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TRANSIENT ELECTRICAL CHARACTERISTICS OF A SOLAR CELL IN THE CASE OF A COOLING AND NON-COOLING SOLAR CELL

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Abstract: This paper presents the temperature dependence of solar cell characteristics by laboratory measurements in case of cooled and non-cooled solar cells. The voltage and current level of electricity, provided by solar cells are highly influenced by the temperature change. The output voltage level of both an idle and a loaded solar cell is decreased by the temperature increase which also leads to power decrease and efficiency deterioration. The intensity increase of the irradiating light linearly increase the current, provided by the power cell which highly increase the temperature of the solar cell and that leads to voltage decrease and efficiency deterioration too. To prevent these processes it is needed to reduce the temperature of the solar cells. The measured characteristic curves at different temperatures are presented in this paper.
Keywords: PV module, energy efficiency, maximal power point

1. INTRODUCTION

Our society will run out of fossil energy sources soon, so it is necessary to find new ways of energy production. Solar energy utilization means environmental friendly energy production that is why it is needed to deal with this question.

Today's technology of solar energy utilization must be developed to be able to produce more electricity with higher efficiency. For the development many experiments and measurements are required to know more about the current used solar cells and be able to produce new ones.

The maximum electrical powers of solar panels are influenced by many factors, like the temperature and the age of the PV, the intensity of illumination, and the load resistance. During this experiment, the temperature dependence parameters of solar panels were examined and compared to the ones which the manufacturer gave [1, 6].

2. THE EXPERIMENTAL COMPOSITION

The solar panel was placed on a table with the same size during the measurement. A flow channel was created by placing two 50 mm thick wooden slats between the solar panel and the table. The cooling air was provided by an Orion CSHP 9001 C4 mobile air conditioner and a TT 150 duct fan. There was turbulent flow in the created flow channel. (Figure 1)

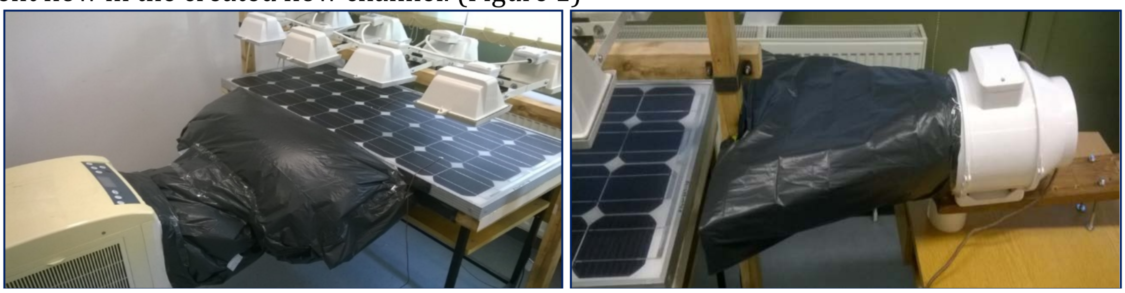

Figure 1 - The experimental composition

The temperature of the solar panel's surface was measured by a four channel YC-747D digital thermometer. The four sensors were placed on four different parts of the solar panel [2]. The previous measurements proved that the back surface of solar panels heat up likewise the absorber surface [2, 3]. Because of this fact, the back surface cooling of the solar panel works as well.The voltage and current of the solar panel was measured at the same time by a Protek DM-301 and a METEX M-3650Ddigital multimeters. The temperature of the lit solar panel was around 80°C while in case of operating both the air conditioner and the fan, the average temperature was decreased by 50°C. Table 1.contains the parameters of the solar panel, given by the manufacturer.

Table 1 -Electrical parameters of the solar panel

Parameter	Symbol and measurements	Value
Year of manufacture	-	2008
Intensity of illumination	I_{ill} [W/m²]	861
Peak Power	P_{max} [W]	85
Max. power current	I_m [A]	4.88
Max. power voltage	U_m [V]	17.45
Short circuit current	I_{sc} [A]	5.40
Open circuit voltage	U_{oc} [V]	21.20
Serial resistance	R_s [Ω]	0.0035
Parallel resistance	R_p [Ω]	10,000
Number of serial connected cells	N_s [piece]	18
Number of parallel connected cells	N_p [piece]	2
Temperature co-efficient for P_{max}	K_{pm} [W/°C]	-0.391
Temperature co-efficient for I_{sc}	K_{sc} [A/°C]	0.001674
Temperature co-efficient for U_{oc}	K_{oc} [V/°C]	-0.073776
Efficiency (maximal power)	η [%]	12.75
Nominal operating temperature	T_N [°C]	25

3. TEMPERATURE TRANSIENT ANALYSIS

During these experiments I examined the solar cell in a transient state of temperature. For the measurements, I observed the increase of the solar cell's temperature without any cooling and with cooling as well. The measurement started at 30°C. Basing on previous experiences, the temperatures of the illuminated solar panels are stabilized in both cases, after about 20 minutes. The temperature was measured at the four points of the solar panel, as mentioned above, together with the voltage and current at given load. The temperature-time graphs are shown in Figure 2.

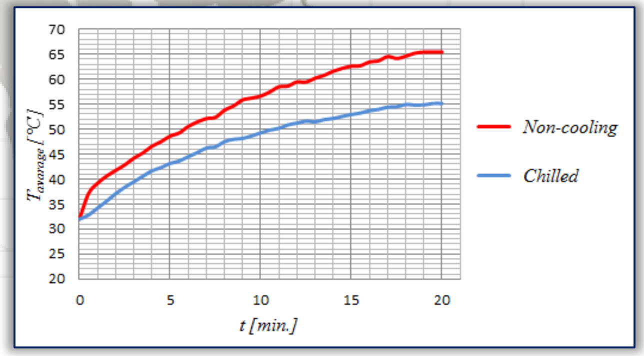

Figure 2 - Warming up the solar panel without cooling or cooling

Due to the increasing of temperature, the maximum power current and voltage values are slightly increased too, so the power associated with that load. This result was is not the same as expected because it was thought that the maximal power voltage will decrease, just the open circuit voltage. The short circuit current increase as the temperature is increased. This is described in the given literature.

The maximal power voltage, the maximal power current and the maximal power can be observed in terms of temperature and time in Figures 3-Figure 8.

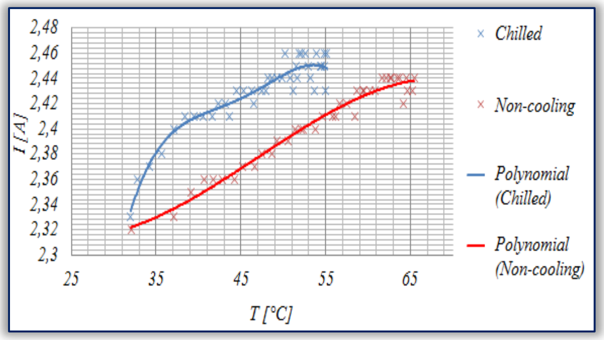

Figure 3- Maximal power current in case of non-cooling and chilled solar panel

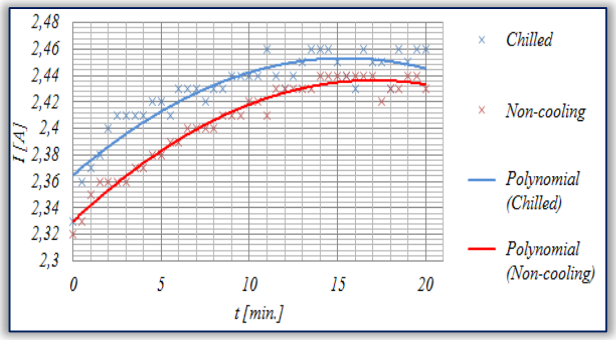

Figure 4 - Maximal power current of the time by the chilled and non-cooled solar cell

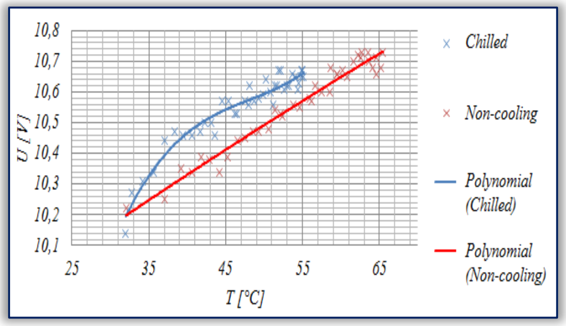

Figure 5 - Maximal power voltage of the temperature by the chilled and non-cooled solar cell

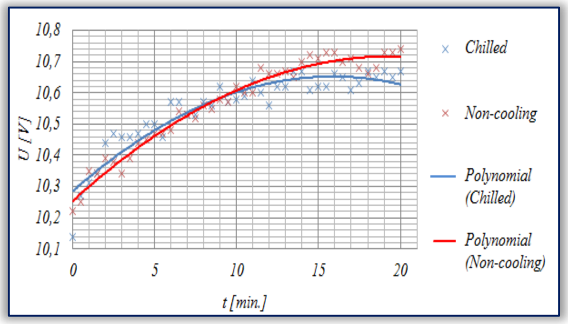

Figure 6 - Maximal power voltage of the time by the chilled and non-cooled solar cell

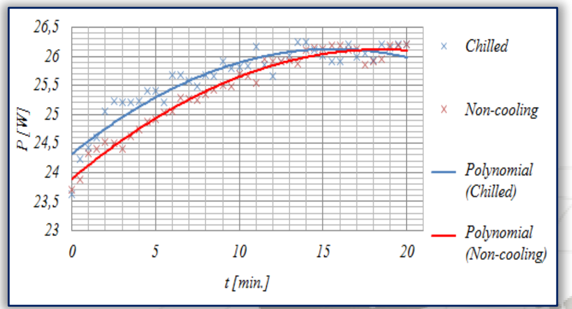

Figure 7 - Maximal power of the temperature by the chilled and non-cooled solar cell

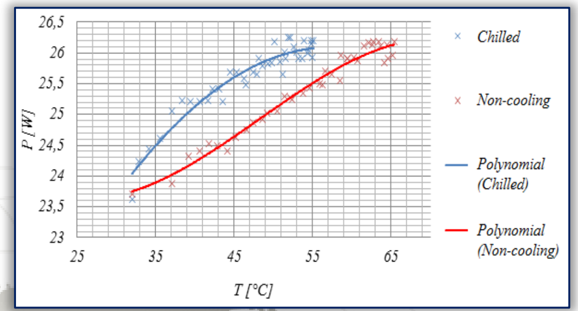

Figure 8 - Maximal power of the time by the chilled and non-cooled solar cell

According to the measurement results, it can be said that cooled solar panels operate by more favorable electrical properties than non-cooled ones. This is caused by the temperature dependence of solar panel's microelectronic properties.

4. ANALYSIS OF TEMPERATURE TRANSIENT WITHOUT LOADING

Literature says that the open circuit voltage of solar panels decreases, while short circuit current slightly increases by the temperature increase of the semiconductor. Voltage decreases more than the current increases by the temperature. The idle power decreases too and can be counted by equation 1 [1, 5].

$$P_{theoretical} = U_{oc} \cdot I_{sc} \qquad (1)$$

The given parameters (Table 1.) contain so called temperature constants that determine the change of the solar panel's idle voltage (U_{oc}) and current (I_{sc}) in case of 1°C temperature change. In this case:

- K_{oc}= (-0.073776)$\left[\frac{V}{°C}\right]$ = (-0,348)$\left[\frac{\%}{°C}\right]$,
- K_{sc} =0.001674$\left[\frac{A}{°C}\right]$= 0,031$\left[\frac{\%}{°C}\right]$,
- K_{pm} = (-0.391)$\left[\frac{W}{°C}\right]$ = (-0.46)$\left[\frac{\%}{°C}\right]$.

With the help of these constants it is possible to determine the U_{oc}-T and I_{sc}-T functions. The functions had been compared to the measured ones. Figure 9 and Figure 10 show these lines.

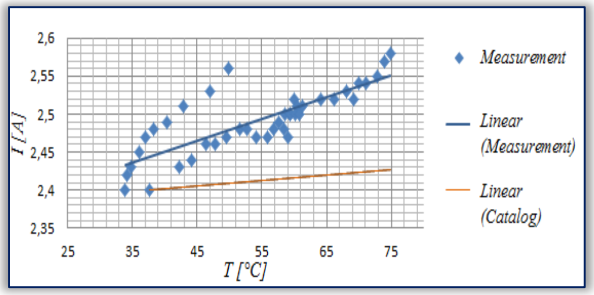

Figure 9 -Idle and measured functions of I_{sc}-T

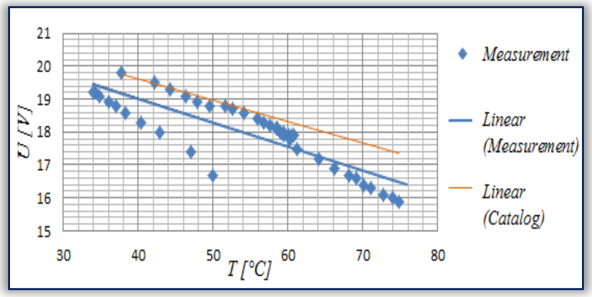

Figure 10 - Idle and measured functions of U_{oc}-T

Temperature constants were counted with the help of the measured line's steepness and equation 4. Equations of measured line [4, 5]:

$$I_{sc} = 0{,}0028 \cdot T + 2{,}3373 \qquad (2)$$

$$U_{oc} = (-0{,}0729) \cdot T + 21{,}941 \qquad (3)$$

$$A = \frac{x_{n+1}-x_n}{x_n} \cdot \frac{100}{T_{n+1}-T_n} = 100 \cdot \frac{m}{x_n} \qquad (4)$$

where: the temperature constant $\left[\frac{\%}{°C}\right]$, xn– value of voltage or amperage at any point [V], [A], m – steepness of a given line $\left[\frac{A}{°C}\right]$, $\left[\frac{V}{°C}\right]$, $\left[\frac{W}{°C}\right]$, Tn- value of temperature at any chosen point [°C]

The temperature constants, counted this way are the followings:

» K'_{oc}=(-0.08692)$\left[\frac{V}{°C}\right]$= (-0.41)$\left[\frac{\%}{°C}\right]$,

» K'_{sc}= 0.000594$\left[\frac{A}{°C}\right]$ = 0.011$\left[\frac{\%}{°C}\right]$,

» K'_{pm} =(-0.525)$\left[\frac{W}{°C}\right]$= (-0.459) $\left[\frac{\%}{°C}\right]$.

Table 2 - The ratio of idle (catalogue) and counted temperature constants

	Catalog	Measurement	Ratio
K_{oc}	(-0,348)$\left[\frac{\%}{°C}\right]$	(-0.41)$\left[\frac{\%}{°C}\right]$	117.82%
K_{sc}	0,031$\left[\frac{\%}{°C}\right]$	0.011$\left[\frac{\%}{°C}\right]$	0.355%
K_{pm}	(-0.46) $\left[\frac{\%}{°C}\right]$	(-0.459) $\left[\frac{\%}{°C}\right]$	99.78

As it can be seen on Table 2 the given and the counted constants are equal at maximum power operating point. The counted constant in case of open circuit voltage is really closed to the given one that proves that the measurement was correct. The minimal difference can be caused by the age of the solar panel. There is great difference in case of the short circuit current. The reason might be the illumination of the solar panel, because the lights that were used during this experiment may not be the same as the manufacturer used during their tests.

5. SUMMARY

After the experiments it can be said that the maximum power of solar panels are highly influenced by many factors, mainly their temperature, as their current and voltage also change by the temperature change. The effect of the temperature can be seen on the figures above. Cooled and non-cooled solar panels behave different ways.

The measurements proved that the given temperature constants are correct, because catalogue parameters were really closed to measured ones. This means that the experiment worked as it was expected, but for the perfect examination, another kind of solar panel or a high power illuminating device would be necessary to get the same result in case of the short circuit current measurement too.

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