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TEMPERATURE DEPENDENCE OF SOLAR CELLS' EFFICIENCY

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Abstract: The solar panels which produce electric energy directly from the solar radiation are widely used in residential applications. The principle of operation of these is quite simple, and there is no need for expensive and complex auxiliary equipments. Alongside its advantages, its biggest disadvantage should be mentioned as well: the relatively low efficiency, which is affected by several factors, for example the cell's temperature. In this paper the investigation of the effects of temperature is presented.
Keywords: solar energy, photovoltaic cells, efficiency, effects of temperature

INTRODUCTIONS

Like most of semiconductor devices, the operating parameters of the solar cells are influenced by theirs temperature [1]. The regarding literature describes the relationship between the solar cell's electrical parameters and the temperature (1), (2), (3), (4), [2].

$$I_{SC} = K \cdot E \, , \tag{1}$$

$$V_{OC} = \frac{k \cdot T_{cell}}{e} \cdot \ln\left(\frac{I_{SC}}{I_s} + 1\right) , \tag{2}$$

$$I_s = qN_DN_A\left(\frac{D_p}{L_pN_d} + \frac{D_n}{L_nN_a}\right) exp\left(-\frac{E_g}{kT_{cell}}\right) , \tag{3}$$

where: I_{SC} – short-circuit current [A]; V_{oc} – open-circuit voltage [V]; T_{cell} - the solar cell's temperature [°C]; P - the solar cell's electrical power [W]; φ - fill factor [-]; I_s - the saturation amperage [A], E-solar radiation intensity $\left[\frac{\mathrm{W}}{\mathrm{m}^2}\right]$, K-proportional factor (the solar module's specific) [-].

We can see that the increase of the temperature causes a reduction in the voltage. The changes in the amperage are negligible.

$$P = V_{OC} \cdot I_{SC} \cdot \varphi \, , \tag{4}$$

$$\eta = \frac{A \cdot E}{P} \cdot 100\% \, , \tag{5}$$

where: P - the solar cell's electrical power [W]; φ - fill factor [-]; A - the solar modul's effective surface [m^2]; η - the solar module's efficiency [%].

Based on (2), (4), (5), formulas we can say that: at higher temperature the solar module produces less power so its efficiency decreases.

DETAILS OF MEASUREMENT

In this workthese physical phenomenons were investigated in laboratory conditions. First of all we had to create the measurement equipment.

The type of the investigated small scale polycristalline modul was Korax Solar KS-85. The solar radiation was substituted with eight pieces of halogen bulb reflectors, with electris power of 300W each. Figure 1 shows the dispersion of light intensity caused by the illuminance.

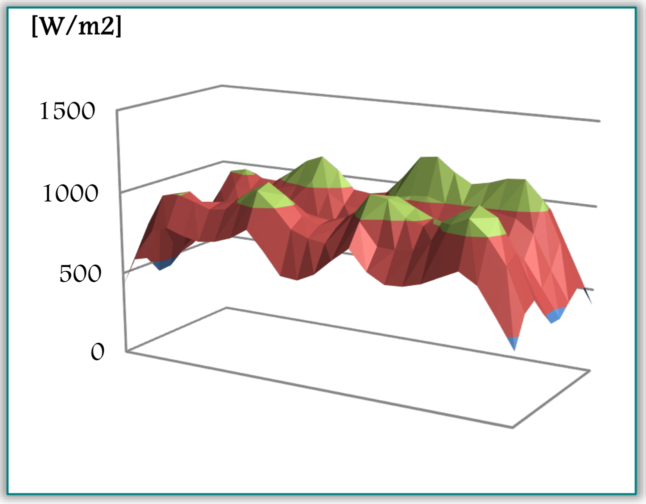


Figure 1. The dispersion of light intensity

The next important question was this: how can we influence the solar module's temperature? A channel was created below the solar panel, where cold air was then circulated. Over and above, the solar surface of panel was cooled down with a fan. Without cooling, the temperature of the solar module has reached about 80°C. By combining the two cooling systems it was possible to stabilize three solar module's temperatures: 65°C, 40°C, 30°C. The surface temperature was measured by a YC-747D - type digital thermometer in four points. The measuring arrangement is presented in figure 2.

Figure 2. The illuminated PV module and the cooling system

RESULTS OF MEASUREMENT

First of all the „transient temperatures" measurements were performed, where we constantly modified the temperature while the open-circuit voltage and the short-circuit current were measured. We know that the theoretical electric power can be calculated by using the formula (6), [3].

$$P_{th} = V_{OC} \cdot I_{SC} \qquad (6)$$

So the changes in the temperature and the electric power were followed, and were illustrated on a graph. (Figure 3)

This experiment demonstrated how the theoritical power changes due to the temperature changes. It can be observed if the solar radiation is constant, the warmer PV module produces less power.

Tests at constant temperatures

In this case, we stabilized the temperature of PV module and a variable electric resistance was connected to the output wires. The value of resistance was changed whilemeasurement of the voltage and the amperage was carried aut. Figure 4 shows the voltage-amperage characteristics in case of four constant temperatures.

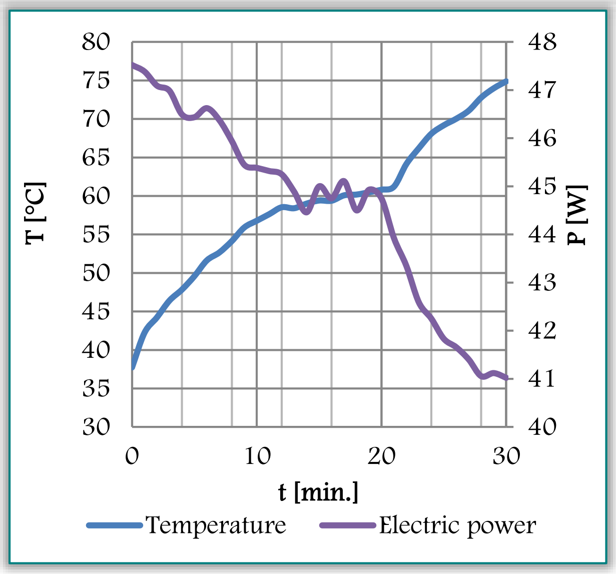


Figure 3. Relationship between the temperature and the power as a function of time

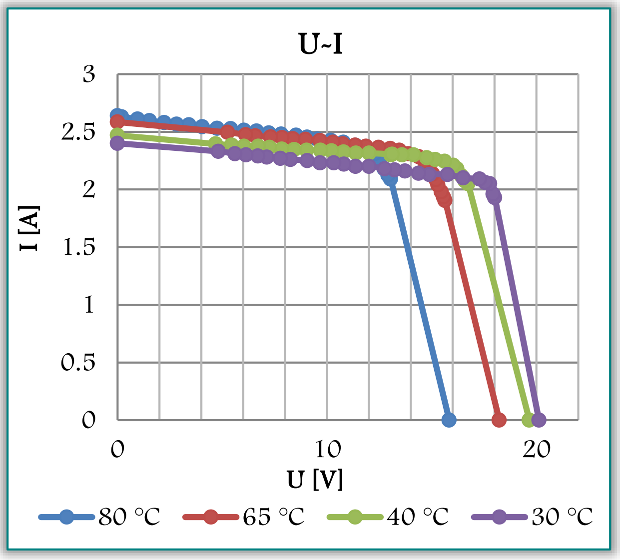


Figure 4. U-I characteristics in different temperatures

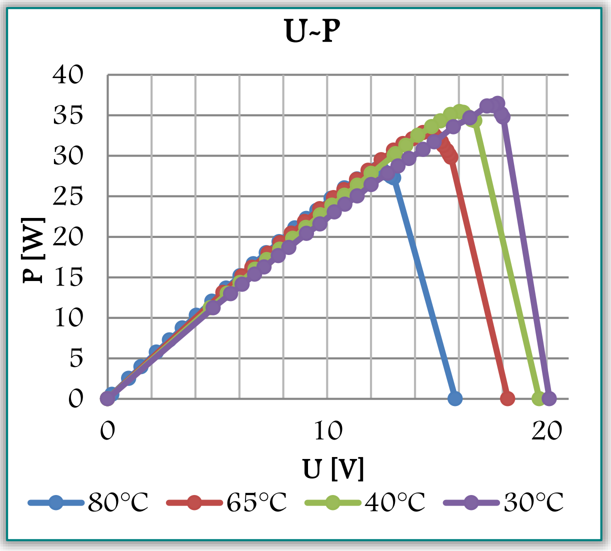
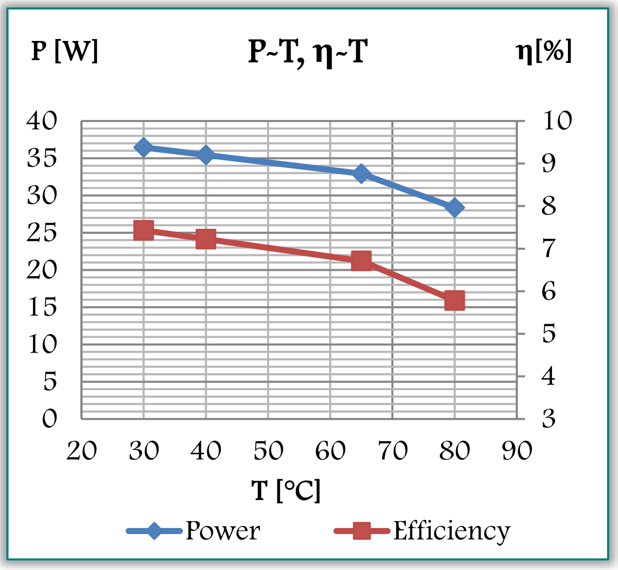


Figure 5. U-P characteristics in case of different temperatures

By increasing the resistance, the electric power was increased to a certain point, too. Following this point it began to decrease. This point is called the Maximum Power Point where the solar module produces the most electricity [4]. Figure 5 presents the voltage-electric power characteristic in different constant temperatures.

Solar panel temperature coefficients

Temperature coefficients show how the module's electric parameters change by the effects of temperature change [5]. Using the available data (from our measurements) it was possible to calculate these coefficients for voltage, amperage, electric power, efficiency, fill factor and ideal electric resistance (formula (7)). The electrical parameter (for example voltage) wich depends on the temperature was illustrated. After that the rise of the function had to be found. (Using linear regression a line was created from the measured curve.)



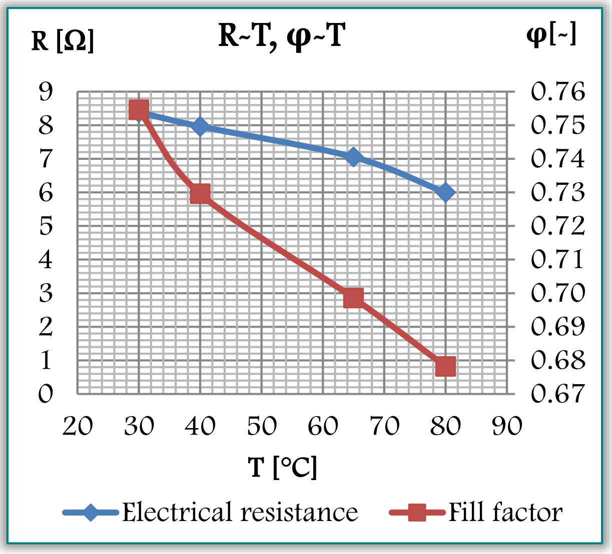


Figure 6. Functional relationship between the parameters and the temperature

$$A = \frac{x_{n+1}-x_n}{x_n} \cdot \frac{100}{T_{n+1}-T_n} = 100 \cdot \frac{m}{x_n}, \tag{7}$$

where: A- temperature coefficient $\left[\frac{\%}{°C}\right]$; x_n – the chosen electrical parameter's value at a fixed temperature (for axample: amperage [A] at 40°C); m - rise of the line; T_n- the chosen temperature [°C].

Figure 6 shows the functional relationship between the parameters and the temperature. (In this case these parameters are the following: efficiency, power, fill factor and the ideal electrical resistance) The calculated coeffitients (8)-(12) are:

$$A_p = A_\eta = (-0{,}459)\left[\frac{\%}{°C}\right], \tag{8}$$

power and efficiency;

$$A_R = (-0{,}633)\left[\frac{\%}{°C}\right], \tag{9}$$

ideal resistance;

$$A_\varphi = (-0{,}211)\left[\frac{\%}{°C}\right], \tag{10}$$

fill factor;

$$Au=(-0{,}41)\left[\frac{\%}{°C}\right], \tag{11}$$

voltage;

$$A_i = 0{,}11\left[\frac{\%}{°C}\right], \tag{12}$$

amperage.

CONCLUSION

During our investigations it was possible to reproduce the phenomenons described in the regarding literature. In every cases the reduction of the solar cell's temperature caused the increase of the electric power output and the efficiency. In conclusion one way of increasing the solar cell's efficiency is to reduce its temperature. By the help of the temperature coefficients the solar cell's design and return calculations will be more accurate.

Note

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