Modeling and Simulation of Photovioltaic Cell with Matlab for Different Temperature and Different Solar Radiation

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Abstract

In this paper the photovoltaic (PV) effect is studied for different Environment parameters (solar radiation and temperature). Modern research focuses on the renewable energy sources such as solar energy. Solar energy can be converted in to electricity by using photovoltaic cells. The photovoltaic system is a mechanism that allows the transformation of solar radiation into electricity (convert photon energy into the form of electrical signals in a PN silicon junction or other material) that we can use for our needs, for example in the electricity supply of an apartment or in the electricity supply of electricity distribution operators in public networks. The PV cells have nonlinear nature, so numerical methods are preferred in these cases. Numerical results are generated by MATLAB software and they are presented graphically. In this study, PV cell specification characteristic curves current-voltage and power-voltage have been obtained for different temperature at constant irradiance and different irradiance at constant temperature. From this graph we can see the effect of irradiance and temperature on the current and voltage. Finally, we have presented power-voltage characteristic curves of photovoltaic cell for different solar radiation in Durres city.

Keywords: PV effect, solar energy, photovoltaic cells, characteristic curves.

1. Introduction

The phenomenon of converting light into electric current was first studied in 1839 by the French Physicist Becquerel (Becquerel, 1839; Williams, 1960). By conducting an experiment, at age 19, Becquerel discovered the photovoltaic effect (Becquerel, 1839). In this way, he created the first solar cell in the world. Initially, in the 1870s the photovoltaic effect was first studied in solids, such as the element selenium. Later, in the 1980s, the selenium solar cell had a small efficiency of 1%-2% in converting light into electricity (https://www.nrel.gov/docs/legosti/old/1448.pdf).
In the years 1940-1950, an important development of photovoltaic cells took place, advancing their technology and in 1954, the efficiency of a silicon photovoltaic cell reached 4%, then 6% and then 11% (Durand, 1979; Stiller, Eichler, and Kilar, 1980). In 1981, the photovoltaic cell could transform 1 kW of solar energy per square meter into about 100 W of electricity. 100 W of electricity can power most household appliances such as a television, an electric typewriter or an electric lamp (Durand, 1979; Stiller, Eichler, and Kilar, 1980).
As of 2017, typical photovoltaic cells produce around 265 watts of power and photovoltaic cell efficiency is closer to 20%. So, we will have photovoltaic cells that produce energy of 210, 280, even 320 watts. Panels with a high yield and efficiency are more expensive and at these values they would be suitable to install in your home only if you have different things in your home.

Most solar panels around the world are installed on roofs or building walls. Here are the top three best solar panel manufactures in 2019 ranked based on the highest efficiency solar panel they have to offer: Sun Power (22.2%), LG (21.1%), and Panasonic (20.3 %) (https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/). Maps compiled in 2016 suggest that by 2030 the photovoltaic cells could supply around 13% of global electricity (https://solarpowerrocks.com/solar-basics/how-much-electricity-does-a-solar-panel-produce/; https://www.ashden.org/sustainable-energy/ashden-guides/solar-for-the-grid).
The territory of Albania is located in a convenient position to use solar panels because it has a Mediterranean climate with hot summers with a large amount of radiation in the long summer days. Also, the territory of Albania has a mild winter with a lot of rain, thus possessing a significant potential solar energy: most areas of Albania are exposed to more than 1500 kWh/m^2 per year ranging from 1185 to 1690 kWh/m^2 per year (http://aea-al.org/wp-content/uploads/2012/04/renewable-energy-albania.pdf). So, Albania is a very good place to install solar panels. Therefore, in this work we have studied photovoltaics for different temperatures and radiations. Also, a specific case of the dependence of electric power on electric voltage, in a city in Albania, Durres, has been examined.
The remainder of this paper is organized as follows. Section 2 describes the materials and methods used in this study. We use a single diode model and a numerical technique, such as an iterative method. In section 3, we describe our results and discussion, and our conclusions are presented in section 4.

2. Materials and methods

The study of solar cells in the mathematical and physical aspect by modeling them then we will make it possible updating them, so that researchers have a better understanding of their work. Their modeling varies according to the respective software that is used for them, such as the well-known software, MATLAB (Xuan and Minh, 2015).
In this article using this software we calculate and graphically present the electric current as a function of the electric voltage for different values of temperature and radiation. Electrical power as a function of electrical voltage is also calculated and presented graphically.
In the MATLAB software environment, there is a function that is used to calculate the current and electrical power for a given value of electrical voltage, solar radiation, and temperature. For more about this, see the studies done by Walker, 2001; Gonzalez and Longatt 2005. Here, the effect of temperature, solar irradiation, and diode quality factor and series resistance is evaluated. A difficulty of this method is to require readers programming skills so it is not easy to follow. Another method which is the combination between MATLAB m-file and C-language programming is even more difficult to clarify (Gow and Manning 1999). This model is made only in MATLAB, based on mathematical equations that define the photovoltaic cell. From the work of Walker, 2001, Gonzalez and Longatt, 2005 and Oi, 2005 a function in MATLAB (Ramos, Zamora, Campayo, 2010) has been developed which calculates the current module from data of voltage, solar radiation and temperature. Setting the constant temperature or radiation, characteristic curves current-voltage and power-voltage will be obtained. From another script also calculates the maximum power point (Sharma, Ansari, Panday, 2013).
Mathematical models used to study photovoltaic cells are different. They are used to better understand the behavior and performance of solar cells. Two of the common methods are Single-

Diode Model, which is called Shokley Model and Double-Diode Model (Jakhrani et al., 2014; Karatepe, Boztepe, and Colak 2006).
The analytical expression for the current in a PV cell, according to the model is:

$$I = \frac{G}{G_n}\left[I_{pvn} + K_i(T - T_n)\right] - I_{on}\left(\frac{T}{T_n}\right)^3 \exp\left[\frac{eE_g}{ak_B}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right]\left[exp\left(\frac{e(V+IR_s)}{aN_s k_B T}\right) - 1\right] - \frac{V+IR_s}{R_{sh}}.$$

In the above formula, the quantity G represents the solar radiation, G_n gives the nominal radiation, K_i represents the short circuit temperature coefficient, T_n - nominal temperature, T-operating temperature, I_{pvn} - rated solar current at nominal weather conditions, e and k_B are the charge of electron and Boltzmann's constant, a-ideality factor of the diode (De Soto, Klein, and Beckman, 2006; Karatepe, Boztepe, and Colak, 2006), N_s is the number of the PV modules connected in series, V-voltage across the diode and I_{on} is reverse saturation current of PV cell for nominal temperature and irradiance values and E_g is band-gap energy of silicon (Goss et al., 2017; Md.W.Shah, Robert L.Biate, 2016; Savita Nema, R.K.Nema, Gayatri Agnihotri, 2010).

3. Results and discussions

In this paper, photovoltaic cell specification characteristic curves current-voltage and power-voltage have been obtained for different temperature at constant irradiance and different irradiance at constant temperature.
In Figure 1, the temperature varies from 10^{o}C to 50^{o}C at nominal irradiance so in this case we can see the effect of cell temperature on current and voltage. The curve presented in this figure with sky-colored dots represents the dependence of the electric current on the electric voltage for $T = 10$ ^{o} C, curve with green dots for $T = 20$ ^{o} C, curve with blue dots for $T = 30$ ^{o} C, curve with pink dots for $T = 40$ ^{o} C and curve with red dots for $T = 50$ ^{o} C.
The current-voltage characteristics are presented in figure 2 by different irradiance from 700 W/m^2 to 1100 W/m^2 at constant temperature. In this case we can see the effect of irradiance on current and voltage. Figure 3 show the power- voltage curves for five different temperature. The maximum electric power in this case is for $T = 10$ ^{o} C. This is represented on the graph through the ink-sky color curve.
Figure 4 shows the P-V characteristic curve for some values of solar radiation. The maximum electrical power in this case is for G_5 = 1100 W/m^2. This is shown in the graph through the red curve. Table 1 shows the distribution of the global average daily radiation in Durres (http://www.akbn.gov.al/images/pdf/energji-te-rinovueshme/Energjia_Diellore.pdf). Figure 5 show the P-V characteristic curves for different irradiance in Durres City. For G=6802 W/m^2 is the maximum power. This is shown in the graph through the black curve.

City	Durres
January	1840 (W/m^2 per day)
February	2559 (W/m^2 per day)
March	3504 (W/m^2 per day)
April	4693 (W/m^2 per day)
May	5730 (W/m^2 per day)
June	6557 (W/m^2 per day)
July	6802 (W/m^2 per day)

August	6029 (W/m^2 per day)
September	4751(W/m^2 per day)
October	3235 (W/m^2 per day)
November	2018 (W/m^2 per day)
December	1567 (W/m^2 per day)

Table 1. The daily average of solar radiation in Durres (http://www.akbn.gov.al/images/pdf/energji-te-rinovueshme/Energjia_Diellore.pdf).

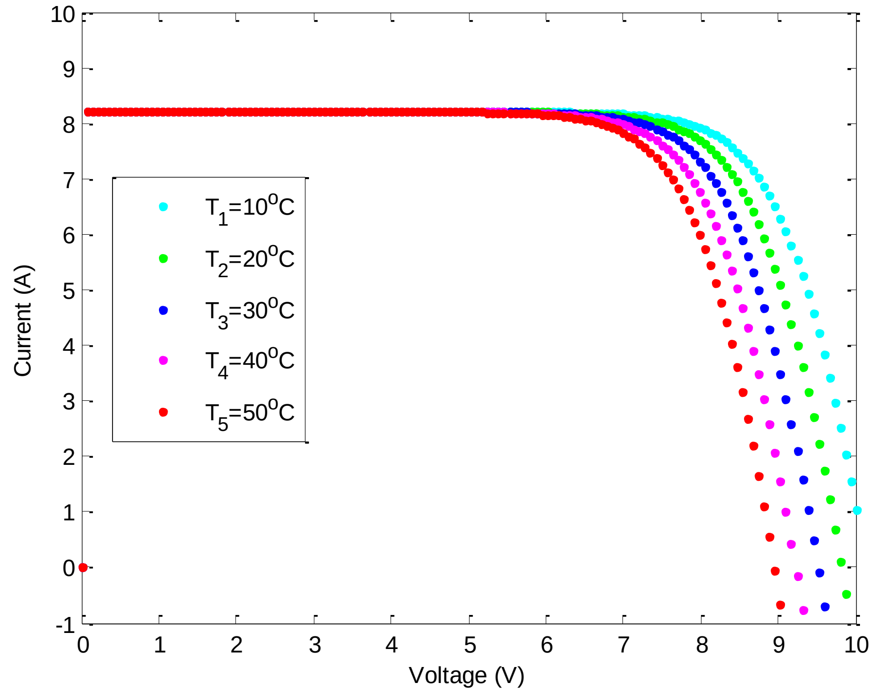

Figure 1. Effect of photovoltaic cell temperature in the current-voltage characteristic curves.

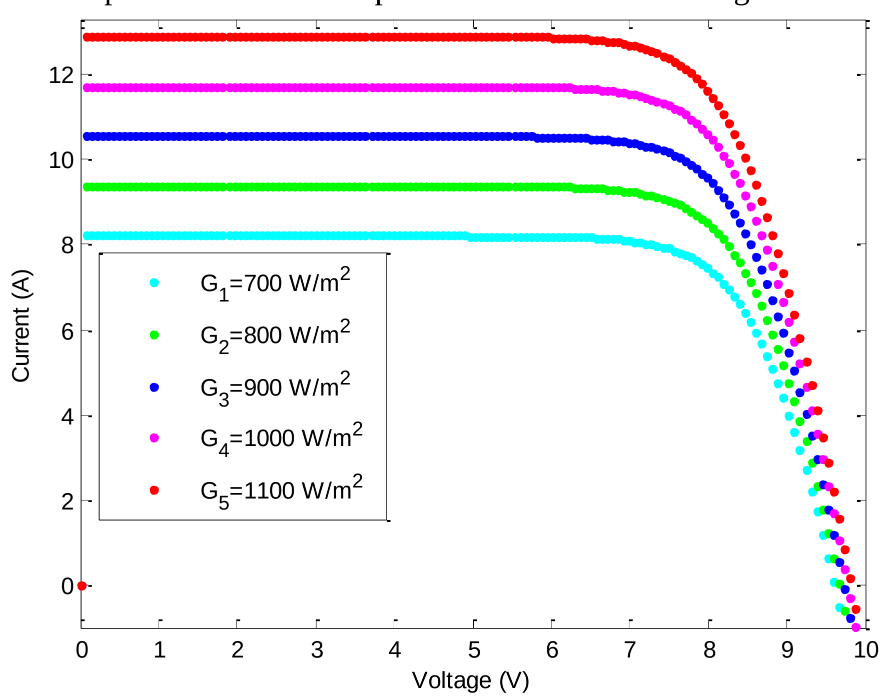

Figure 2. Current-voltage characteristic curve of photovoltaic cell for different solar radiation intensities (irradiance).

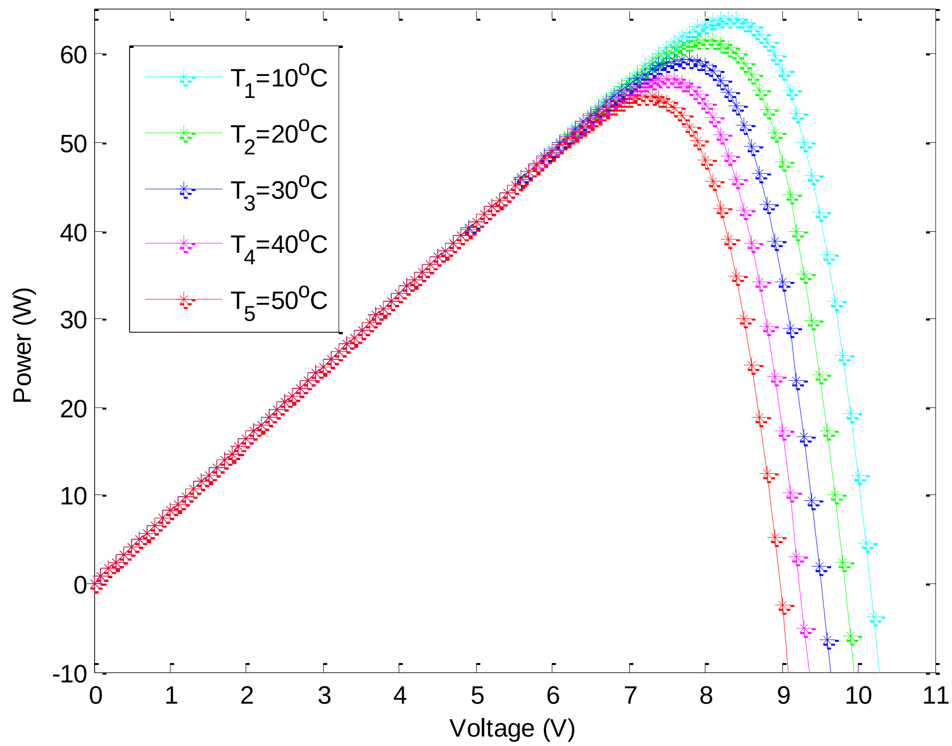

Figure 3. Power-voltage characteristic curves of photovoltaic cell for different temperature and constant irradiance.

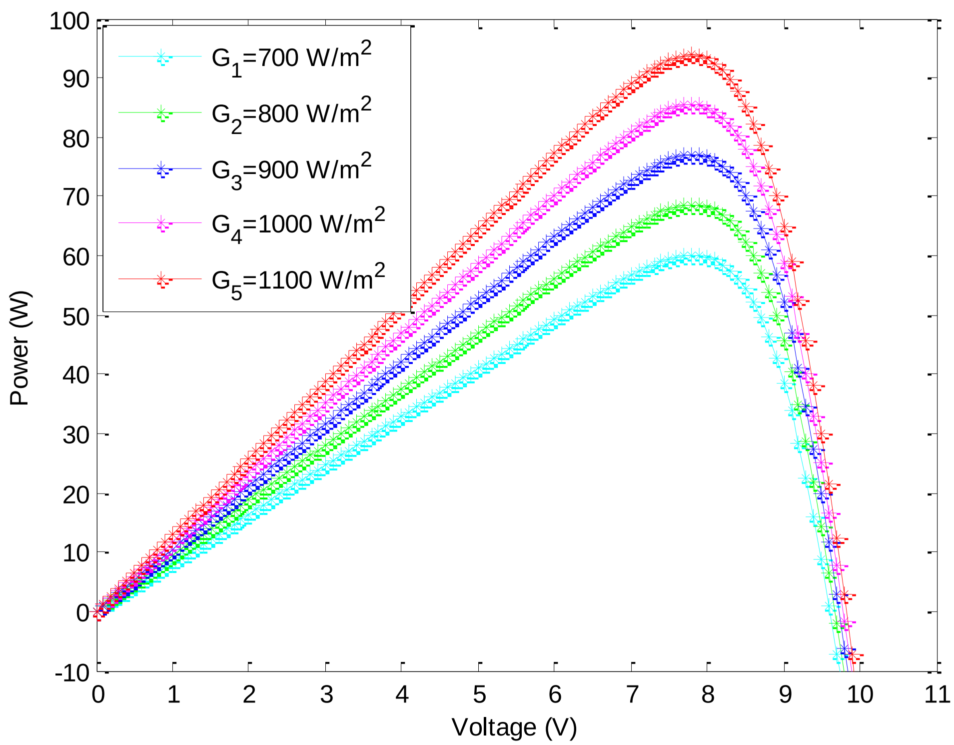

Figure 4. Power-voltage characteristic curves of photovoltaic cell for different irradiance.

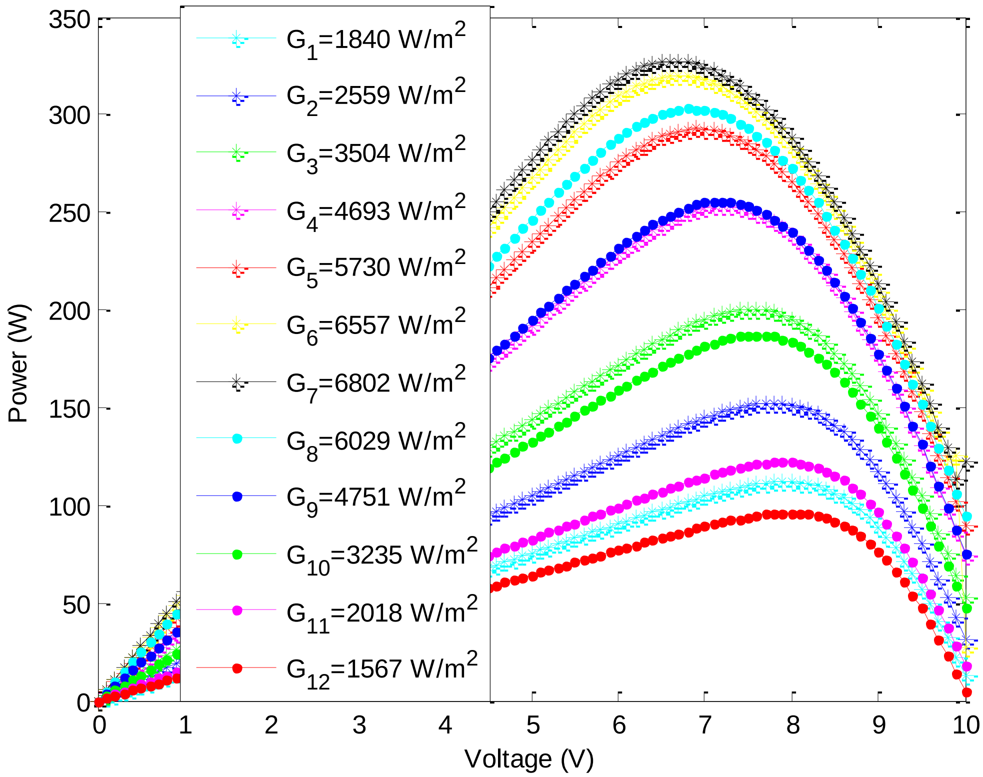

Figure 5. Power-voltage characteristic curves of photovoltaic cell for different irradiance for one year in Durres city.

4. Conclusions

In the 2012 a photovoltaic cell could convert into power 15% of the sun hitting energy. As of 2017, typical PV panels produce around 265 W of power and photovoltaic cell efficiency is closer to 20%. In the 2018 PV panels produce around 320 W. The efficiency of solar panels (Sun Power- the best solar panel) in 2019 is 22.2%. People use solar energy for transforming solar power into electricity. Solar energy is part of renewable energy and this type of energy is clean and free from environmental damage. In this paper, the MATLAB software used to get the current-voltage curves and power-voltage curves of photovoltaic systems for different temperature and different solar radiation. When the temperature increases the voltage decreases and the produced current remains practically constant. After a certain value of the electric voltage, the electric current decreases immediately. Another important conclusion is the fact that the power and electrical voltage of photovoltaic cells tend to decrease at high temperatures. This has no such effect on the electric current of photovoltaic cells. So, high temperatures do not have a good effect on photovoltaic cells.

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