Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 11(4): 2682-2694, 2021
Journal of the Institute of Science and Technology, 11(4): 2682-2694, 2021

ISSN: 2146-0574, eISSN: 2536-4618

Elektrik ve Elektronik Mühendisliği / *Electrical & Electronics Engineering* **DOI: 10.21597/jist.978148**

Araştırma Makalesi / *Research Article*

Geliş tarihi / Received: 03.08.2021 **Kabul tarihi / Accepted: 07.10.2021**

Atıf İçin: Cangi H, Adak S, Yılmaz AS, 2021. Fotovoltaik Hücre I-V ve P-V Eğrileri Üzerine Sıcaklığın Etkisi. Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 11(4): 2682-2694.

To Cite: Cangi H, Adak S, Yılmaz AS, 2021. Effect of Temperature on The I-V and P-V Curves of The Photovoltaic Cell. Journal of the Institute of Science and Technology, 11(4): 2682-2694.

Fotovoltaik Hücre I-V ve P-V Eğrileri Üzerine Sıcaklığın Etkisi

Hasan CANGI, Süleyman ADAK, Ahmet Serdar YILMAZ

ÖZET: Fotovoltaik (FV) hücreler, yüzeylerinden gelen güneş ışığını doğrudan elektrik enerjisine dönüştüren yarı iletken malzemelerdir. Güneş panelleri, güneş pillerinin yapısına bağlı olarak %5 ile %20 arasında verimlilikle elektrik enerjisine dönüştürülebilir. FV hücrelerinin elektrik enerjisi üretimini etkileyen birçok faktör vardır. Bu faktörler güneş pillerinin verimi, güneşlenme süresi, nem, toz, güneş ışınımı ve sıcaklık gibi faktörlerdir. Bu makalede, sıcaklığın FV hücre Akım-Gerilimi (I-V) ve Güç-Akım (P-V) eğrileri üzerindeki etkisi araştırılmıştır. Düşük sıcaklıklar, güneş pili verimini olumsuz etkilemezken, yüksek sıcaklıklar üretkenliği önemli ölçüde azaltır. Bu çalışma 10 (°C), 30 (°C) ve 50 (°C) ortam sıcaklığında gerçekleştirilmiştir. Sıcaklığın FV güneş pilinin P-V ve I-V üzerindeki etkisi Matlab / Simulink yazılım programı ile analiz edilmiş ve çizilmiştir. Bir fotovoltaik hücresinin verimliliği, esas olarak ortam sıcaklığına, FV hücre sıcaklığına, güneş ışınlama yoğunluğuna ve FV hücresinin üretildiği yarı iletken malzemenin türüne bağlıdır. Bu çalışmada, FV hücre kataloğu verileri kullanılarak, panelin eşdeğer devresi Matlab yazılım programında modellenmiş ve sıcaklık değişimlerinin FV hücre gücü üzerindeki etkileri araştırılmıştır.

Anahtar Kelimeler: FV hücre tek diyot eşdeğer devre modellemesi, PV hücre I-V ve V-P özellikleri, FV hücre sıcaklığı, FV hücre tek diyot eşdeğer devresi, Ortam sıcaklığı.

Effect of Temperature on The I-V and P-V Curves of The Photovoltaic Cell

ABSTRACT: Photovoltaic (PV) cells are semiconductor materials that convert sunlight coming on their surfaces directly into electrical energy. Solar panels can be converted into electrical energy with efficiency between 5% and 20% depending on the structure of the solar cells. There are many factors which affect the PV cells' generation of electrical energy. These factors are such as efficiency of the solar cells, sunshine duration, humidity, dust, solar radiation and temperature. In this article, the effect of temperature on the PV cell current-voltage (I-V) and power- current (P-V) curves were investigated. Low temperatures do not adversely effect on solar cell efficiency, while high temperatures reduce productivity significantly. This study was carried out for 10 (°C), 30 (°C) and 50 (°C) of ambient temperature. The effect of temperature on the P-V and I-V of the PV solar cell analyzed and plotted by Matlab/Simulink software program. The efficiency of a photovoltaic PV cell mainly depends on the ambient temperature, PV cell temperature, solar irradiation intensity and the type of semiconductor materiel which the PV cell is produced. In this study, using the PV cell catalog data, the equivalent circuit of the panel is modeled in Matlab software program and the effects of temperature changes on the PV cell power have been investigated.

Keywords: PV cell single diode equivalent circuit modeling, PV cell I-V and V-P features, PV cell temperature, PV cell single diode equivalent circuit, Ambient temperature.

[1]Hasan CANGİ (**Orcid ID:** 0000-0001-6954-7299), HasCan Mühendislik, Elektrik-Elektronik Teknolojileri Bölümü, Mardin, Türkiye
[2] Süleyman ADAK (**Orcid ID:** 0000-0003-1436-2830), Mardin Artuklu Üniversitesi, Mardin MYO, Elektrik ve Enerji Bölümü, Mardin, Türkiye
[3] Ahmet Serdar YILMAZ (**Orcid ID:** 0000-0001-8082-5448), Kahramanmaraş Sütçü İmam Üniversitesi, Mühendislik-Mimarlık Fakültesi, Elektrik-Elektronik Mühendisliği Bölümü, Kahramanmaraş, Türkiye

***Sorumlu Yazar/Corresponding Author:** Hasan CANGİ, hasancangi@yahoo.com

INTRODUCTION

Solar energy is a powerful source of energy obtained from solar photons. Its important advantages that solar energy is a renewable energy source and it can be always used anywhere in the world. The solar photons are converted into electrical energy through solar panels. This energy is an alternative to fossil fuels. Fossil resources such as coal, oil and natural gas, which are not renewable energy. As the reserves of these resources decrease, their prices increase. Fossil resources have great damage to the environment. They reduce the amount of oxygen in the atmosphere and cause air pollution. Solar energy is the most important among the renewable energy sources. This enegy does not have a negative effect on the environment. The simulink scheme for plotting I-V and P-V curves at different temperature values is given in Figure 1.

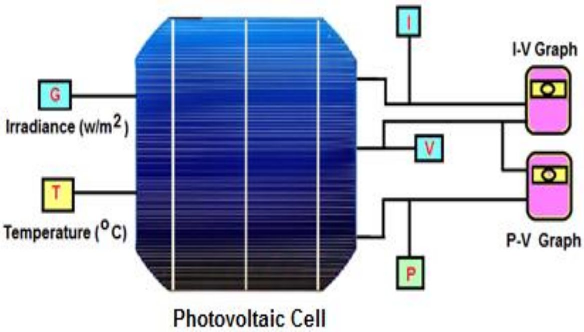

Figure 1. Schematic Diagram of PV Cell for Plotting the I-V and P-V Curves

The design of the simulink equivalent of the photovoltaic system is very important for analyzing the performance and efficiency of photovoltaic systems. PV solar panels are used while generating electricity from solar energy. These solar panels have no harmful effects on the environment during the generation and use of electricity. PV cells are manufactured semiconductor materials converting sunlight into electrical energy. Solar panels are created by combining photovoltaic cells in series and parallel (Villalva et al., 2009; Farivar et al., 2010). The values on the PV panel label are the values determined under standard conditions. In cases where the test results of the PV panel are less or more than the standard test conditions, the output power value of the PV panel may be less or more than the standard test conditions. The PV module consists of a solar cell connected in series, as given in Figure 2.

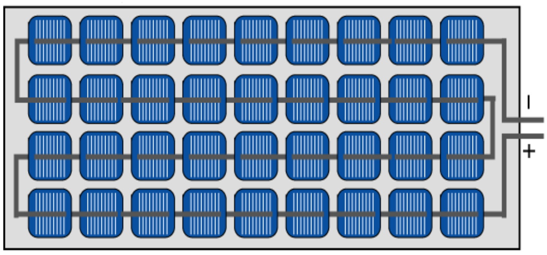

Figure 2. A typical Module with 36 Cells, Series Connected

Solar cells are made up of photovoltaic semiconductor materials. A silicon cell generates approximately 0,5 Volts of voltage. The desired PV module voltage and current value is achieved by connecting the cells in series. A small portion of the solar irradiation energy is absorbed on the PV panel surfaces and converted into electrical energy by the PV cells. The other part of the radiation is reflected back by PV cells. The type of material covering the panel surface is important in order to minimize this reflected part. Various PV cells are used to increase the absorption of the sun's radiation. PV cells made of mono-crystal have higher yields than those made of poly-crystal in environments where the temperature is too high (Özcelik., 2018; İzgi et al., 2013). When photovoltaic cells are connected in series with each other, the voltage increases and the current remains the same. In parallel combinations of cells, the voltage remains the same and the current increases. Solar panels are created by combining photovoltaic cells in series and parallel. In this way, both voltage and current magnitude increase. Solar panels get their energy from the sun, which is an endless source of energy. Another important reason why PV systems are preferred in energy production is that they are renewable energy systems and have not a negative effect on the environment. The efficiency of monocrystalline solar cells is higher than polycrystalline solar cells. While the efficiency of polycrystalline solar panels is around 15 percent, this value reaches 20 percent in monocrystalline solar panels.

MATERIALS AND METHODS

Material

The PV cells used for analysis of temperature effects on I-V and P-V have been measured in Mardin Artuklu University.

Solar Cell Single Diode Model

The maximum amount of power that the PV cells can give varies depending on the radiation, temperature and other environmental effects. Based on the values of these factors, the voltage, current and power values that can be produced by the PV cells change and the operating characteristics appear according to the conditions. In order to determine these characteristics, PV cells should be modeled. Single diode and double diode models are generally used in PV cell modeling. The PV cell equivalent circuit model consists of a photo- current source, diode connected in parallel to it, and resistors in series and parallel. The practical model of equivalent circuit single diode solar cell model is shown in Figure 3.

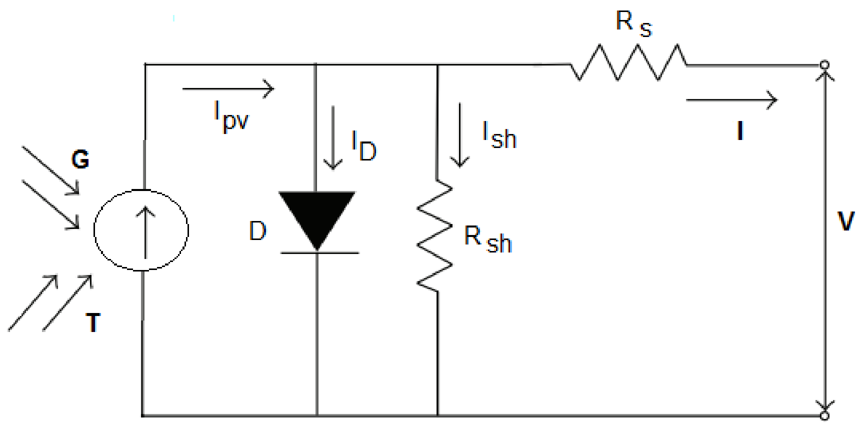

Figure 3. PV Cell Equivalent Circuit

Where, Iph is the photo-current, Rs represents series resistance of PN junction PV cell, n ideality factor of diode and Rsh is shunt resistance (Saleem et al., 2009; Mishra et al., 2016). Series resistor has great impact on the I-V characteristic of PV cell. Output current of the PV cell is given below.

$$I = I_{ph} - I_0 (e^{\frac{q(V+IR_s)}{nkT_c}} - 1) - \frac{V + R_s}{R_s} \quad (1)$$

Where, V is PV cell output voltage, I is current flowing through the load resistor, q is electron charge, Iph is photo-current, n diode ideality coefficient and k is the Boltzmann constant. PV cells, which are the most basic building blocks of PV systems are semiconductor elements. Solar Irradiation intensity and temperature, which are significantly effective on PV cell equivalent circuit parameters. In addition, parameters such as series circuit resistance (Rs), parallel circuit resistance (Rp), short circuit current temperature coefficient (µIsc) and open circuit voltage temperature coefficient (µVoc) have a significant effect on PV cell equivalent electrical circuit parameters. Therefore I-V characteristics are not linear. The most suitable semiconductor materials are materials such as silicon, gallium arsenide, cadmium. The power of the produced PV cells varies in proportion to the current passing through the circuit. In order to increase this current, it is necessary to increase the number of electrons and spaces in the photovoltaic structure. It is achieved by increasing the PV cell surface area. The PV cell equivalent circuit ideal model of is presented in Figure 4. It consists of a photo-current source and a diode (Prakash et al., 2016; Hassan., et al., 2017; Joga., et al., 2020). The configuration of ideal solar PV cell as given below.

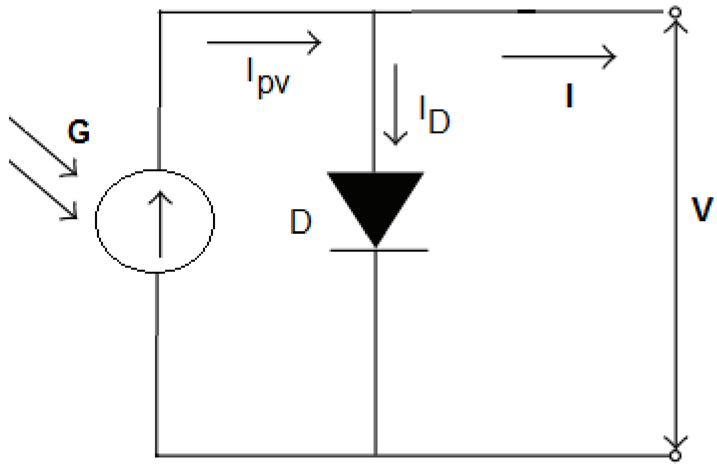

Figure 4. PV Cell Ideal Equivalent Circuit Model

Ideally, the equivalent circuit of a solar cell consists of a diode and a current source parallel to it. In Figure 4, G is the solar irradiance, Iph is the photo-current, Id is the diode current, n is diode ideality factor, I is output current of PV cell. Rsh is greater than the series resistor Rs (Nema et al., 2010; Malla et al., 2012). When we take Rsh = ∞, the value of Ish can be neglected because it is value very small. The output current of the PV cell as given below.

$$I = I_{ph} - I_0 (e^{\frac{q(V+IR_s)}{nkT_c}} - 1) \quad (2)$$

The voltage induced in the PV cell is proportional to the light intensity incident on the cell surface (Özdemir et al., 2017; Rustemli et al., 2011). The open circuit voltage (Voc) of a PV cell is the voltage measured at the cell end terminals when the current flowing through the cell is zero. The main effect of the increase in solar cell temperature is on the open circuit voltage. Open circuit voltage decreases with cell temperature. The voltage value with the highest power determined by using the current-voltage curve of the cell or panel. It is found by the following equation.

$$V_{oc} = \frac{nkT}{q} Ln(\frac{I_{ph}}{I_o} + 1) \quad (3)$$

Open circuit voltage in the solar cell is the voltage value measured at both ends when no load is connected to the solar cell. It is the voltage value we see when we measure the plus and minus ends of the cell with an avometer at maximum irradiance intensity of 1000 (W/m^2). This value is a criterion for the efficiency, quality, of the panel's cells. The open circuit voltage value decreases as temperature increases. If a load is connected to the output terminals of the PV cell, a current flows through the load. PV cell diode current is as given in equation (4).

$$I_d = I_0(e^{\frac{qV}{nkT}} - 1) \tag{4}$$

When the photovoltaic cell is not excited by light energy, it behaves like a standard diode. Any PV cell model is based on diode behavior, which gives to PV cell its exponential characteristic. The PV cell acts as a current source and the photo- current (Iph) it produces is proportional to the irradiation it receives from the sun. PV cell Iph equation is given below:

$$I_{ph} = [I_{sc} + K_i(T - 298)]\frac{G}{1000} \tag{5}$$

In this equation, Isc is current flowing in case of direct short circuit of the positive and negative power outputs of the cell or panel with no load. G is the irradiance value and Isc is the short circuit current, This current occurs when the ends of the panel are short-circuited. and is theoretically the highest current a solar panel can produce. The photovoltaic cell is made of semiconductor materials that absorb the rays emitted by the sun and convert it into electric current. Photo-current depends on temperature, solar irradiation and short circuit current. The simulink circuit of the photo-current is as given in Figure 5.

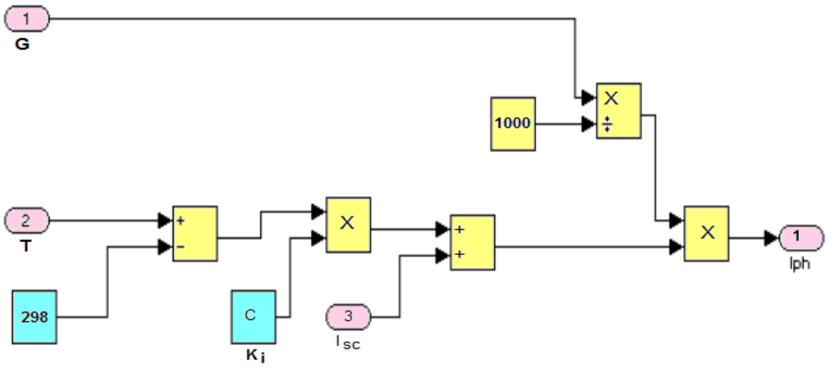

Figure 5. Simulink Model of PV Cell Photo-Current

The photo-current source is directly proportional to photon falling on the to cell surface. The current at maximum point as defined by Eq. (6).

$$I_{mp} = I_{ph} - I_0(e^{\frac{q(V_{mp}+I_{mp}R_s)}{nkT_c}} - 1) - \frac{V_{mp} + I_{mp}R_s}{R_{sh}} \tag{6}$$

The current value with the highest power, which is determined by using the current-voltage curve of the PV cell or panel. Mathematical models of PV cells are to relate the relationship between the current and voltage values of the PV cell with the irradiation intensity falling on the cell and the surface temperature of the cell. In some cases, analytical expressions are used for open circuit temperature coefficient and short circuit temperaturen coefficient to calculate parameters instantaneously. To use PV models, the values of the circuit parameters should be determined. Reverse saturation current of diode can be defined by the following equation (7).

$$I_o = Io_{ref}(\frac{T}{T_{nom}})^3 \exp[(\frac{T}{T_{nom}} - 1)\frac{E_q}{nV_t}] \tag{7}$$

Where I_0, ref is diode saturation reverse current in the referred cell temperature condition. Eg is the band gap energy of the diode and Vt is the thermal voltage (Rustemli et al., 2011; Çelik et al., 2020). The diode reverse saturation current is as given in Figure 6.

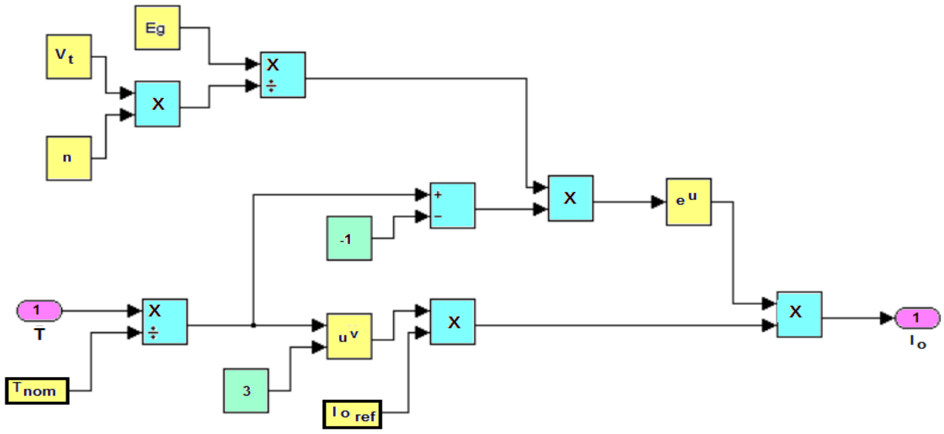

Figure 6. Simulink Model of Diode Reverse Saturation Current

The diode reverse saturation current is a parameter that changes depending on the temperature and short circuit current. Since the diode reverse saturation current changes with temperature, the changes in monthly temperature averages cause this current to change as well. Voltage and current values of PV panels vary according to atmospheric weather conditions (Md Tofael, 2013). As the amount of solar radiation coming to the photovoltaic panel surface increases, the current at the panel output increases. As the ambient temperature increases, the open circuit voltage at the panel terminals decreases, so the maximum power value that can be obtained from a photovoltaic system depending on operational conditions varies.

Simulation of The PV Cell's Single Diode Equivalent Model

In the PV cell, the photon current is highest in sunny and full open air, whereas in cloudy or overcast weather, the photon current decreases depending on the amount of irradiation from the sun (Yilmaz et al., 2014; Savitha et al., 2014). In addition, decreases in short circuit current (Isc) are observed in cloudy weather. Generally, solar cells are exposed to inhomogeneous solar irradiation all day long. Even if the solar panel is subjected to a small shading effect, the output power of the PV panel is considerably reduced. In the case of shadowing in PV panels, many maximum power points occur in the P-V curve. Only one of these power points are general and the others are local points. One effective way to increase the efficiency of the PV module is to reduce the operating temperature of the PV module surface. Solar cell P-V characteristic curve is given in Figure 7.

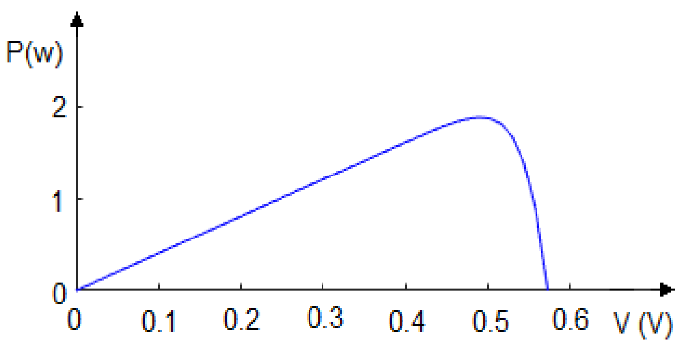

Figure 7. P-V Characteristic Curve of the PV Cell (at T=25 °C and G=1000 W/m^2)

The highest power (Pmp) value that can be obtained by determining the I-V curve of a solar cell. The electricity energy produced by the PV cell increases depending on the sunshine duration of the region. Shading in any PV cell also affects the performance parameters of another PV cell (Gumus et al., 2018; Motahhir et al., 2017). The shading on the PV cell surface causes the efficiency of the system to decrease. In order to reduce the reflection on the panel surface, which causes low efficiency in the PV panel, the type of material that the panel surface is covered should be reflects the radiation at the least amount. The efficiency of PV solar panels is very low, in order to benefit from them in the most efficient way, PV systems must be operated at the maximum power point [Hussein, 2017). The I-V characteristic curve of the PV cell as given in Figure 8.

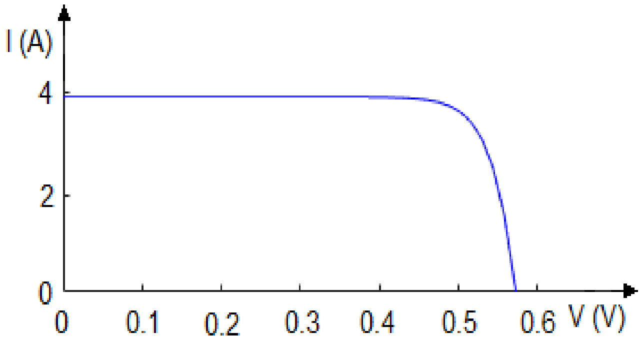

Figure 8. I-V Characteristic Curve of the PV Cell (at T=25 °C and G=1000 W/m^2)

Solar panel efficiency depends on the cell type used, cell design and quality, and the quality of glass and other components. Since the amount of light is minimal in rainy weather, the amount of electricity generated will not be enough to fill the batteries in off grid systems. Therefore, when designing the system, attention should be paid to the number of rainy days in the region. PV cells give maximum efficiency when they are directed to the south facade. Output power tolerance of PV panels is between ± 2,5% and ± 5%. The P-V and I-V characteristic of PV module is shown in Figure 9.

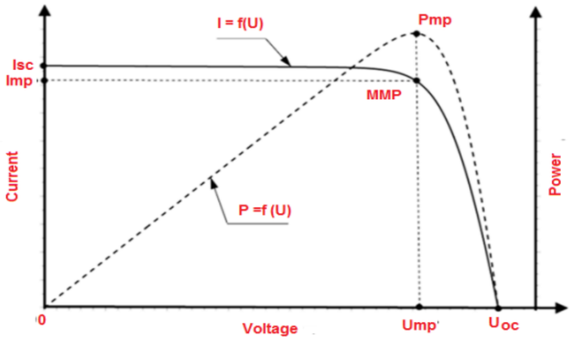

Figure 9. The Power- Voltage P-V And Current–Voltage I–V Characteristic of the PV Module

PV cells provide different output power values depending on the change of solar irradiation and temperature value. PV solar panels are tested in an ideal 25 (°C) temperature, 1000 (W/m^2) solar irradiation and 1,5 AM (Air Mass) environment. According to this environment, the efficiency and the effects of the panels are calculated. As the panel receives the sun's rays, electricity generation starts, but due to the fact that the efficiency is not 100%, some of the energy from the sun turns into electrical energy and some of it is transferred to the environment as heat energy. This event causes the PV panels to heat up, while the current increases with the heating of the solar cells, the voltage value decreases more than the current. Due to the high drop in voltage, the output power decreases and this causes a decrease in efficiency (Salmi et al., 2012; Utma et al., 2017). The maximum power expression is as follows calculated:

$$P_{mp} = I_{mp} * V_{mp} \tag{8}$$

The purpose of this research was not only to perform the next implementation of the mathematical model of the PV cell, but also to ınvestıgate the effects of ambient temperature on PV cell I-V and P-V characteristics. If the PV cell power tolerance of a 280 W panel is 4%, the actual output power varies between 291,2 W and 268,8 W. This tolerance value increases the mismatch losses in the PV system. PV panels with low tolerance should be chosen in practice. The power value generated by the PV cell varies depending on the pollution rate of the cell surfaces and the cloudiness of the air. Increasing the temperature decreases the efficiency significantly. The principle scheme of PV panel, PV module and PV cell is as given in Figure 10.

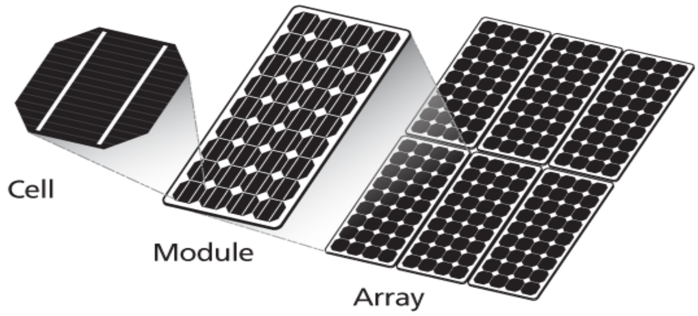

Figure 10. Schematic Representation of PV Cell, Module and Array

Considering their 25-30 years of service life, they shuld be resistant to weather conditions, heat-cooling, corrosion, physical impact and sunlight, and have a waterproof feature. PV panels shuld be produced in accordance with international quality standards. The PV solar cell generates a voltage between 0,5 and 0,7 volts depending on the type of semiconductor. Therefore, the cells shuld be connected in series configuration to increase the voltage of the PV module. To create a PV array when PV modules are connected to each other in series and parallel configurations. Hence, the total power of the PV solar system increases.

Effects of Different Ambient Temperature on I-V and P-V Curves of Pv Cell

PV cell temperature changes in proportion to the change of ambient temperature and irradiation from the sun. Since the amount of decrease in voltage is greater than the amount of decrease in current the output power of the PV cell decreases. Whereas low temperatures do not affect the efficiency of PV panels, high temperatures adversely affect the output power. PV cell temperature at different ambient temperatures is calculated from eq. (9).

$$T_c = I_{amb} + (\frac{NOCT - 20}{0.8})G \tag{9}$$

Here, Tc represents PV cell temperature (^{O}C), Tamb is ambient temperature (^{O}C), G is solar irradiation (W/m2) at the Nominal Operating Cell Temperature (NOCT). It is not true that the efficiency of PV cells is high at high temperatures. In this paper complete model of the PV system containing solar PV cell is simulated in simulink program. The I-V and P-V characteristics are obtained from different values of temperature. Monocrystalline solar panel features are composed of single-cell crystals, high efficiency and providing more electricity in small sizes are some of the reasons why these panels are in demand. There are many factors that affect the PV panel efficiency. These; panel inclination angle, shading, dusting, solar radiation intensity, temperature and wiring losses. Solar irradiation intensity and panel temperature are the most important parameters affecting panel efficiency. The decrease in solar irrradiation intensity also decreases the power of the PV cell. The relationship between cell temperature and PV cell power is inversely proportional. So; the power of the cell decreases as the ambient temperature increases. Table 1 shows PV Cell's Single Diode Equivalent Circuit Parameters.

Table 1. PV Cell's Single Diode Equivalent Circuit Parameters

Parameters	Value
Boltzmann's Constant (k)	1.3806488×10^{-23}
Electron Charge (q)	1.6×10^{-19} (C)
Saturation Current (Io)	1×10^{-10} (A)
Diyode Ideality Factor (n)	1.3
Short Circuit Current of PV cell (Isc)	3.885(A)
Series Resistance of PVcell (Rs)	0.001 (Ω)
Shunt Resistance of PV cell (Rsh)	1000 (Ω)
Band Gap Energy (Eg)	1.11
Temperature Coefficient (Ki)	0.0017 (A/ºC)
Solar Irradiation (G)	1000 (W/m^2)

In this study, the effect of temperature on the PV cell I-V and P-V characteristic curves were analyzed. Effective use of photovoltaic solar cells is capable of being an important factor in reducing greenhouse gas emissions and preventing environmental pollution. The temperature effects on I-V and P-V have been measured in Mardin Artuklu University, in Figure 11.

Figure 11. Measurement of solar panel temperature and other parameters

There are many factors that affect the efficiency of PV cells. Temperature change is a very effective variable that needs to be analyzed for efficiency. While low temperatures do not cause any problems for the efficiency of the PV cell, high temperatures significantly affect the output power negatively. Table 2 shows values of solar cell current and voltage at different ambient temperatures.

Table 2. Values of solar cell current and voltage at different ambient temperatures

Solar Cell voltage (at 50 ºC)	Solar Cell current (at 50 ºC)	Solar Cell voltage (at 30 ºC)	Solar Cell current (at 30 ºC)	Solar Cell voltage (at 10 ºC)	Solar Cell current (at 10 ºC)
0.08682	4.00	0.09262231	3.98082	0.0811127	3.93569
0.18328	4.02286	0.1852668	3.93863	0.191012	3.92101
0.281672	3.95425	0.268113	3.91021	0.314566	3.92197
0.399357	3.88571	0.387833	3.90635	0.43034	3.90383
0.441801	3.88572	0.45939	3.76622	0.505925	3.54711
0.472669	2.85714	0.494644	3.21899	0.535513	2.87406
0.484244	2.33143	0.512602	2.60253	0.549841	2.02066
0.4996678	1.37143	0.528719	1.89457	0.559942	1.54913
0.535466	0.594285	0.537164	1.14065	0.562478	0.920014
0.511254	0.0457143	0.547868	0.043875	0.574899	0.044075

When the number of serial cells increases, the open circuit increases and the short circuit current value remains constant. Likewise, when the number of parallel cells increases, the current increases and the open circuit voltage does not change. The I-V characteristic curves of the PV solar cell I-V characteristic curves at different ambient temperatures are as shown in Figure 12.

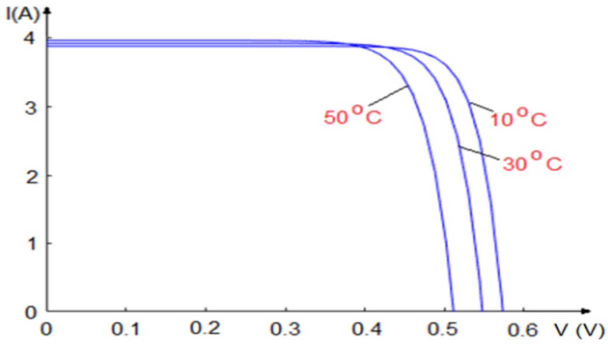

Figure 12. PV Cell I-V Characteristic at Different Ambient Temperatures

The effect of temperature on the PV cell is due to the cells being semi-conductive. Temperature has a direct effect on current transitions in semiconductors. Low temperatures do not adversely affect efficiency, high temperatures reduce productivity significantly.

Table 3. Values of solar cell power and voltage at different ambient temperatures

Solar Cell voltage (at 50 ºC)	Solar Cell power (at 50 ºC)	Solar Cell voltage (at 30 ºC)	Solar Cell power (at 30 ºC)	Solar Cell voltage (at 10 ºC)	Solar Cell power (at 10 ºC)
0.0979753	0.390318	0.0942254	0.390381	0.091700	0.370323
0.195976	0.790687	0.195963	0.780637	0.182151	0.730617
0.298976	1.19097	0.295201	1.17093	0.287664	1.14091
0.395664	1.54111	0.374339	1.48117	0.363026	1.43110
0.446925	1.55030	0.447126	1.71110	0.437101	1.69117
0.474111	1.29859	0.48710	1.69033	0.505976	1.79052
0.489896	0.926467	0.506874	1.50910	0.550296	1.24706
0.500706	0.574527	0.526245	1.00626	0.563355	0.694081
0.506566	0.262871	0.539354	0.493478	0.567890	0.322146
0.511272	0.0316367	0.547514	0.0209795	0.572526	0.0306107

PV cells made of mono-crystal have higher efficiency than those made of polycrystal in environments where the temperature is very high. There is an inverse proportion between the power output of the PV cells and the cell temperature. As the cell temperature increases, PV cell output power decreases. PV cell P-V curves of different ambient temperatures are as given in Figure 13.

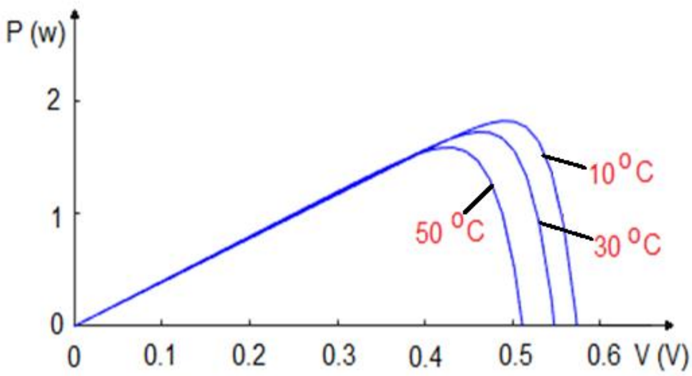

Figure 13. PV Cell P-V Characteristic Curves at Different Ambient Temperatures

Temperature affects some parameters in the circuit and changes the characteristics of the panel. In this study, PV cell was modeled and the effects of different ambient temperature values on I-V and P-V were analyzed. These two characteristics give important clues about the conditions under which the power taken from the PV cell reaches its highest value. It is an important research subject to get maximum power from solar cell at the highest efficiency at all times. Contrary to what is known, it was observed that the power value produced by the PV cell decreased at high temperature values. In PV cells, some of the irradiation from the sun is absorbed and converted into electrical energy. The other part is reflected back from the module surface without being absorbed by the PV cells. The other part of the radiation is reflected back by the PV cells. In order to minimize this reflected part, the type of material covering the surface of the cell is important. Various PV cells are used to increase the absorption of the sun's irradiation.

CONCLUSION

As a result of this study, it shows that the idea of more energy production in hot weather is not correct. Energy production and efficiency are increased when the panel temperature decreases due to air circulation in hot places. On the other hand, energy production and efficiency are decreased in hot regions where there is no air circulation. The I-V and P-V curves are obtained from generalized PV cell model by simulation and effects of ambient temperature on the I-V and P-V curves were analyzed with the simulation program. Hence, when the ambient temperature is increased I-V and P-V curves which results decreasing in output power and voltage. While the ambient temperature 50oC and voltage 0,18328 V then the PV cell output current is 4.02286 A. However, the PV cell output current drops to 3.92101 A while the ambient temperature 10oC and voltage 0.191012 V. When temperature of enviroment is increased, the cell temperature rises accordingly. This situation leads the losses to occur in the PV panels so that these PV panels are being cooled to minimize such these losses. Before positioning the PV panels in the area where the solar facility will be installed, annual temperature values and sunshine duration in the region are investigated and positioning should be done accordingly. As the panel temperature increases, PV panel output power decreases. While the ambient temperature 50oC and voltage 0,446925 V then the PV cell output power is 1,55030 W. However, the PV cell output power rises to 1,69117 W while the ambient temperature 10oC and voltage 0,437101 V. The losses caused by temperature are proportional to the PV solar cell temperature. When the temperature of the environment increases, the PV solar cell losses increases. For this reason, it has been determined that the output power and temperature of the PV panels are inversely proportional to each other. PV variables such as open circuit voltage, short circuit current, peak output power, filling factor and efficiency are generally affected by cell temperature, while the highest level of exposure occurs at open circuit voltage. Therefore, the open circuit voltage of the PV cell is very sensitive to the cell temperature. Open circuit voltage, high giving filling factor short circuit current increases with temperature while output power decreases with temperature. Therefore, the temperature coefficient is negative for open circuit voltage, filling factor and highest output and positive for short circuit current.

ACKNOWLEDGEMENTS

"MAU. BAP.20.MYO.015" numbered this Project; supported by Mardin Artuklu University-Scientific Research Projects Coordinator ship. The authors thank for the support.

Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have conributed equally for the manuscript.

REFERENCES

Çelik AN, Koça F, 2020. Polikristal Tür bir Fotovoltaik Panelin I-V Karakteristiğinin Analitik Modellenmesi ve Deneysel Doğrulanması. Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 8: 2491-2515.

Farivar GB, Asaei B, 2010. Photovoltaic module single diode model parameters extraction based on manufacturer datasheet parameters. In Proc. International Conference IEEE Power Energy, 929–934.

Gumus B, Kılıc H, 2018. Time dependent prediction of monthly global solar radiation and sunshine duration using exponentially weighted moving average in southeastern of Turkey. Thermal Scıence, 22(2): 943-951.

Hassan ZS, Li H, Kamal T, Arifoğlu U, Mumtaz S, Khan L, 2017. Neuro-Fuzzy Wavelet Based Adaptive MPPT Algorithm for Photovoltaic Systems. MDPI energies, 10(3): 1-16.

Hussein A, 2017. A simple approach to extract the unknown parameters of PV modules. Turkish Journal of Electrical Engineering Computer Sciences, 25: 4431 – 4444.

İzgi E, Akkaya YE, 2013. Exergoeconomic analysis of a solar photovoltaic system in. Istanbul, Turkey. Turkısh Journal Of Electrıcal Engıneerıng And Computer Sciences, 21: 350-359.

Joga G, Rao G, Lokesh HG, Mounika G, Navya Sai Kuma DP, 2020. Modelling and Design of Solar PV Cell Using Matlab/Simulink. International Journal of Scientific Research in Science, Engineering and Technology, 7(2): 50-55.

Malla SG, 2012. Novel Control of Photovoltaic based Water Pumping System without Energy Storage. International Journal of Emerging Electric PowerSystems, 4(13): 2.

Md Tofael A, 2017. Modelization and Characterization of Photovoltaic Panels. Masters in solar Energy Engineering, Unıversıdade De Évora.

Mishra S, Manish Kumar Madhav K, 2016. Design and simulation study of solar photovoltaic array using simulink model. International Journal of Research and Development in Applied Science and Engineering (IJRDASE), 11(1): 1-4.

Motahhir S, El Ghzizal A, Sebti S, Derouich A, 2017. MIL and SIL and PIL tests for MPPT algorithm. Cogent Engineering, 4: 1-17.

Nema S, Nema RK, Agnihotri G, 2010. MATLAB/Simulink based study of photovoltaic cells/modules/array and their experimental verification. International journal of Energy and Environment, 1(3): 487-500.

Özçelik MA, 2018. Increasing energy efficiency for integrating small scale pv power generation to grid system. The International Journal of Materials and Engineering Technology1(1): 1-7.

Özdemir A, Erdem Z, 2017. Double-loop PI controller design of the DC-DC boost converter with a proposed approach for calculation of the controller parameters. Journal of Systems and Control Engineering, 232(2).

Prakash R, Sandeep Singh S, 2016. Designing and Modelling of Solar Photovoltaic Cell and Array. Journal of Electrical and Electronics Engineering (IOSR-JEEE), 11(2): 35-40.

Rustemli S, Dincer F, 2011. Modeling of Photovoltaic Panel and Examining Effects of Temperature in Matlab/Simulink. Electronics and Electrical Engineering, 3(109): 35-40.

Saleem H, Karmalkar S, 2009. An analytical method to extract the physical parameters of a solar cell from four points on the illuminated J-V curve. IEEE Electron Device Letters, 30: 349 – 352.

Salmi T, Bouzguenda M, Gastli A, Ahmed Masmoudi A. 2012. Matlab/Simulink Based Modelling of Solar Photovoltaic Cell. Internatıonal Journal of Renewable Energy Research, 2(2).

Savitha PB, Shashikala MS, Puttabuddhi KL, 2014. Modelling of Photovoltaic Cell/Module under Environmental Disturbances using Matlab/Simulink. International Journal of Engineering Trends and Technology (IJETT), 9(1): 48-55.

Utma A, Özçelik MA, Yılmaz AS, 2017. The Desıgn Of A Smart Energy Management System For Microgrids. International Journal of Energy and Smart Grid (IJESG), 2(2): 34-42.

Villalva MG, Gazoli JR, Filho ER, 2009. Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays. IEEE Transactions on Power Electronics, 24(5): 1198-1208.

Yilmaz AS, Kececioglu OF, Tekin M, Ozalp A, Sekkeli M, 2014. A Field work for Power Quality in City Centers: A casestudy of Kahramanmaras City. Academic Platform Journal of Engineering and Science (APJES), 2(3): 22-34.