INFLUENCE OF TEMPERATURE AND SOLAR RADIATION ON THE POWER OF PHOTOVOLTAIC PANELS

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Abstract. *There are many factors that lead to low panel efficiency, such as panel angle, shading, dust, solar radiation level, temperature and other losses. Among these factors, solar radiation levels and temperature are more prominent. The level of solar radiation varies throughout the year. The average annual variation in the level of extraterrestrial solar radiation is 1367 W/m^2 and is shown by dotted lines. On the other hand, the level of solar radiation falling on the Earth is less than the level of extraterrestrial solar radiation and varies depending on the geographical location of countries. Changes in atmospheric conditions such as solar radiation levels and temperature during the day have a major impact on the panel's efficiency. Therefore, it is very important to know the level of solar radiation and the effect of temperature on the photovoltaic panel. In this paper we examine the equivalent circuit of the panel and carries out simulations in MATLAB using standard photovoltaic panel data, and also studies the influence of temperature and solar radiation on the power and current-voltage characteristics of the photovoltaic panel.*

Keywords*: solar energy; tilt angle; South side, annual optimal inclination angle, monthly inclination angle, solar radiation.*

Introduction

In recent years, there has been a high demand for electricity due to population growth and the pace of industrialization. Most of the electricity is generated from fossil fuels such as oil, natural gas, etc. However, there are many environmental problems associated with the use of fossil fuels. Moreover, the fact that these energy sources will run out in the near future and renewable energy sources will have to be used in the future. Solar energy, one of the renewable energy sources, indirectly influences the formation of other renewable energy sources. In addition, solar energy has become more attractive because it is clean, renewable and easy to use [1, 2].

The solar cell is the smallest part of a photovoltaic system that directly converts solar radiation into DC voltage. Solar cells form a photovoltaic module by connecting in series or parallel. A photovoltaic panel with the required values of current, voltage and power are obtained by connecting modules in series-parallel [3, 4]. Solar energy in a photovoltaic panel is converted into electrical energy with an efficiency of 6-20% depending on the semiconductor material used in the photovoltaic panel. There are many factors that lead to low panel efficiency, such as panel angle, shading, dust, solar radiation level, temperature and other losses [5, 6]. Among these factors, solar radiation levels and temperature are more prominent. The level of solar radiation varies throughout the year.

The average annual variation in the level of extraterrestrial solar radiation is 1367 W/m^2 and is shown by dotted lines. On the other hand, the level of solar radiation falling on the Earth is less than the level of extraterrestrial solar radiation and varies depending on the geographical location of countries [7]. Changes in atmospheric conditions such as solar radiation levels and temperature during the day have a major impact on the panel's efficiency. Therefore, it is very important to know the level of solar radiation and the effect of temperature on the photovoltaic panel. However, in the catalogs, which are carried out in laboratory conditions and are called standard, panel manufacturers provide only the electrical characteristics of the photovoltaic panel at a solar radiation level of 1000 W/m^2, a cell temperature of 25 °C and an air mass flow rate of AM 1.5. As a result, the electrical parameters of a PV panel other than STC are unknown. It is necessary to know the electrical parameters of photovoltaic panels under atmospheric conditions. Taking these conditions into account, especially when designing autonomous and networked systems, will give more accurate results [8, 9].

The solar radiation directly affects the power of the panel

Solar energy is converted into electrical energy directly using semiconductor materials used in photovoltaic (PV) panels. Despite great advances in semiconductor materials technology, panel efficiency has remained quite low in recent years. Panel performance is affected by many factors such as tilt angle, shading, dust, solar radiation, temperature and conductor losses. Among these factors, the more important are the level of solar radiation and temperature. The level of solar radiation hitting photovoltaic panels varies depending on the location of the panel and time intervals per day. Thus, the level of solar radiation directly affects the power of the panel. As a result, decreased solar radiation reduces the power of the panel. On the other hand, there is an inverse proportion between temperature and panel power. In other words, the panel's power decreases as the ambient temperature rises

Many researchers have developed a model of photovoltaic panels in Matlab/Simulink program depending on the basic equivalent circuit of the photovoltaic cell, taking into account environmental factors such as solar radiation and temperature [10-12]. In these studies, the equivalent circuit of the photovoltaic panel is modeled in MATLAB with Using standard panel values and the effects of changes at temperatures of 0, 25, 50 °C and 200, 400, 600, 800, 1000 W/m^2, solar radiation levels are investigated by panel current, voltage and power. The results section evaluates the most appropriate temperature and solar radiation levels for PV panels depending on the simulation analysis.

1. Mathematical model of a photovoltaic cell.

Obtaining the equivalent circuit of a photovoltaic cell plays a crucial role in studying the electrical energy obtained from photovoltaic panels. Solar cells are modeled as diodes because they are made from semiconductor materials. The current-voltage characteristic of a solar cell acts as a diode when it is not receiving solar radiation. Electricity generation in a solar cell is represented by the current source, and losses in photovoltaic cells are represented by series and parallel resistances. The electrical equivalent circuit of a photovoltaic cell is shown in Figure 1 [8].

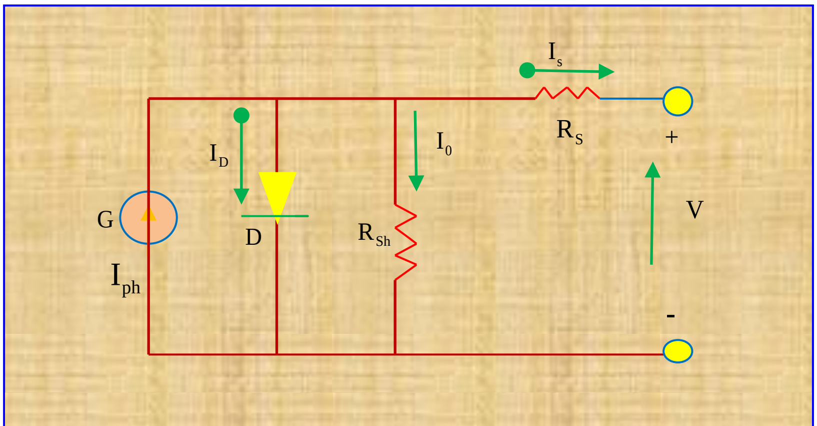

Figure 1. A practical model of a single solar cell

A practical model of a single solar cell is shown in Figure 1. In this circuit, Rs represents the series resistance of the PN junction cell and represents the shunt resistance, which is inversely proportional to the ground leakage current. The series resistor has a great influence on the I-V characteristic of the solar cell. and are the diode current and the shunt leakage current, where the output terminal current I is estimated by applying KCL in the solar cell equivalent circuit [3 - 5]

$$I = I_{ph} - (I_d - I_{sh}). \qquad (1)$$

Photon current is generated when solar radiation is absorbed by a solar cell, so the value of photocurrent is directly related to changes in solar radiation and temperature, namely [3]:

$$I_{ph} = (I_{scr} + k_i \Delta T)\frac{G}{G_r}. \qquad (2)$$

Where in this equation Iscor is the rated solar current under rated weather conditions (250C and 1000 W/m^2), k is the short circuit temperature coefficient. G - solar radiation in W/m^2, and G_r - nominal illumination in normal weather conditions (250°C and 1000 W/m^2). ΔT - difference between operating temperature and nominal temperature $(T - T_{rf})$. On the other hand, the reverse saturation current of the solar cell will be calculated using the formula [7]:

$$I_o = I_{rs}\left(\frac{T}{T_{rf}}\right)^3 \exp\left[\frac{qE_g}{nK}\left(\frac{\Delta T}{T_{rf} - T}\right)\right] \qquad (3)$$

Where I_{rs} is the reverse saturation current of the cell for nominal values of temperature and irradiance, and E_g is the band gap of the semiconductor material.

4. Effect of temperature on the performance of a photovoltaic system

An increase in temperature around the solar cell negatively affects the ability to generate electricity. An increase in temperature is accompanied by a decrease in the open circuit voltage, as shown in Fig .2. Increasing the temperature causes the material's band gap to increase, and therefore more energy is required to overcome this barrier. Thus, the power output will be reduced and hence the efficiency of the solar cell will be reduced. In Fig . 2 shows the V - P and I - P curves characteristics when the temperature of the solar cell changes.

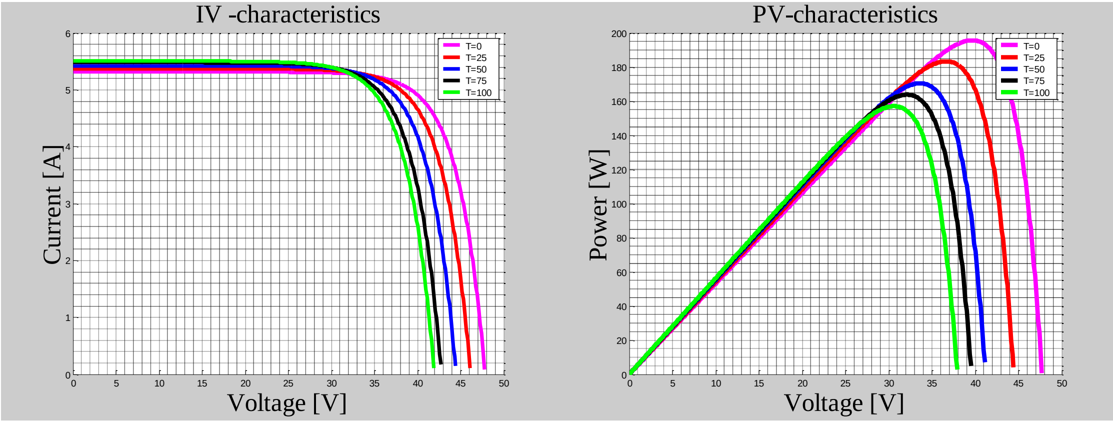

Fig. 2. Volt-ampere (I - V curve) and Volt-power (P - V curve) characteristics at different temperatures (temperatures with values of 0, 25, 50, 75 and 100 º C) under constant sunlight, respectively.

4. Values of short circuit current, open circuit voltage, maximum current, maximum voltage and maximum power of the photovoltaic panel

The values of short circuit current, open circuit voltage, maximum current, maximum voltage and maximum power of the PV panel were obtained at temperatures of 0, 25 and 50 °C and powers of 200, 400, 600, 800 and 1000 W/m^2 using Matlab software and the results are shown in tables.

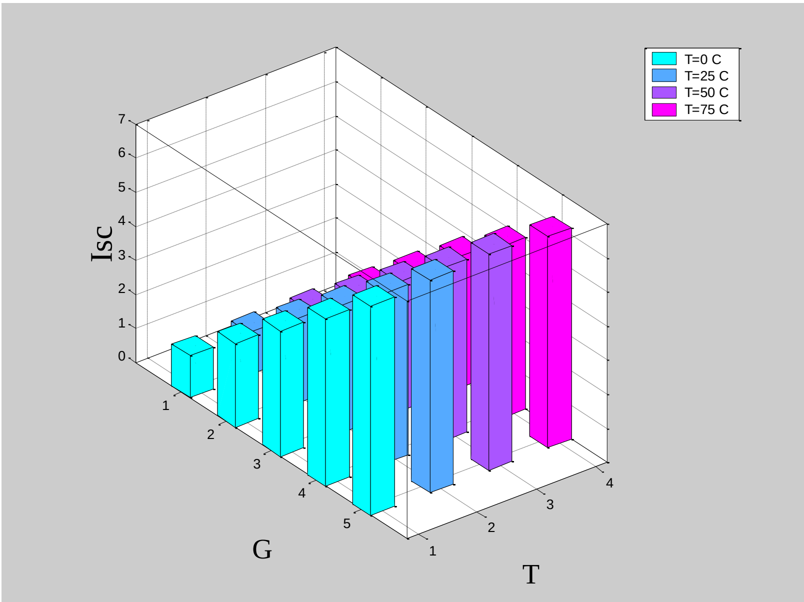

Fig.3. Changes in short circuit current of photovoltaic panel

The simulation results show that when the panel temperature is 0 °C, the short-circuit current and maximum panel current increase in proportion to the solar radiation level. On the other hand, there is a slight increase in open circuit voltage and maximum panel voltage. Thus, when the level of solar radiation increases from 200 W/m^2 to 1000 W/m^2, the panel power increases by 5.5 times. Similarly, when the solar radiation level gradually increases at panel temperatures of 25 and 50 ° C, the short circuit and maximum panel current increase proportionally. However, there is a slight increase in open circuit voltage and maximum voltage. When comparing panel temperatures below 0° C and 25° C, it can be seen that as the panel temperature increases there is a slight increase in short circuit current and the maximum current values are almost the same.

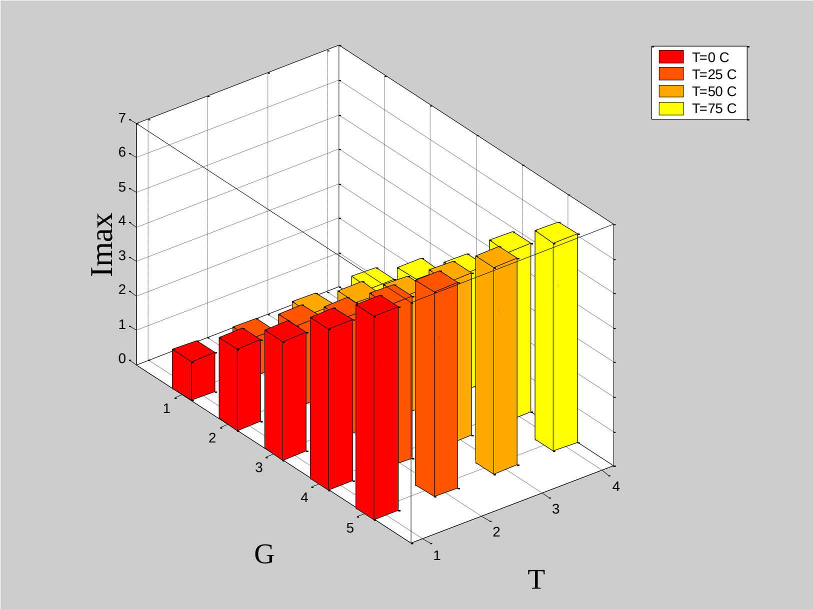

Fig.4. Maximum changes in PV panel current

6. Results and discussions

The simulation results show that although the panel current increases proportionally to the solar radiation level, the panel voltage increases slightly. Similarly, the power of the panel increases in proportion to the level of solar radiation. On the other hand, panel temperature causes a slight increase in panel current and a proportional decrease in panel voltage. The panel's power decreases because the rate of voltage drop is greater than the rate of current increase. The results show that low temperature and high solar radiation conditions are more suitable for the obtained power values.

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