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Торайгыров университета

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ANALYSIS OF PERFORMANCE OF A PV SOLAR CELL AND EFFECT OF PHYSICAL PARAMETER

In recent days, PV solar systems have been commercialized in almost the whole world because of its advantageous efforts like a long-term supply of power at a very lower cost and various governments are also encouraging consumers to use sustainable green energy. The purpose of this study was to develop a model that allows the user to predict PV cell's current-voltage (I-V) and power-voltage (P-V) characteristic curves by varying irradiance, cell temperature, and diode ideality factor, and the value of series resistance. The characteristic curves obtained from the simulation of the MATLAB/Simulink model are matched with the data given by the manufacturers by changing the value of mentioned internal parameters. Comparative results of one and two diode models with different electrophysical parameters are shown. There are analyses for photocurrent, voltage and power, as well as their dependence on single and two diode models. Block diagram models for diodes are also presented.

Keywords: Irradiance, Temperature, Ideality Factor, Series Resistance, current-voltage characteristics.

Introduction

Solar cell is mainly p-n junction which is made up of thin wafer or layer of semiconductor. Electromagnetic radiation coming from Sun can be directly converted into electricity when it is exposed to the metallic plates forming the photovoltaic cell through photoelectric effect. When solar cell is exposed to sunlight then photon that are coming from electromagnetic radiations having high energy to the band gap energy of semiconductor are absorbed and create a deficient of electron as a result electron hole pair is produced. The number of emitting photoelectrons is directly proportional to the intensity of incident radiation. When photons get absorbed in the cell, energy of photons will cause the electrons to get free and they can move in the cell, these electrons exist from both ends of cell and creates a flow of electrons (creates electricity). With the increase in intensity of sunlight number of photo-electrons emission can be increased (Intensity is proportional to the number of photoelectrons) creates the passage of electrons which in turn produces a more electricity. Internal electric field of p-n junction may have impact on these carriers which are swept apart and produces a flow of electrons emitted by photons is proportional to solar insulation [1]. PV system naturally exhibits a non-linear I-V and P-V characteristics which may vary with the intensity of radiation and temperature of cell.

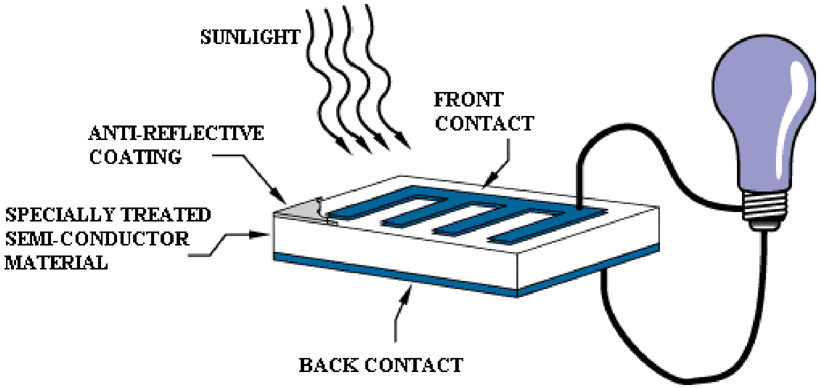


Figure 1 - Basic solar cell

These solar cells don't produce sufficient energy individually so by combining these solar cells in photovoltaic panels we can produce enough energy to power our homes as well as for many other purposes like space satellites.

The evolution of modeling and simulation has been made and this makes a necessary part in modern time. The modeling of module comprises of non-linear V-I and P-V characteristics. The literature of PV cell, this begins in beginning of 1977 with [2]. After 1977 many researchers have studied it to enhance its efficiency and reduce the cost. Many of the researchers have used circuit-based method to characterize solar module of a simpler model; that is a current source in parallel with a diode [3–6]. In solar modules, continually changing environmental conditions such as partial shading can adversely affect the peak output power from the model. Many calculating techniques have been suggested by the researchers [3, 7–10]. Modest circuit constructed model was proposed in [3, 9–11]. Secondary methods have also been given by researchers in which the V-I characteristics can be adjusted through mock intelligence methods [12–15]. However, some of the methods are ideally difficult to implement and need much of the computational efforts while the other methods are only limited up to the simulation of PV module. Because of all the constraints, a correct and complete design of PV system was presented circuit model in MATLAB Simulink model. In 29 Apr 2013 (Updated 06 May 2013) Shivananda Pukhrem analysis, «A circuit based simulation model for a PV cell for estimating the IV and PV characteristic curves» [16].

Materials and methods

The important formulation used in modeling PV cell metallization is as follows. For single diode model the relation between output current of a PV cell and terminal voltage.

$$I = I_{ph} - I_0 \left[exp\left(\frac{q \times V}{A \times k \times T}\right) - 1 \right] \tag{1}$$

PV cell"s basic equation does not represent practical I-V characteristics. A lot of PV cells are connected along with additional parameters like parallel and series resistances (RS & RP) to form a practical module. Hence equation of current is given by

$$I = I_{ph} - I_0 \left[exp\left(\frac{V + R_S \times I}{A \times VT}\right) - \frac{V + R_S \times I}{R_p} \right] \tag{2}$$

For two diode model equation of PV cell current equation becomes,

$$I = I_{ph} - I_1 \left[exp\left(\frac{V + R_S \times I}{A_1 \times VT} - 1\right) \right] - I_2 \left[\exp\left(\frac{V + R_S \times I}{A_2 \times VT}\right) - 1 \right] - \frac{V + R_S \times I}{R_p} \tag{3}$$

Where Iph is light generated photo current, I is diode current, V is diode voltage, T is temperature, A, A1, A2 diode ideality factor, k is Boltzmann constant, I0 is reverse saturated current, q is charge of electron, I the reverse saturation current of diode D1 and D2 respectively, I1 is diode equation due to diffusion, I2 diode equation due to change recombination mechanisms. Modeling of single diode ideal model.

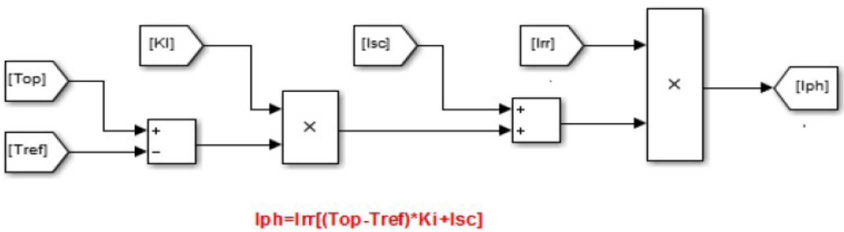


Figure 2 – Light generated current block diagram

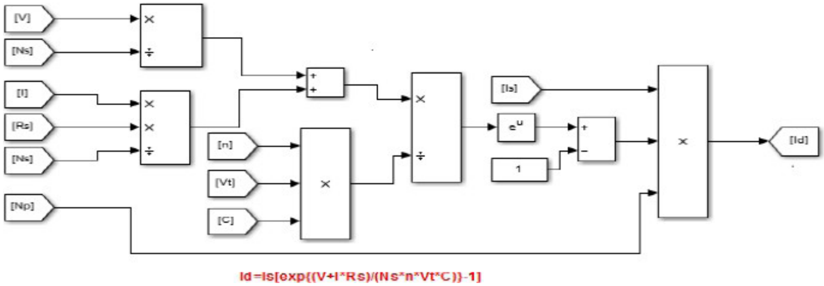


Figure 3 – Diode current block diagram

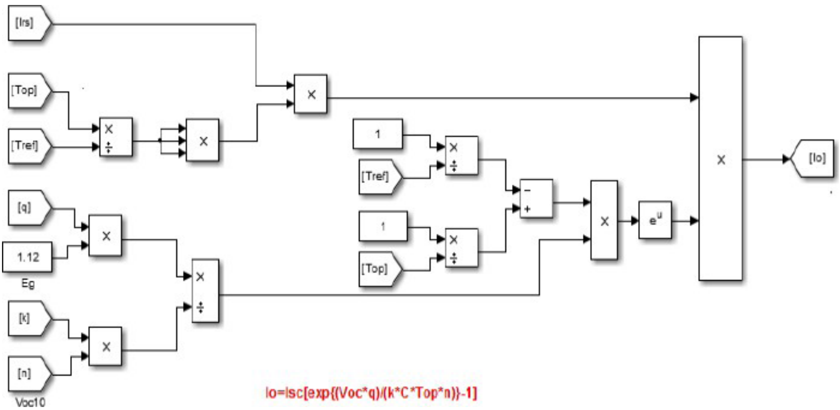


Figure 4 – Reverse saturation current block diagram

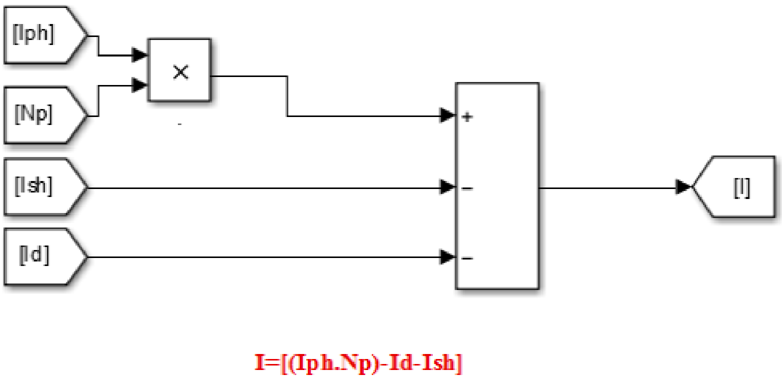
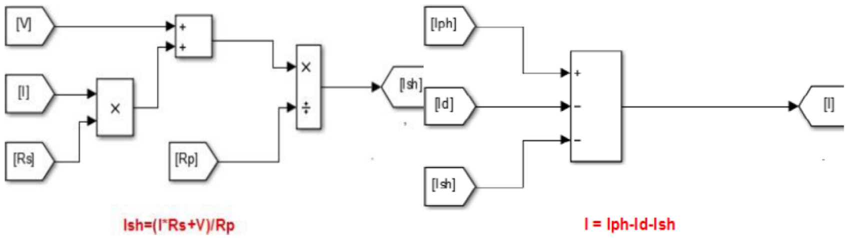


Figure 5 – Output current block diagram

Modeling for single diode with Rs. Now we have to consider shunt current (ISH) for the modeling of single diode with series resistance Rs, for that that we must know the value of series resistance (RS) and parallel resistance (RP). So, we will vary the values of series resistance (RS) and parallel resistance (RP) iteratively, by using MATLAB hence we can find shunt current.



a) Shunt Current block diagram b) Block diagram of output current for single diode with series resistance

Figure 6 – Block diagram

Modeling for two diodes with Rs. Current calculation process of two diode model with series resistance is exactly same as that of single diode model but in this case, we have to consider two diodes.

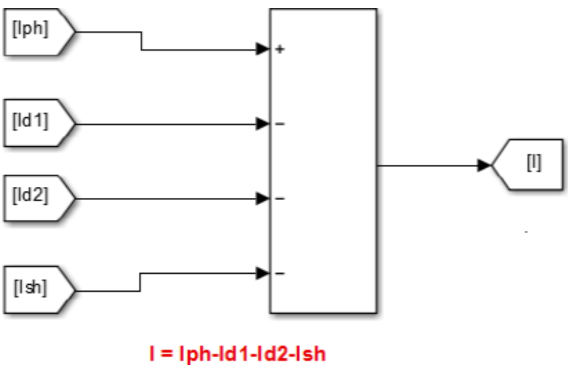


Figure 7 – Block diagram of output current for two diode with series resistance

Modeling of Subsystem for single diode and two diode models with Rs

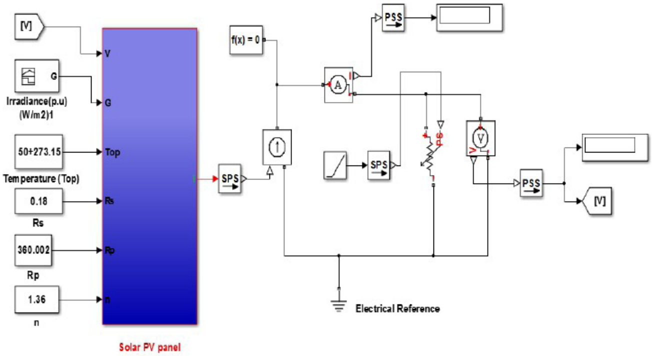
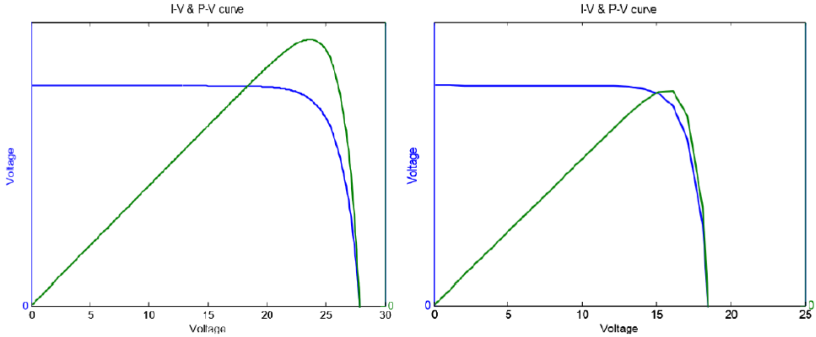


Figure 8 – Subsystem block diagram for single and
two diode models with series resistance Rs

Blue block is basically a subsystem, this part is user defined. On that block a user can input his/her required data for temperature, Sunlight/irradiance, and Voltage. Two diode model sub system is also same, but main difference in this case is that we have to consider one extra diode for modeling. By using this model of PV solar cell we can put data values of different solar cell models in this model. Suppose if we are using a solar model named MX-65 it will have different values of open circuit voltage, short circuit current and temperature co-efficient of open circuit voltage and short circuit current as compared to that of MX-60 solar cell model. Now by varying these inputs we can observe different I-V and P-V characteristics curves.

Results and discussions

P-V and I-V characteristic curves of a PV solar cell and radiations are highly non-linear. For solar cell's MSX-60 module (with pre set parameters given in table 1) we have simulated P-V and I-V characteristics using MATLAB-Simulink by varying different parameters like ideality factor, temperature, series and shunt resistances to match the parameters set by the manufacturer (short circuit current open circuit voltage, maximum current, maximum voltage and maximum power) at standard temperature (298 K) and irradiance (1000 W/m^2).



a) Single diode b) Single diode with series resistance

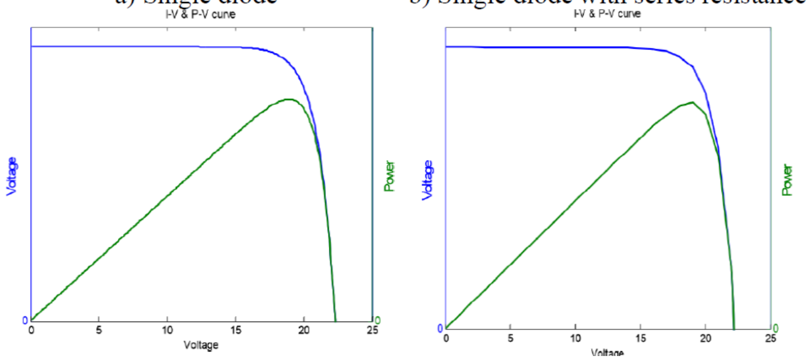
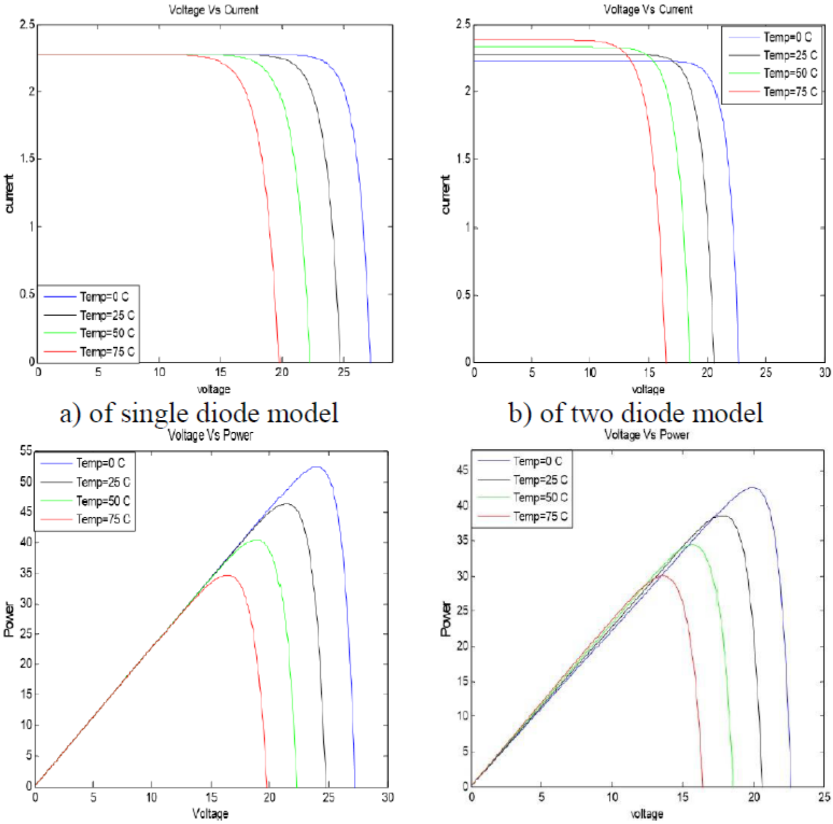


Figure 9 – Model I-V and P-V characteristics curves

Table 1 – Solarex MSX-60 module specification data

Characteristic	**SPEC**
Typical peak power (P_p)	60 W
Voltage at peak power (V_p)	17.1 V
Current at peak power (I_p)	3.5 A
Short-circuit current (I_{sc})	3.8 A
Open-circuit voltage (V_{OC})	21.1 V
Temperature coefficient of open-circuit voltage	-73mV/ºC
Temperature coefficient of short-circuit current (K_i)	3 mV/ºC
Approximate effect of temperature on power	-0.38 W/ºC
Nominal operating cell temperature (NOCT)	49 ºC

Effect of Temperature Variations on Solar Cell. We have taken diode ideality factor 1.2, irradiance 600 W/m^2 and circuit temperature varied between 0 ºC and 75 ºC. Effect of temperature on solar cell maximum output power is simulated and resultant I-V and P-V characteristics curves are shown below. Hence it is clear from these curves that maximum output power of cell is greatly affected by temperature variations. Power is reduced because with the increase in temperature diode current is also increased. Maximum output voltage of single diode falls with the increase in temperature is approximately 1.75 V/ ºC and for two diode model approximately 3.5 V/ ºC.



a) of single diode model

b) of two diode model

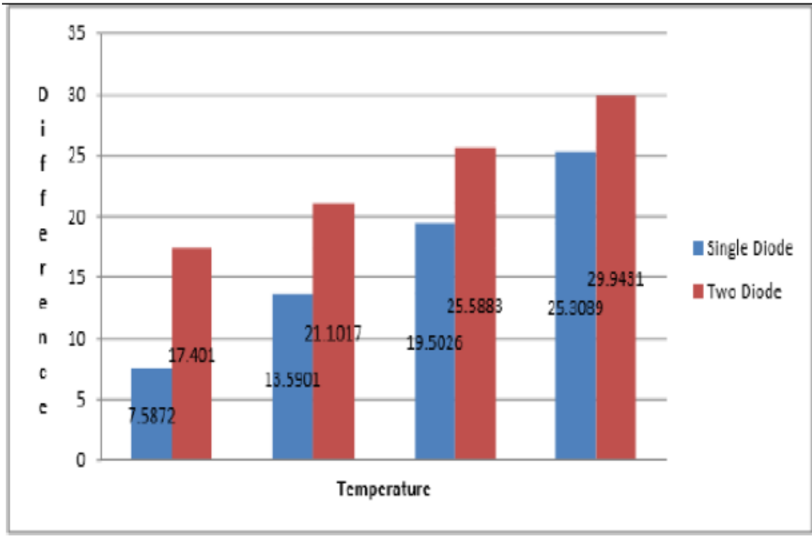
c) of single diode model

d) of two diode model

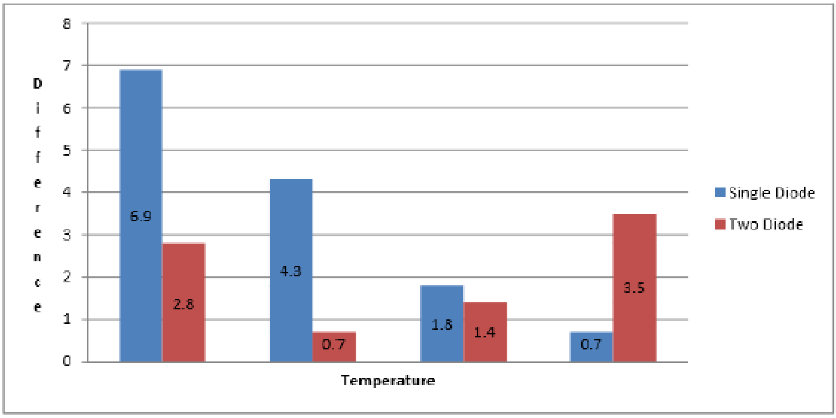
Figure 10 – Model I-V (a, b) and P-V (c, d) characteristics curves

Table 2 – Single diode model and two diode model temperature variations

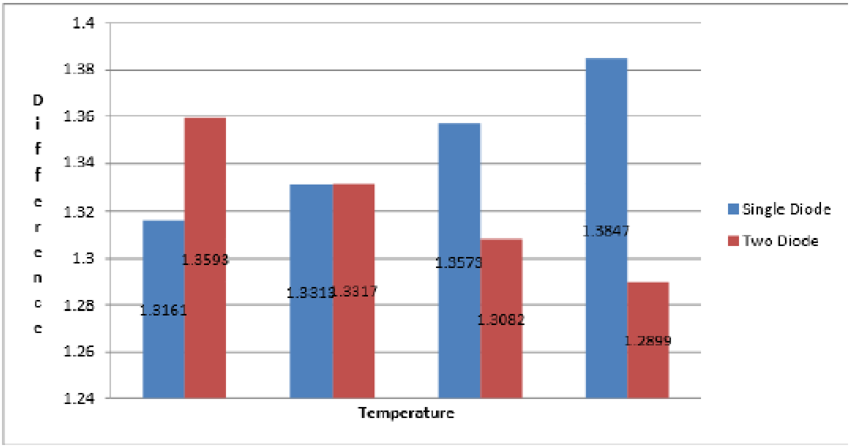
Tempera-ture (ºC)	No series cell (Ns)	273	298	323	348
Pm(W)	36 (two diode)	42.5990	38.5953	34.4117	30.0569
Vm(V)		19.9000	17.8000	15.7000	13.6000
Im(A)		2.1407	2.1683	2.1918	2.2101
Pm(W)	36 (single diode)	52.4128	46.4099	40.4974	34.6911
Vm(V)		24.0000	21.4000	18.9000	16.4000
Im(A)		2.1839	2.1687	2.1427	2.1153



a) for power



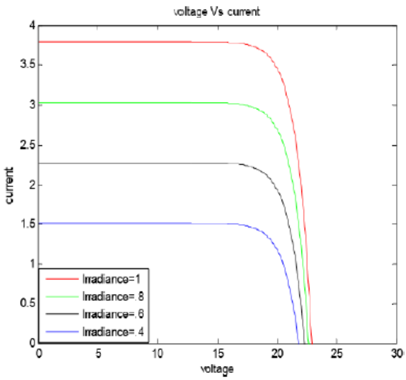
b) for voltage



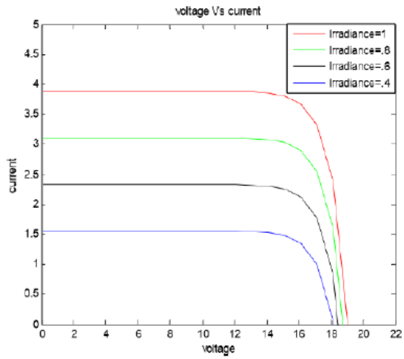
c) for current

Figure 10 – Single diode and two diode model difference compared to ideal diode model

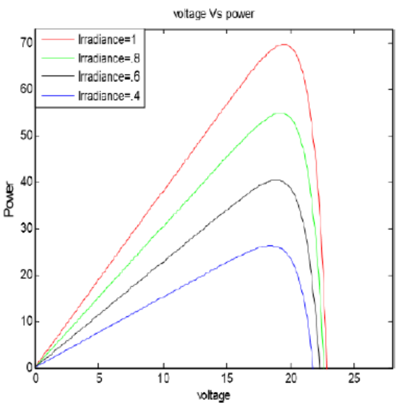
Effect of Irradiance. When we have varied irradiance value in steps as 400 W/m^2, 600 W/m^2, 800 W/m^2, 800 W/m^2 and 1000 W/m^2 with constant conditions (diode ideality factor 1.2 and temperature kept 25 ºC) resultant changes in I-V and P-V characteristics curves are shown below. It is very clear from these plots that short circuit current and open circuit voltage are greatly affected by these irradiance variations especially short circuit current. With the increase in irradiance short circuit current increases and hence maximum power is also increased.



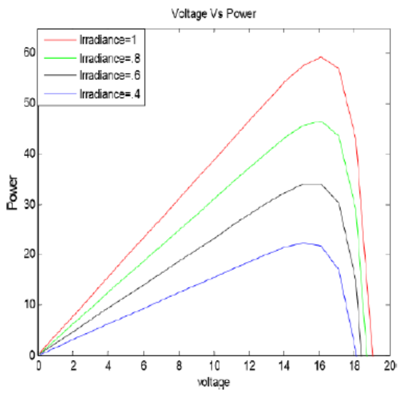
a) of single diode model



b) of two diode model



c) of single diode model



d) of two diode model

Figure 11 – I-V (a,b) and P-V (c,d) characteristics curves

Table 3 – Single diode model and two diode model irradiance variations

Irradiance (W/m^2)	No series cell (Ns)	273	298	323	348
Pm(W)	36 (two diode)	59.2289	46.7111	34.1934	22.3043
Vm(V)		16.1000	16.1000	16.1000	15.1000
Im(A)		3.6788	2.9013	2.1238	1.4771
Pm(W)	36 (single diode)	69.6928	54.9860	40.4974	26.3007
Vm(V)		19.5000	19.2000	18.9000	18.4000
Im(A)		3.5740	2.8639	2.1427	1.4294

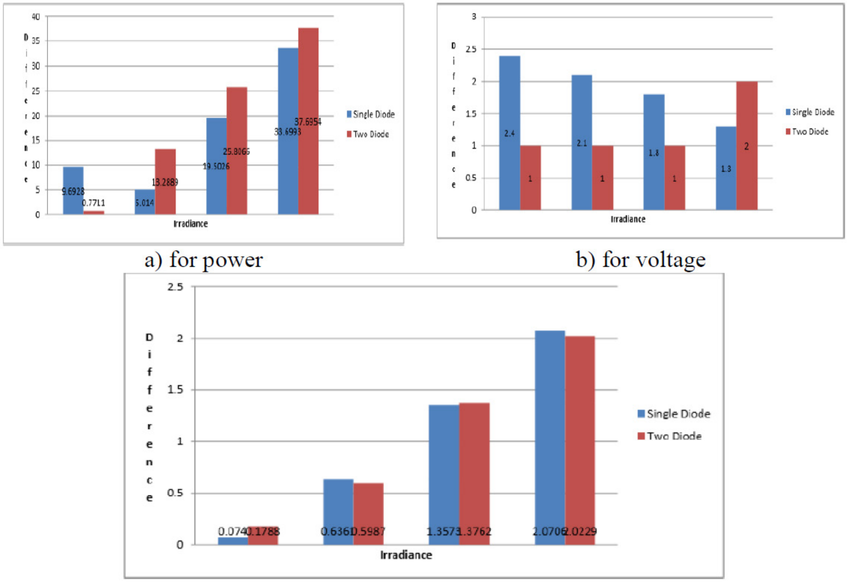


Figure 12 – Single diode and two diode model difference for power, voltage and current compared to ideal diode model

Conclusion

Photovoltaic (PV) cell, module and array are represented by a generalized photovoltaic (PV) model. This model is formed with the help of MATLAB and verified with different models. Main inputs to our model are irradiance and temperature while the outputs are I-V and P-V characteristics curves under various conditions. This model is designed in the form of Simulink block libraries. The masked image makes the block model more user friendly and a dialog box permits the users to easily configure the PV model The proposed model takes sunlight irradiance and cell temperature as input parameters and outputs the I-V and P-V characteristics under various conditions. For MATLAB modeling and simulation such a comprehensive PV model is simple to be used.

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Басып шығаруға 15.12.23 қабылданды.

ФОТОЭЛЕКТРЛІК КҮН БАТАРЕЯСЫНЫҢ ӨНІМДІЛІГІН ЖӘНЕ ФИЗИКАЛЫҚ ПАРАМЕТРЛЕРДІҢ ӘСЕРІН ТАЛДАУ

Соңғы күндері фотоэлектрлік күн жүйелері өте төмен бағамен ұзақ мерзімді электрмен жабдықтау сияқты артықшылықтарына байланысты бүкіл әлемде коммерцияланды және әртүрлі үкіметтер тұтынушыларды тұрақты жасыл энергияны пайдалануға шақырады. Бұл зерттеудің мақсаты пайдаланушыға фотоэлементтің ток кернеуінің (I-V) және қуатының (P-V) сипаттамалық қисықтарын жарықтандыруды, элементтің температурасын және диодтың идеалдылық коэффициентін және сериялық кедергі мәндерін өзгерту арқылы болжауға мүмкіндік беретін модель жасау болды. MATLAB/Simulink моделін модельдеу нәтижесінде алынған сипаттамалық қисықтар көрсетілген ішкі параметрлердің мәндерін өзгерту арқылы өндірушілер ұсынған мәліметтермен салыстырылады. Әр түрлі электрофизикалық параметрлері бар диодтардың бір және екі моделінің салыстырмалы нәтижелері келтірілген. Фототокты, кернеуді және қуатты талдау нәтижелері, сондай-ақ олардың бір *және екі диодты модельдерге тәуелділігі келтірілген. Диодтарға арналған құрылымдық схемалардың модельдері де ұсынылған.*

Кілтті сөздер: жарықтандыру, температура, идеал коэффициенті, дәйекті қарсылық, вольт-амперлік сипаттамалары.

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АНАЛИЗ ПРОИЗВОДИТЕЛЬНОСТИ ФОТОЭЛЕКТРИЧЕСКОГО СОЛНЕЧНОГО ЭЛЕМЕНТА И ВЛИЯНИЯ ФИЗИЧЕСКИХ ПАРАМЕТРОВ

В последние дни фотоэлектрические солнечные системы были коммерциализированы почти во всем мире из-за их преимуществ, таких как долгосрочное снабжение электроэнергией по очень низкой цене, и различные правительства также поощряют потребителей использовать устойчивую зеленую энергию. Целью этого исследования была разработка модели, которая позволяет пользователю прогнозировать характеристические кривые напряжения тока (I-V) и мощности (P-V) фотоэлемента путем изменения освещенности, температуры элемента и коэффициента идеальности диода, а также значения последовательного сопротивления. Характеристические кривые, полученные в результате моделирования модели MATLAB/Simulink, сопоставляются с данными, предоставленными производителями, путем изменения значений указанных внутренних параметров. Показаны сравнительные результаты одной и двух моделей диодов с различными электрофизическими параметрами. Приведены анализы фототока, напряжения и мощности, а также их зависимость от моделей с одним и двумя диодами. Также представлены структурные схемы диодов.

Ключевые слова: Освещенность, температура, коэффициент идеальности, последовательное сопротивление, вольт-амперные характеристики.

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