ANALYSIS OF THE EFFECT OF TEMPERATURE ON SOLAR PANELS AND THEIR COOLING METHODS

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Abstract

One of the most widely used renewable energy sources is solar energy, and it is predicted to continue to be so in the future. Recently, a great increase has been observed both in the study of the working principle of photovoltaic (electricity generated by the effect of light) devices and in increasing their efficiency. Solar cells change as a result of temperature fluctuations. The purpose of the article is the effect of temperature on the efficiency of solar panels and their cooling methods. The novelty. Solar cells change as a result of temperature fluctuations. Methods. Taking into account that the cooling system is implemented by spraying water, we can determine when the cooling starts at the moment when the temperature reaches the maximum by building a mathematical model. Results. In this article, the relationships between solar radiation, efficiency and temperature are determined under different conditions. Practical value. Based on the heating and cooling models, it was determined that starting the cooling process when the temperature of the panels reaches 45 0C is the most convenient method.

Keywords: temperature, photovoltaic elements, efficiency, effect of temperature, physical properties.

I. Introduction

Recent high energy consumption and fuel depletion have increased interest in renewable (solar) energy. Photovoltaic power is a technology that has seen tremendous growth in its use over the past 10 years. One of the most important problems faced by photovoltaic panels is heating caused by solar radiation and excessive temperature. High temperature heating reduces the efficiency of the panels. Depending on the temperature change between 0-75 celsius, the ideal characteristics of the solar panel also change. The characteristic is true as long as solar irradiance E and module temperature Tm are kept constant. If one of these two parameters changes, the entire characteristic changes. As the temperature of the solar panel increases, the maximum power output decreases. The temperature coefficient of the solar panels used in this study is 0.5%/^{0}C. Based on this coefficient, it can be seen that when the temperature rises by 1 Celsius, the efficiency decreases by 0.5%.

A solar cell is a semiconductor structure with p-n conductivity. Direct current is generated when the sunlight hits it. One of the most important problems faced by solar panels is overheating caused by solar radiation and extreme temperatures. It is known that high temperature heating reduces the efficiency of the panels. The ideal p-v characteristic of the solar panel according to the temperature change between 0-75^{0}C is shown in figure 1. In this characteristic, the relationship between the power produced by the solar panel and the voltage is given. The characteristic is paid as long as the solar irradiance E and the module temperature Tm are kept constant. If one of these two parameters changes, the entire characteristic changes [1-3].

The electrical scheme of photovoltaic elements is shown in the figure (Figure 1).

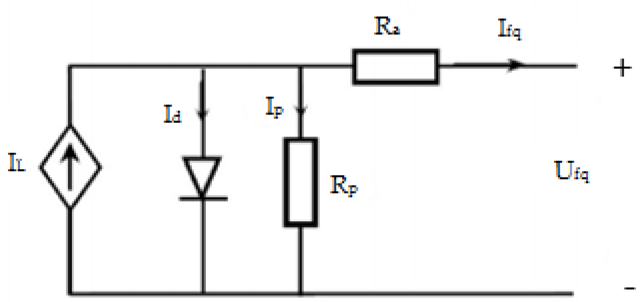

Figure 1: *Electrical scheme of photovoltaic cells*

Photovoltaic (FQ) curves differ with solar insolation and temperature modulus. Let's look at the formula below.

(1)

The change in temperature affects the solar cells and also the power. The voltage generated in FQ changes depending on the temperature [5]. As the temperature increases, the voltage decreases (Figure 2). Figure 2 shows the I-V characteristic of FQ at constant radiation. As the temperature decreases, the current of FQ decreases and its voltage increases [4-6].

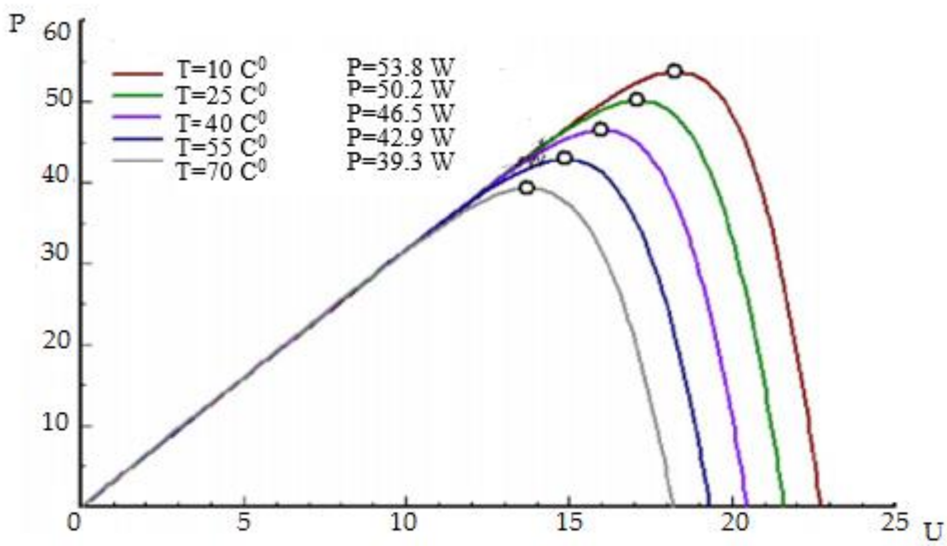

Figure 2: *I-V characteristic of FQ in constant radiation*

II. Materials and methods

The efficiency of solar cells is given by the following formula:

(2)

Here I_{max} and U_{max} are the maximum voltage and current respectively. Based on the air change function, let's take the temperature of the FQ module as T_P, and the temperature of the environment as T_x. Taking into account the effect of temperature on solar modules, we can write its useful efficiency as follows.

$$(T \quad)$$ (3)

Here, η_x is the useful work coefficient at the adopted temperature. The parameters η_x and β_x are normally supplied by photovoltaic cells. The temperature coefficient depends not only on the material of the FQ module, but also on T_x and is given as follows.

—— (4)

Here, T_0 is the high temperature that reduces the useful work coefficient to 0. For crystalline silicon solar cells, this temperature is up to 270^0 C. Convection is the main mechanism for spreading heat on the ground. The useful performance factor mainly depends on the installation of the module, the wind speed, the humidity of the environment and the characteristics of the module. The temperature of the module is measured under open circuit. When the temperature is 200 C, the brightness is 0.8 W/m2 and the wind speed is 1 m/s.

Figure 3 shows the dependence of efficiency on temperature in case of solar radiation of 1000 W/m2. As can be seen, there is a linear relationship between temperature and efficiency. As the temperature increases, the efficiency decreases. As a result, we can get the efficiency we want by changing the temperature.

The degree of cooling of solar panels is one of the important factors that have a high impact on their quality. Therefore, we can find the cooling period by determining the cooling rate of the panel. The cooling period is determined based on the energy balance. Since solar cells are mainly made of glass, the physical properties of the glass should be taken as the physical properties of the panels. The temperature of the panel was respectively 45 ^{0}C before cooling and 35 ^{0}C after cooling. It is assumed that the maximum permissible temperature is 45 ^{0}C [7-11].

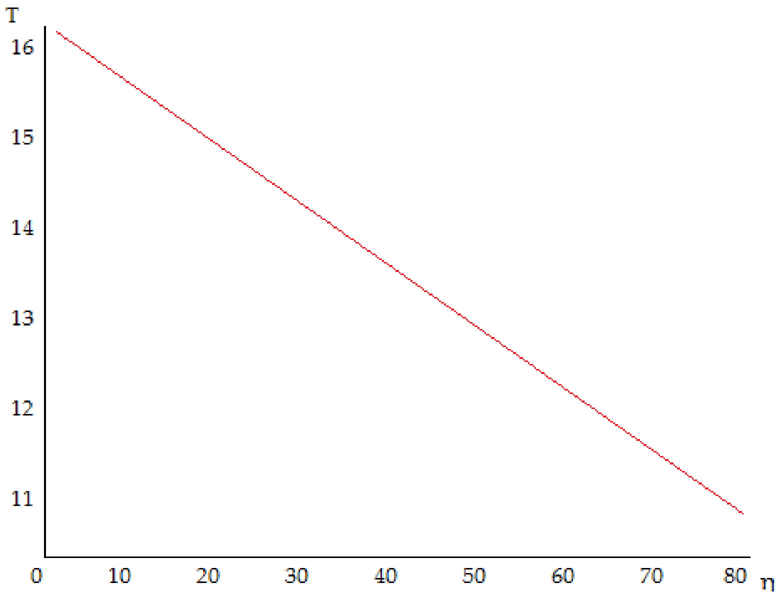

Figure 3: *Temperature dependence of efficiency in case of solar radiation of 1000 W/m2*

Certain results have been obtained from the conducted experiments. (In solar cells, a 10 ^{0}C increase in temperature (from 35 ^{0}C to 45 ^{0}C) causes the efficiency to decrease from 12% to 10.5%. From the above, it can be said that the rise in temperature is a negative thing. That's why, every 5 minutes, the cooling system lowers the temperature by 10 ^{0}C and increases efficiency. The obtained results are shown in Figure 2, and it was observed that the difference between the theoretically obtained result and the result in real life does not exceed 5%. As a result, it can be concluded that formula 1 can be used to determine the module temperature as a function of ambient conditions. Here it is also possible to determine when the panel should be cooled down when the temperature of the panel reaches its maximum. A linear fit of module temperature is plotted to determine its heating rate [12-15].

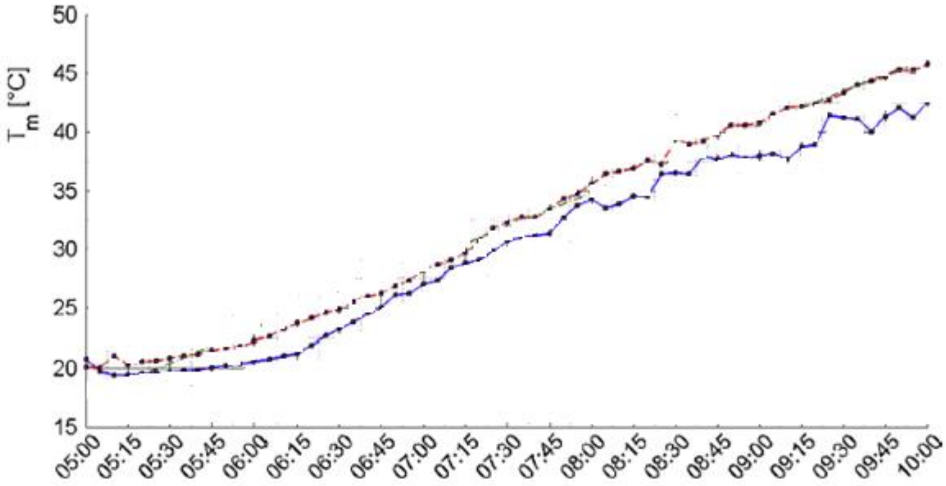

Figure 4: *Time dependence of temperature*

The proposed cooling system can solve the problem of overheating due to solar radiation and maintain efficiency with minimum water consumption. In addition, this method is suitable for use in very hot and sandy areas. The selection of the maximum permissible temperature should be based on the conditions of minimum energy and water consumption and maintaining the efficiency at the accepted level. If we turn on the cooling system for every 1 Celsius increase in temperature, in this case, the energy received from the panel will be used to cool the same panel. Buda means a decrease in efficiency. One of the main goals of this study is to determine when to start the cooling process. Analyzes performed are paid for any panels. The panel is first allowed to heat up to a given limit and then cooled down to normal operating temperature. It can be concluded that the maximum permissible temperature for the panel is 45 ^{0}C, and in this case it is possible to produce the highest energy. As the maximum allowable temperature increases, evaporation of water during cooling will increase and therefore water usage will increase. Therefore, choosing a temperature of 45 ^{0}C is considered the most suitable option [16-20].

III. Conclusions

1. In this article, the temperature effect and photovoltaic sources were investigated. The relationship between solar radiation and temperature was determined using simple formulas. The influence of the temperature effect on the efficiency of photovoltaic sources in cloudy conditions was shown.

2. It was determined that the increase in temperature leads to a decrease in the efficiency of photovoltaic elements. It can be concluded that by reducing the temperature, we can increase the efficiency of photovoltaic elements. At the same time, using comparative analyzes and mathematical models, relationships between temperature, efficiency, and cooling rate were determined.

3. From the obtained results, it can be said that if we take into account the selection of the maximum permissible temperature, the minimum energy and water consumption, and the maintenance of the efficiency at the accepted level, the maximum permissible temperature for the panels is 45 ^{0}C, and in this case it is possible to produce the highest energy.

References

[1] N.S. Mammadov, N.A. Ganiyeva, G.A. Aliyeva, "Role of Renewable Energy Sources in the World". Journal of Renewable Energy, Electrical, and Computer Engineering, Vol. 2, №2, pp. 63-67, Indonesia, 30 September 2022

[2] Haddad, A.; Ramadan, M.; Khaled, M.; Ramadan, H.S.M.; Becherif, M. Triple Hybrid System Coupling Fuel Cell with Wind Turbine and Thermal Solar System. Int. J. Hydrogen Energy, 45, 11484–11491, 2020

[3] Jiao, C.; Li, Z. An updated review of solar cooling systems driven by Photovoltaic–Thermal collectors. Energies, 16, 5331, 2023

[4] Ibrahim, K.A.; Luk, P.; Luo, Z. Cooling of Concentrated Photovoltaic Cells—A review and the perspective of Pulsating flow Cooling. Energies, 16, 2842, 2023

[5] Mammadov N., Mukhtarova K. "Analysis of the smart grid system for renewable energy sources", Journal «Universum: technical sciences", № 2 (107), pp. 64-67, 2023

[6] Herrando, M.; Wang, K.; Huang, G.; Otanicar, T.; Mousa, O.B.; Agathokleous, R.A.; Ding, Y.; Kalogirou, S.A.; Ekins-Daukes, N.J.; Taylor, R.A.; et al. A review of solar hybrid photovoltaic-thermal (PV-T) collectors and systems. Prog. Energy Combust. Sci., 97, 101072, 2023

[7] Sattar, M.; Rehman, A.; Ahmad, N.; Mohammad, A.; Alahmadi, A.; Ullah, N. Performance Analysis and Optimization of a Cooling System for Hybrid Solar Panels Based on Climatic Conditions of Islamabad, Pakistan. Energies, 15, 6278, 2022

[8] Abdelgaied, M.; Kabeel, A.E.; Zeleňáková, M.; Abd-Elhamid, H.F. Floating Photovoltaic Plants as an Effective Option to Reduce Water Evaporation in Water-Stressed Regions and Produce Electricity: A Case Study of Lake Nasser, Egypt. Water, 15, 635, 2023

[9] Kandeal, A.; Algazzar, A.M.; Elkadeem, M.R.; Thakur, A.K.; Abdelaziz, G.B.; El-Said, E.M.; Elsaid, A.M.; An, M.; Kandel, R.; Fawzy, H.E.; et al. Nano-enhanced cooling techniques for photovoltaic panels: A systematic review and prospect recommendations. Sol. Energy, 227, 259–272,2021

[10] Pomares-Hernández, C.; Zuluaga-García, E.A.; Escorcia Salas, G.E.; Robles-Algarín, C.; Sierra Ortega, J. Computational Modeling of Passive and Active Cooling Methods to Improve PV Panels Efficiency. Appl. Sci., 11, 11370, 2021

[11] Mojumder, J.C.; Chong, W.T.; Show, P.L.; Leong, K.W.; Abdullah-Al-Mamoon. An experimental investigation on performance analysis of air type photovoltaic thermal collector system integrated with cooling fins design. Energy Build., 130, 272–285, 2016

[12] Mankani, K.L.; Chaudhry, H.N.; Calautit, J.K. Optimization of an air-cooled heat sink for cooling of a solar photovoltaic panel: A computational study. Energy Build., 270, 112274, 2022

[13] Li, D.; King, M.; Dooner, M.S.; Guo, S.; Wang, J. Study on the cleaning and cooling of solar photovoltaic panels using compressed airflow. Sol. Energy, 221, 433–444, 2021

[14] Nižetić, S.; Jurčević, M.; Čoko, D.; Arıcı, M. A novel and effective passive cooling strategy for photovoltaic panel. Renew. Sustain. Energy Rev., 145, 111164, 2021

[15] Bayrak, F.; Oztop, H.F.; Selimefendigil, F. Experimental study for the application of different cooling techniques in photovoltaic (PV) panels. Energy Convers. Manag., 212, 112789, 2020

[16] I.N. Rahimli, S.V. Rzayeva, E.E. Umudov, "DIRECTION OF ALTERNATIVE ENERGY", Vestnik nauki, Issue 2, Vol. 61, №4, April 2023

[17] Zilli, B.M.; Lenz, A.M.; de Souza, S.N.M.; Secco, D.; Nogueira, C.E.C.; Junior, O.H.A.; Nadaleti, W.C.; Siqueira, J.A.C.; Gurgacz, F. Performance and effect of water-cooling on a microgeneration system of photovoltaic solar energy in Paraná, Brazil. J. Clean. Prod., 192, 477–485, 2018

[18] Tina, G.M.; Scavo, F.B.; Aneli, S.; Gagliano, A. Assessment of the electrical and thermal performances of building integrated bifacial photovoltaic modules. J. Clean. Prod., 313, 127906, 2021

[19] Bei, Y.; Yuan, B.; Wang, Z.; Tang, J. Floating Photovoltaic for the Coal Mining Subsidence Water Area—An Effective Way to Reduce Evaporation. In Proceedings of the 2022 5th International Conference on Energy, Electrical and Power Engineering (CEEPE), Chongqing, China, pp. 1126–1130, 22–24 April 2022

[20] Xu, Q.; Ji, Y.; Riggs, B.C.; Ollanik, A.; Farrar-Foley, N.; Ermer, J.; Romanin, V.; Lynn, P.; Codd, D.S.; Escarra, M.D. A transmissive, spectrum-splitting concentrating photovoltaic module for hybrid photovoltaic-solar thermal energy conversion. Sol. Energy, 137, 585–593, 2016