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MODELING AND SIMULATION OF PHOTOVIOLTAIC CELL WITH MATLAB FOR DIFFERENT TEMPERATURE AND DIFFERENT SOLAR RADIATION

Abstract

In this paper the photovoltaic (PV) effect is studied for different Environment parameters (solar radiation and temperature). The PV effect was first studied in solids, such as selenium, in the 1870. In the 1980, selenium solar-cell was built exhibited 1%-2% efficiency in converting light to electricity. In the 1920 and 1930, quantum mechanics laid the theoretical foundation for our present understanding of PV cells. 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.

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.

In this research, MATLAB used to get the power-versus-voltage characteristics curves for photovoltaic cells. These curves used to calculate the specifications of a photovoltaic cell system such as short circuit current, open circuit voltage, power and maximum power. Equivalent circuit of photovoltaic cell and mathematical model for photovoltaic cell and array are examined in this research.

The numerical results are shown in the graph. 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 graphs 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 irradiance in Durres.

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

1. Introduction

The physical phenomenon responsible for converting light to electricity-the photovoltaic effect-was first observed in 1839 by a French physicist, E. Becquerel. Becquerel noted a voltage appeared when one of two identical electrodes in a weak conducting solution was illuminated. The PV effect was first studied in solids, such as selenium, in the 1870s. In the 1980s, selenium solar-cell was built exhibited 1%-2% efficiency in converting light to electricity. In the 1920s and 1930s, quantum mechanics laid the theoretical foundation for our present understanding of PV. A major step forward in solar-cell technology came in the 1940s and early 1950s when a method was developed for producing highly pure crystalline silicon. In 1954, work at Bell Telephone Laboratories resulted in a silicon photovoltaic cell with a 4% efficiency. Bell Labs soon bettered this to a 6% and then 11% efficiency, heralding an entirely new era of power-producing cells. In 1981, photovoltaic cell was capable of transforming one kilowatt of solar energy falling on one square meter into about a hundred watts of electricity. One hundred watts can power most household appliances: a television, a stereo, an electric typewriter, or a lamp [22-27].

The improvement of new vitality sources are ceaselessly upgraded due to the basic circumstance of the synthetic chemical powers. Therefore, the inexhaustible vitality sources turned into a more critical patron to the aggregate vitality devoured on the planet. Truth be told, the interest for sunlight based vitality has expanded by 20% to 25% in the course of recent years. With a specific end goal to get advantage from the utilization of PV systems, explore exercises are being led trying to increase promote change in their cost, productivity and unwavering quality, therefore numerical displaying of sun powered cells is fundamental for any operation yield improvement [1].

In the 2012s photovoltaic cell could convert 15% of the energy hitting them from the sun into power. As of 2017, typical photovoltaic cells produce around 265 watts of power and photovoltaic cell efficiency is closer to 20%. That can vary based the size and efficiency of the solar panel you choose; you'll see photovoltaic cells that produce 210, 280, even 320 watts. More efficient panels are a little more expensive, and are usually only needed if you have limited space on your roof. 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 %) [32]. Maps compiled in 2016 suggest that by 2030 the photovoltaic cells could supply around 13% of global electricity [28, 29].

The territory of Albania is located in the western part of the Balkan Peninsula, at the eastern coast of Adriatic and Ionian seas. It is situated between latitudes 39º38' - 42º38' and longitudes 19º16' - 21º04' east. Thanks to this geographical position, Albania belongs to Mediterranean climate belt with hot dry summer, with long days of sunshine and mild winter with abundant rainfall, possessing in this way a considerable solar potential energy: most areas of Albania are exposed to more than 1500 kWh/m^2 per year varying from 1185 to 1690 kWh/m^2 per year [30]. So Albania is a very good place for installation of solar panels.

2. Methodology

Mathematical modeling of photovoltaic cells is being continuously updated to enable researchers to have a better understanding of its working. The models differ depending on the types of software researchers used such as MATLAB. [4]. A function in MATLAB environment has been developed to calculate the current output from data of voltage, solar irradiation and temperature in the study of (Walker 2001) and (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 [17], Gonzalez [18] and Oi [19] a function in MATLAB [20] 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 [10].

The analytical expression for the current in a PV cell, according to the model is:

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

where a is ideality factor of the diode, V is the voltage across the diode, N_s is the number of photovoltaic cells modules connected in series, k_B=1.381×10^{-23} J/K is the Boltzmann's constant,), e = 1.602×10^{-19} C is the electron charge, T is operating temperature in Kelvin (K), I_{pvn} is rated solar current at nominal weather conditions (25^oC and 1000 W/m^2) or short circuit current, K_i is short circuit temperature coefficient, G is solar irradiance in W/m^2, G_n is nominal irradiance in normal weather conditions (25°C and 1000 W/m^2) and T_n is nominal temperature = 298.15 K.

3. Results

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°C to 50°C at nominal irradiance so in this case we can see the effect of cell temperature on current and voltage. The current-voltage characteristics are presented in figure 2 by varying 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 different temperature. Figure 4 show the P-V curves for different irradiance.

The effect of increasing irradiance while temperature was fixed is increasing the output and short circuit current, the output voltage almost not affected very much. Some physical parameters used in this paper have been assumed in order to accomplish the work. Nevertheless, the current-voltage equation is a transcendental expression. It has no explicit analytical solution. The analytical methods give exact solutions by means of algebraic equations. However, due to implicit nature and nonlinearity of photovoltaic cell or module characteristics, it is hard to find out the analytical solution of all unknown parameters. Analytical methods have also some limitations and could not give exact solutions when the functions are not given. Thus numerical methods preferred in this case. It is because of the fact that numerical methods give approximate solution of the nonlinear problems without searching for exact solutions.

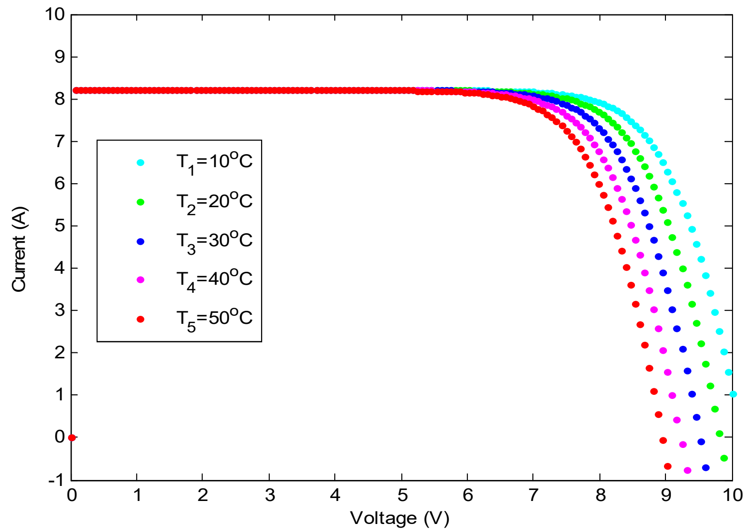

Figure 1. Effect of photovoltaic cell temperature in the current-voltage characteristic curves.

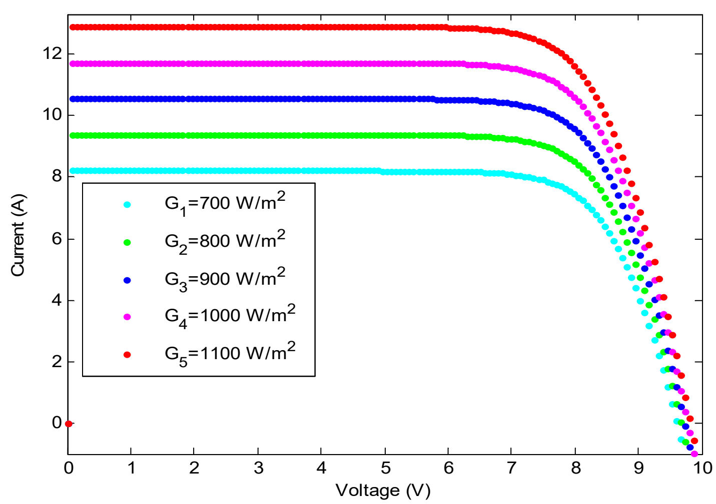

Figure 2. Current-voltage characteristic curve of photovoltaic cell for different solar radiation intensities (irradiance).

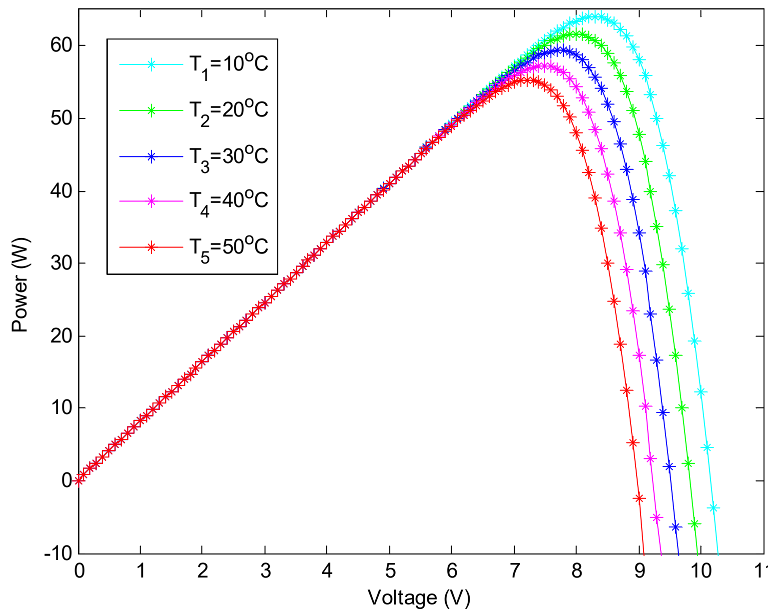

Figure 3. Power-voltage characteristic curves of photovoltaic cell for different temperature and constant irradiance.

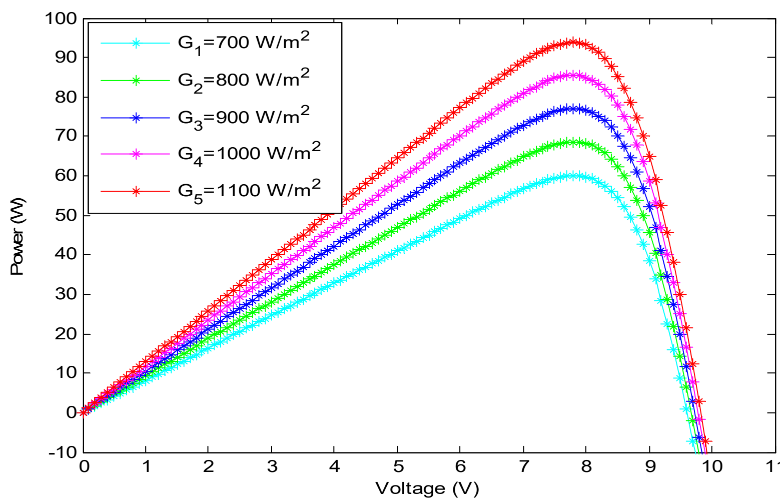

Figure 4. Power-voltage characteristic curves of photovoltaic cell for different irradiance.

Table 1 shows the distribution of the global average daily radiation in Durres [33]. Figure 5 show the P-V characteristic curves for different irradiance in Durres.

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 [33].

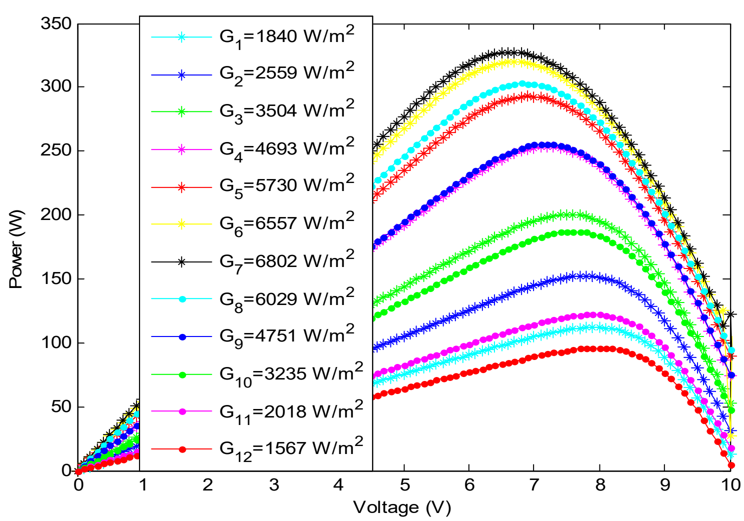

Figure 5. Power-voltage characteristic curves of photovoltaic cell for different irradiance for one year in Durres.

4. Conclusions

In this paper, MATLAB 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 as seen in figure 1. Figure 3 show that a higher temperature at constant irradiance produces a decrease power. So the voltage and the photovoltaic cell output power tend to decrease at higher temperatures, but there is no noticeable effect on the photovoltaic cell current. Thus, it is important to keep the cell temperature as low as possible, because higher temperatures have negative effect on output power of photovoltaic cell. On the other hand, the effect of irradiance on photovoltaic cell, it reveals that higher irradiance gives higher current and higher power (for this conclusion sees figure 3 and figure 5 respectively). In the next article we will publish some other interesting results.

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