary factor of the cell temperature rise is on open circuit voltage (V_{OC}), which is the cell will decrease linearly with temperature that make the efficiency of the cell fall. As can be expected, with the rise of cell temperature, the short circuit current (I_{SC}) increases moderately [7].

b) Irradiances

The measure of power density of sunlight earned at a place on the earth is described as irradiance, *D*. With the increasing solar irradiance, both the open circuit voltage and the short circuit current increase and the maximum power point also changes [8].

3.0 METHODOLOGY

This paper explains the methodology and substance of the research report. This research concentrates on modeling the double diode PV model to find the MPP by simulate using LtSpice software. To obtain the PV cell parameters, this calculation must be done and compared with the datasheet. After all the parameter has been acquired, process to observe I-V graph can be done and it will ease the estimation to find MPP. Figure 1 shows the block diagram of PV modelling.

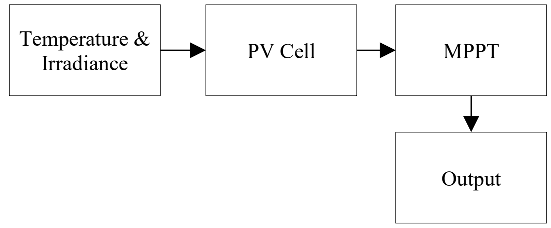

Figure 1 Block diagram of PV Model

The cell is constructed as a supply of current induced by the photo-electric effect of solar irradiance parallel to a diode with a series and parallel resistance that shows source of the current and voltage function from solar cell.

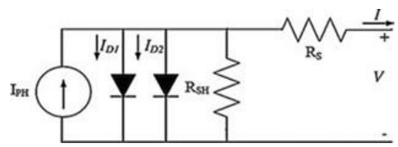

Figure 2 Double Diode Model

Based on the circuit in Figure 2, the double-diode equation can be expressed as (1):

$$I = I_{ph} - I_{s1}\left[e^{\left(\frac{V_d}{n_1 V_t}\right)} - 1\right] - I_{S2}\left[e^{\left(\frac{V_d}{n_2 V_t}\right)} - 1\right] - \left[\frac{V + IR_S}{nV_t}\right] \quad (1)$$

The two-diode model was demonstrated where two diodes are attached to the current source with separate I_{S1} and I_{S2} saturation currents that are linked in parallel to a shunt and resistance in series.

The second diode which parallel to the other that used to distinguish the two-existing mix of saturation current, one in the depletion region and the other in the quasi- neutral region. That is why it is said the more effective model of PV cell is using two diodes.

Figure 3 shows the flowchart of the PV model. The first steps must be taken whether to pick or specify the temperature, irradiance, and value of ideality factor (n) as parameters used in the modelling of PV to determine the I_{SC} and V_{OC}. The model must be in open and short circuit condition. The voltage open circuit is the voltage output quantity that can be supplied to the load. It happens when infinity is the resistance. The short circuit is the operation of the circuit fully connected. Thus, through the circuit, the current will flow. This happens when the resistance present in PV module is zero.

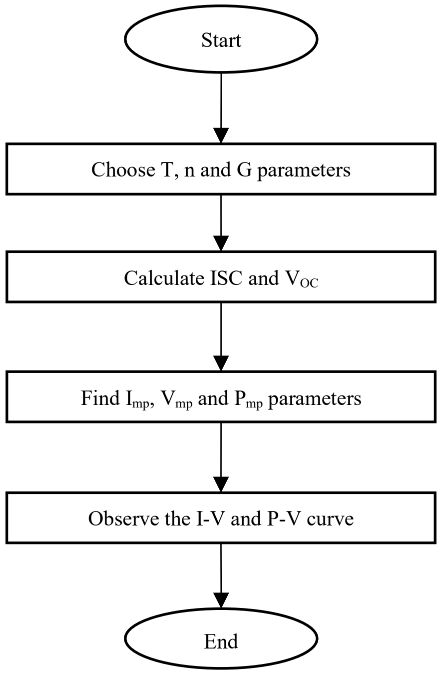

Figure 3 Flowchart of PV model

By varying the temperature and irradiances the result of the I-V and P-V can be observed. Parameter's data in terms of I_{SC}, V_{OC}, I_{mp}, V_{mp} and P_{max} will be collected as all the parameters can be determined. The final step is comparing the outcome of the model in the terms of the different temperature and state of irradiance. It is important to perceive the efficiency of the model.

4.0 RESULTS

The simulations were run in LtSpice software where the parameters of the double diode model were extracted from previous research and has been verified using datasheet form the manufactures. Each possible outcome obtained by varying the parameters affecting the PV cell has been observed and discussed. Changes in various parameters have an impact on the PV cell's characteristic.

Parameters	Value
PV Current, $\mathbf{I_{ph}}$.	9.027 A
Ideality Diode Factor, $\mathbf{n_1}$.	1.2034
Ideality Diode Factor, $\mathbf{n_2}$.	1.8450
Diode Saturation Current, $\mathbf{Is_1}$.	1.39427 nA
Diode Saturation Current, $\mathbf{Is_2}$.	1.39690 nA
Series resistance, $\mathbf{R_s}$.	0.0038 Ω
Shunt Resistance, $\mathbf{R_p}$.	73.19 Ω

Table 1 Parameters of Model in Simulation

To validate the result, the comparison between datasheet and the simulation has been done using parameters in Table 1, which was extracted from prior research [9]. An exceptionally proficient monocrystalline silicon PV was picked for the simulation. Table 2 details the datasheet of the PV cell, which contains a restricted measure of data.

Symbol	Description	Value
Voc,cell,ref	Cell open circuitvoltage	0.699V
Isc,ref	Short circuit current	9.026 A
Vmp	Maximum powervoltage	0.572 V
Imp	Maximum power current	8.756 A
Pmp	Maximum power	5.210 W
FF	Fill factor	81.90 %

Table 2 Datasheet of PV cell

The cell's performance is regularly investigated under standard test conditions (STC), with a normal solar spectrum range at AM 1.5. The irradiance is fixed to 1000Wm-2 and the cell temperature is managed to 25ºC. Table 3 details the fundamental outcomes for both the simulation model and the datasheet performed for the PV cell.

Symbols	Description	Datasheet	Simulation	Error
V_{oc}	Open-circuit Voltage	0.699 V	0.699 V	0%
I_{sc}	Short-circuit Current	9.026 A	9.026 A	0%
V_{mp}	Maximum Voltage	0.572 V	0.570 V	0.35%
I_{mp}	Maximum Current	8.756 A	8.746 A	1.12%
P_{mp}	Maximum Power	5.010 W	4.985 W	0.50%

Table 3 Comparison of the result

As seen in Table 3, each reenactment information has shown the most drastic result, which is the optimal working stage. To be effective, the cell should concentrate on these areas. There are two other important focuses on open-circuit voltage and short-circuit current. When these main facts are compared to those included in the manufacturer's datasheet, they indicate a good agreement and illustrate the validity of the simulation model. It very well may be seen that ideal understanding between the datasheet and simulation results is accomplished.

5.0 DISCUSSION

The result from the simulation can be analyzed into three categories effect, temperature, irradiance, and series resistance.

a) Temperature Effect.

The simulation information show that the open circuit voltage diminishes with increasing temperature as can be seen in Figure 4. However, the short out current is brought down to a negligibly level. The maximum power is most elevated at 25 ºC, at which point it consistently reduces as illustrated in Figure 5. Table 4 shows the values in detail.

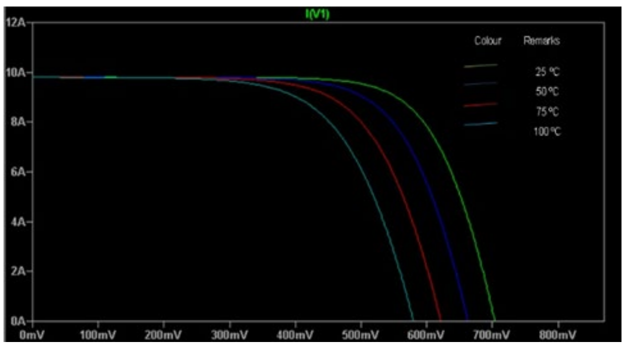

Figure 4 Temperature Effect on I-V Curve

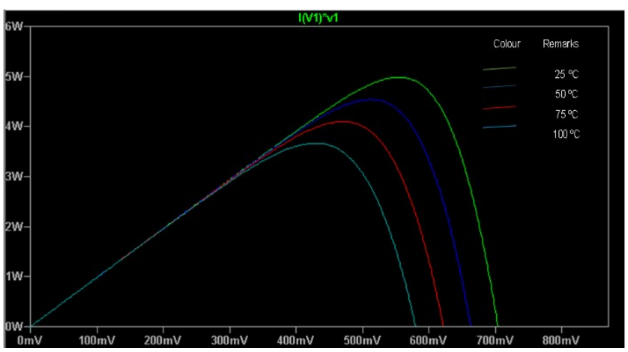

Figure 5 Temperature Effect on P-V Curve

Temperature (ºC)	Open circuit voltage, Voc (V)	Short circuit current, Isc (A)	Maximum Power, Pmax (W)
25	0.699	9.026	4.985
50	0.659	9.026	4.536
75	0.617	9.026	4.096
100	0.575	9.026	3.664

Table 4 Effect of Temperature Data

b) Irradiance Effect

The simulation results in Figure 6 show that as solar irradiance decreases, so does the open circuit voltage and short circuit current. The output power is optimum at high irradiance and steadily decreases as the irradiance decreases. As can be shown in Figure 7, once the irradiance increases, the solar cell can produce greater power, as demonstrated by the higher elevations on the curves. Table 5 details the value obtained from the simulations.

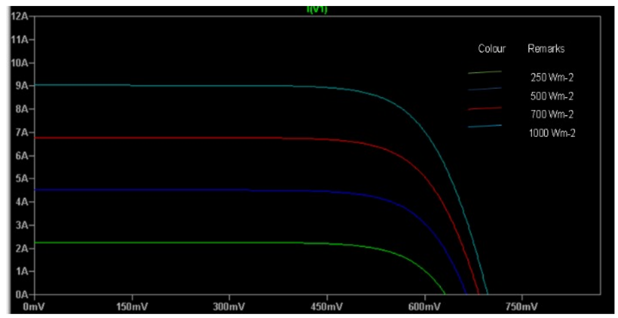

Figure 6 Effect of Temperature Data

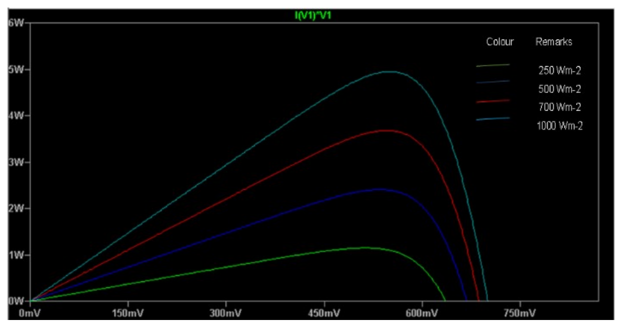

Figure 7 Irradiance Effect on P-V Curve

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Irradiance, G (Wm-2)	Open circuit voltage, Voc(V)	Short circuit current, Isc (A)	Maximum Power, Pmax(W)
1000	0.699964	9.02653	4.98506
750	0.686713	6.77005	3.67773
500	0.668026	4.51336	2.40448
250	0.636036	2.25668	1.14755

Table 5 Effect of Irradiance Data

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c) Series Resistance Effect

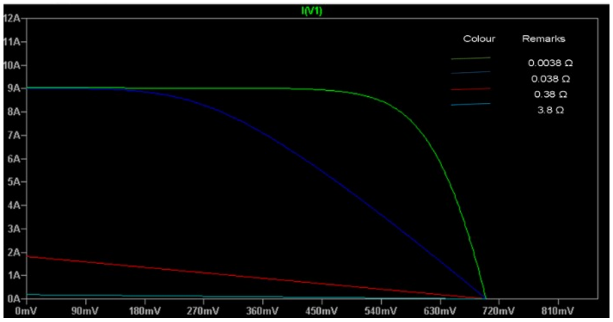

Figure 8 Series Resistance Effect on I-V Curve

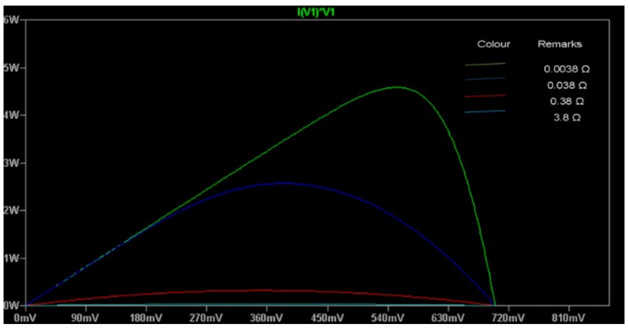

Figure 9 Series Resistance Effect on P-V Curve

Figure 8 shows that short circuit current decreases marginally as series resistance increases, thus short circuit current decreases noticeably as series resistance at high value. However, in the case of P-V Curve, the open circuit voltage stays constant, while the maximum output power dropped significantly as shown Figure 9. The values obtained for the simulation is detailed in Table 6.

Series resistance, Rs (Ω)	**Open circuit voltage, Voc(V)**	**Short circuit current, Isc (A)**	**MaximumPower, Pmax(W)**
0.0038	0.699964	9.02653	4.98506
0.038	0.699964	9.01844	2.65998
0.38	0.699964	1.81480	0.32165
3.8	0.699964	0.18395	0.03254

Table 6 Effect of Series Resistance Data

5.0 CONCLUSION

This research provided a study of clear I–V expression and subtle interpretation for the proposed design for validity of indicating case studies. This model employs previous analysis results to approximate the precise seven parameters of the double diode model and the proposed model also was also validated by comparing it to the manufacturer's datasheet, which is a monocrystalline silicon PV cell. As these key facts are identical to those in the manufacturer's datasheet, they show a strong correlation and clarify the simulation model's validity. The impact of differing parameters is being addressed to evaluate the efficiency of a PV cell. The photocurrent is relative to the irradiance, and the series resistance decreases the short-circuit current and fill factor. The findings indicated that increasing of cell ambient temperature will declines open-circuit voltage and fill factor. Consequently, the efficiency is greatly degrading overtime.

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