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

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Abstract:

This paper examines an equivalent panel circuit and simulates in a MATLAB environment using standard photovoltaic panel data, and investigates the effects of temperature and solar radiation on the power and volt-ampere performance of a photovoltaic panel. Despite great advances in semiconductor material technology, the efficiency of panels has remained quite low in recent years. The efficiency of the panel is affected by many factors, such as tilt angle, shading, dust, solar radiation levels, temperature, and conductor losses. Among these factors, solar radiation levels and temperature are more important. The level of solar radiation reaching photovoltaic panels varies depending on the location of the panel and the time intervals per day. Thus, the level of solar radiation directly affects the power of the panel. As a result, a decrease in the level of solar radiation reduces the power of the panel. On the other hand, there is an inverse relationship between the temperature and the power of the panel. In this paper, we developed a model of photovoltaic panels in the Matlab/Simulink program depending on the basic photovoltaic cell substitution scheme, taking into account environmental factors such as solar radiation and temperature

Keywords: solar energy; angle of inclination; annual optimal angle of inclination, monthly angle of inclination, 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 by fossil fuels such as oil, natural gas, etc. However, there are many environmental challenges associated with the use of fossil fuels. Moreover, the fact that these energy sources will dry up soon and renewable energy sources 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].

A 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 in parallel. A photovoltaic panel with the required current, voltage, and power values is obtained by connecting modules in series and in parallel [3, 4]. The solar energy on the 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 levels, temperature, and other losses [5, 6]. Among these factors, the level of solar radiation and temperature are more prominent. The level of solar radiation varies throughout the year.

The average annual course of extraterrestrial solar radiation is 1367 W/m2 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 big impact on the panel's performance. 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 under laboratory conditions and are called standard, the panel manufacturers give only the electrical characteristics of the photovoltaic panel at a solar radiation level of 1000 W/m2, a cell temperature of 25 °C and an air mass flow rate of AM 1.5. As a result, the electrical parameters of a photovoltaic panel that differ from an STC are unknown. It is necessary to know the electrical parameters of photovoltaic panels under atmospheric conditions. Taking these conditions into account, especially in the design of autonomous and networked systems, will give more accurate results [8, 9].

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

The level of solar radiation directly affects the power of the panel.

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Many researchers have developed a model of photovoltaic panels in the Matlab/Simulink program depending on the basic photovoltaic cell substitution scheme, taking into account environmental factors such as solar radiation and temperature [10-12], In these studies, an equivalent photovoltaic panel circuit is modeled in MATLAB using standard panel values and change effects at temperatures of 0, 25, 50 °C and 200 °C. 400, 600, 800, 1000 W/m2 The levels of solar radiation by current, voltage, and power of the panel are examined. The results section evaluates the most appropriate temperature and solar radiation levels for photovoltaic panels based on the simulation analysis.

2. Mathematical model of a photovoltaic cell.

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

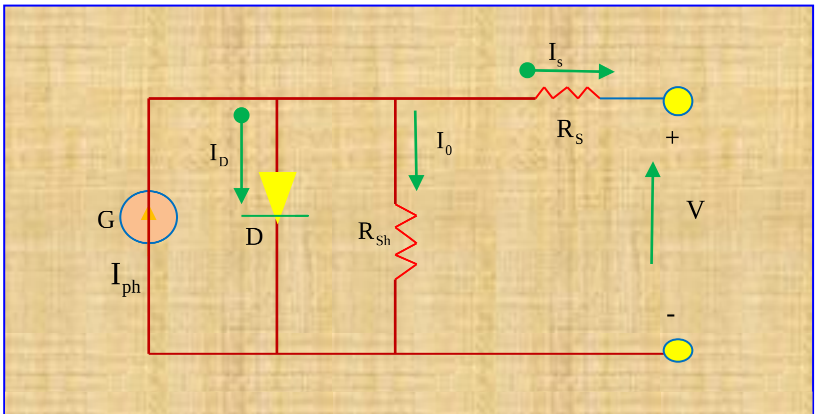

Рисунок 1. Эквивалентная схема фотоэлектрического элемента.

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

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

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

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$$I_{ph} = (I_{scr} + k_i DT)\frac{G}{G_r}. \quad (2)$$

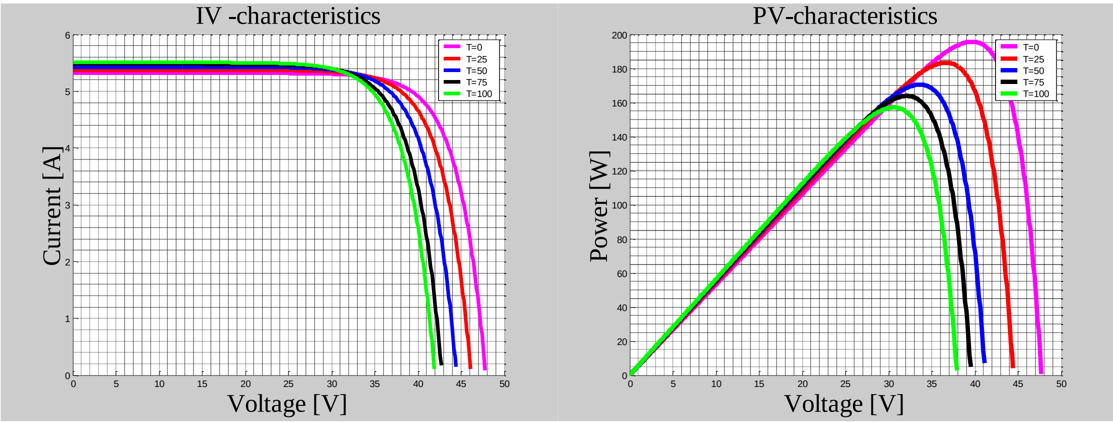
Where in this equation Iscr is the rated solar current under rated weather conditions (250C and 1000 W/m2), k is the short-circuit temperature coefficient. G is the solar radiation in W/m2, and is the G_r nominal illuminance under normal weather conditions (250°C and 1000 W/m2). DT - Difference between operating temperature and nominal temperature $(T - T_{rf})$. On the other hand, the reverse saturation current of a solar cell will be calculated using the formula [7]:

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

where I_{rs} is the reverse saturation current of the cell for the nominal values of temperature and energy illuminance, and is the E_g bandgap of the semiconductor material.

3. Effect of Temperature on PV System Performance

Rising temperatures around a solar cell have a negative impact on the ability to generate electricity. An increase in temperature is accompanied by a decrease in the open-circuit voltage, as shown in Fig. 2. An increase in temperature causes an increase in the bandgap of the material, and therefore more energy is required to overcome this barrier. In this way, the power output will be reduced and hence the efficiency of the solar cell will be reduced. Fig. Figure 2 shows the V-P and I-P curves as the temperature of the solar cell changes.



Rice. 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°C) under constant sunlight, respectively.

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

The short-circuit current, open-circuit voltage, overcurrent, maximum voltage, and maximum power of the photovoltaic panel were obtained at temperatures of 0, 25 and 50 °C and 200, 400, 600, 800 and 1000 W/m2 using the Matlab software. and the results are shown in the tables.

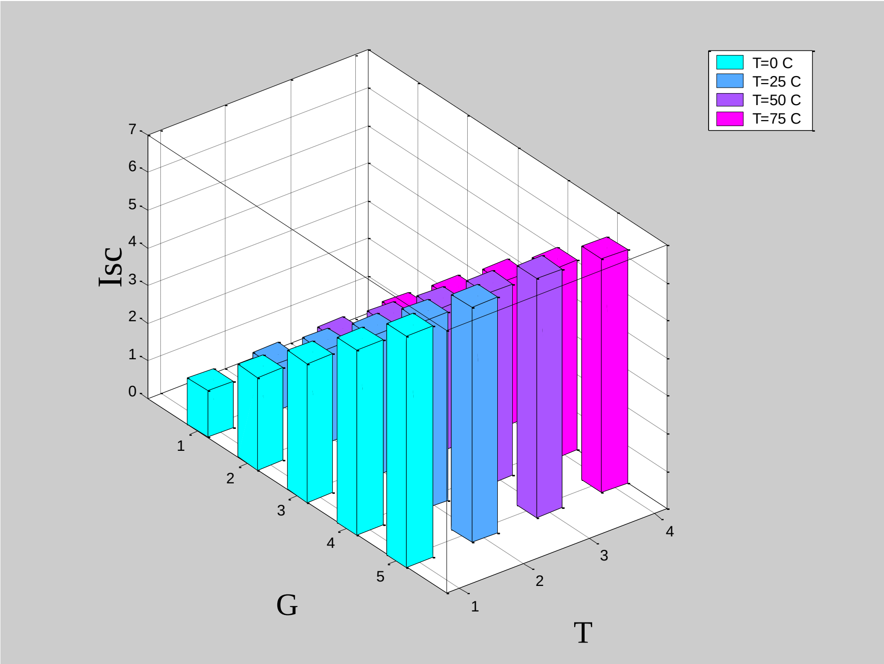

Fig.3. Changes in the short-circuit current of a photovoltaic panel

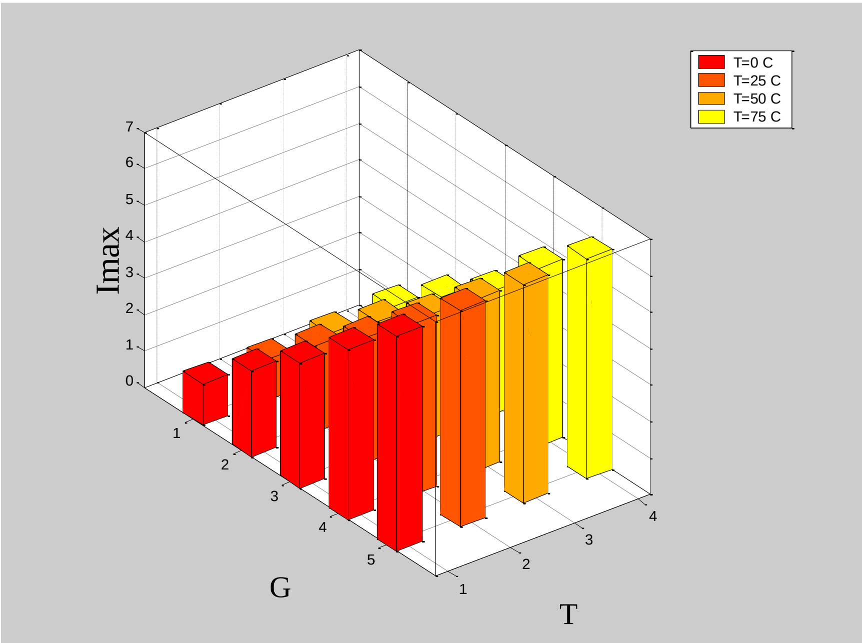

Fig.4. Maximum current changes of a photovoltaic panel

The simulation results show that when the temperature of the panel is 0°C, the short-circuit current and the maximum current of the panel increase proportionally to the level of solar radiation. On the other hand, there is a slight increase in the open circuit voltage and the maximum panel voltage. Thus, when the level of solar radiation increases from 200 W/m2 to 1000 W/m2, the power of the panel increases by 5.5 times. Similarly, when the solar radiation level gradually increases at the panel temperature of 25 and 50 °C, the short circuit and maximum current of the panel increase proportionally. However, there is a slight increase in open circuit voltage and maximum voltage. When comparing the panel temperature below 0°C and 25°C, it can be seen that as the panel temperature increases, there is a slight increase in the short-circuit current, and the maximum current values are almost the same.

5. Conclusions

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

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Table 2. Photovoltaic Panel Short Circuit Current Changes

Short-Circuit Current	Solar Radiation (W/m2)					Temperature
	200	400	600	800	1000	
Isc (A)	1.23	2.46	3.69	4.92	6.15	0°C
Isc (A)	1.25	2.5	3.75	5	6.25	25 °C
Isc (A)	1.27	2.54	3.81	5.08	6.35	50 °C
Isc (A)	1.26	2.58	3.86	5.04	6.20	75 °C

Table 4. Maximum PV Panel Current Changes

Max Current	Solar Radiation (W/m2)					Temperature
	200	400	600	800	1000	
Imax (A)	1.13	2.36	3.44	4.67	5.9	0°C
Imax (A)	1.12	2.37	3.44	4.69	5.94	25 °C
Imax (A)	1.19	2.37	3.41	4.7	5.99	50 °C
Imax (A)	1.26	2.38	3.39	4.9	6.04	75 °C

NOMENCLATURE	
k_B **= 1,381 e-23;**	Boltzmann constant, J/K
q **=1,602e-19;**	Electronic Charge, Cl
N **= 1.3;**	Diode Quality Factor
E_g **=1.12;**	Prohibition Zone Width, B
N_s **=36;**	Number of Consecutive Cells
T_{ref} **=0+273;%**	Temperature for which values are known
T_a **=25;**	Temperature for which you want to find values
V_{oc} **=22.06;**	Open circuit voltage, V

I_{sc} =**8.63;**	Short-circuit current, A
G =**1000;**	Illumination, W/m2
K_0 =**0.0058;**	Temperature coefficient
I_{ph} -	Current produced by incident light, A
I_s -	Diode Reverse Displacement Saturation Current, A
I_{sh} -	Shunt resistance, A
I_{sc} -	Short-circuit current, A
I_{pv} -	Output current, A
V_{pv} -	Terminal voltage, V
V_{ph} -	Photovoltaic voltage, V
I_d -	Diode current, A
V_{oc} -	Open circuit voltage, A
R_s -	Series resistance, ohms
R_{sh} -	Shunt Resistance, Ohm
n -	Diode Ideal Ratio
V_{mp} -	Voltage at the point of maximum power, V
I_{mp} -	Current at the point of maximum power, A
a	Diode ideal coefficient for one diode model.
V_T	Thermal voltage of the module, V
V_{OC}	Idle voltage, V
K_V	Open Circuit Voltage Temperature Coefficient
K_I	The temperature coefficient of the short-circuit current.