Parameters of photovoltaic cells in dependence on irradiance and temperature

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Anotace:

For photovoltaic applications, the knowledge about system behaviour in real operating conditions is desirable. Presented paper describes the dependences of all important parameters of silicon photovoltaic cells on both temperature and irradiance obtained using cell tester Pasan IIc.

INTRODUCTION

The temperature change I-V characteristics of photovoltaic cells (PV cells, solar cells) takes effect mostly on the value of the open circuit voltage V_{OC} and in this way are usually discussed in literature (see e.g. [1], [2]). Less information is available about temperature dependence of other PV cells, given by producers as data valid under Standard Testing Conditions (STC), i.e. irradiation 1000 W/m², spectrum AM 1,5 and cell temperature 25°C. In practical applications, photovoltaic systems never operate under STC and knowledge about dependences of all main parameters of PV cells and modules on both irradiance and temperature is desirable. In this work we present results of measurements PV cell I-V characteristics in a broad range of temperature and irradiance using cell tester Pasan IIc.

PV CELL PARAMETERS

Parameters of PV cells and modules are given by producers as data valid under Standard Testing Conditions (STC), i.e. spectrum AM 1,5 irradiation 1000 W/m²and cell temperature 25°C. A set of parameters of a 4-inch monocrystalline silicon PV cell (manufacturer Solartec, s.r.o.), measured using solar simulator Pasan IIc under STC are shown in table 1.

Concerning the crystalline silicon PV cells, the theoretical assumption gives the open circuit voltage drop approximately 0,4 % / °C. The temperature dependence of cell parameters at different irradiance level is less known. Therefore, a set of measurements was conducted for authentication of the influence of temperature and irradiance on the PV cell parameters.

EXPERIMENT

For our experiments, PV cells were measured using cell tester Pasan IIc. The tester is based on flash-lamp techniques allowing fast I-V measurements and eliminating the risk of PV cell heating during the measurement.

Tab. 1: Parameters of the measured solar cell under STC.

Parameter	Notation	Units	Values
Short circuit current	I_{SC}	A	3,21
Open circuit voltage	V_{OC}	V	0,59
Conversion efficiency	η	%	13,64
Fill factor	FF	%	74,18
Power at MPP	P_m	W	1,405
Voltage at MPP	V_{mp}	V	0,483
Current at MPP	I_{mp}	A	2,91
Series resistance	R_s	Ω	0,018
Parallel resistance	R_p	Ω	19,63

The photovoltaic cell was attached using special contacting system that was adjusted for the ability to be heated. Whole contact system was placed on a heated desk with adjustable temperature. Irradiance
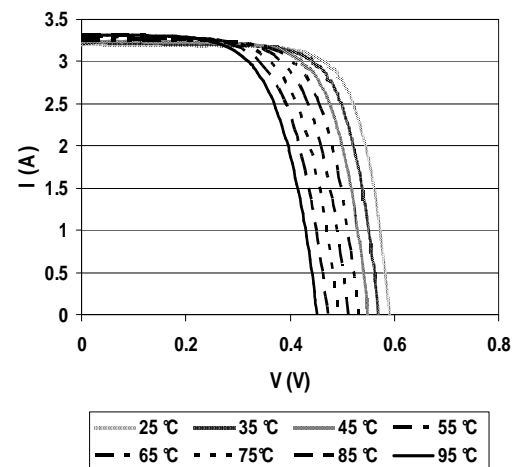

Fig. 1: The temperature influence on the current-voltage characteristics of the PV cell for irradiance 1000 W/m²

was regulated by changing the distance between the flash lamp and the measured photovoltaic cell. Lower irradiance was achieved using a gray filter that was put in front of the lamp. This way, irradiance ranging from 100 W/m^2 to 1000 W/m^2 was obtained. The temperature ranged from 20 °C to 100 °C.

the average in 0,38 % / °C (see figure 2, irradiance 1000 W/m^2) was measured. With the drop of the PV cell open circuit voltage, the maximum power output and thus the efficiency decrease as well.

In practical applications, the system usually operates close to the maximum power point conditions and

Fig. 2: Measured values of V$_{OC}$ of the PV cell as a function of the cell temperature for different irradiance.
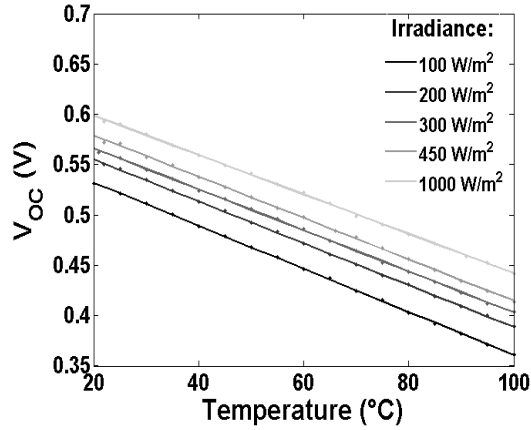

Fig. 4: Measured values of V$_{mp}$ of the PV cell as a function of the cell temperature for different irradiance.

RESULTS AND DISCUSSION

The dependences of measured voltage-current characteristics on the temperature at irradiation 1000 W/m^2 are illustrated on the figure 1. Similar sets of characteristics were measured also at irradiance 450 W/m^2, 300 W/m^2, 200 W/m^2 and 100 W/m^2. This way, dependences of all important cell parameters on both temperature and irradiance were obtained.

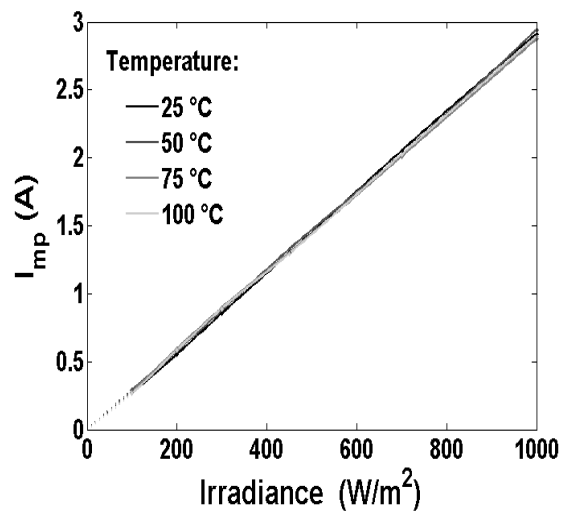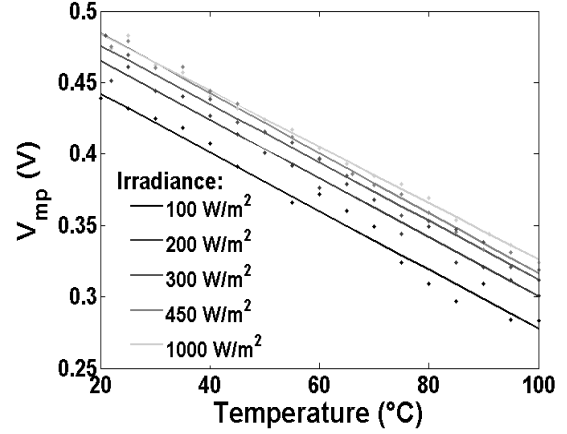Here with this cell, almost linear decline of V_{OC} on

therefore it is useful to know dependences of V_{mp} and I_{mp} on both temperature and irradiance. These parameters were extracted from measured characteristics. In Fig.3 is shown the dependence of I_{mp} on irradiance for four different temperatures. As follows from these measured results, the I_{mp} grows with irradiance linearly and practically it does not depend on temperature.

The measured dependence of V_{mp} is shown in Fig.4. From measured data follows relatively steep decrease of V_{mp} with increasing temperature and also a decrease with decreasing irradiance. Therefore the

Fig. 3: Measured values of I$_{mp}$ of the PV cell as a function of the irradiance for different cell temperature
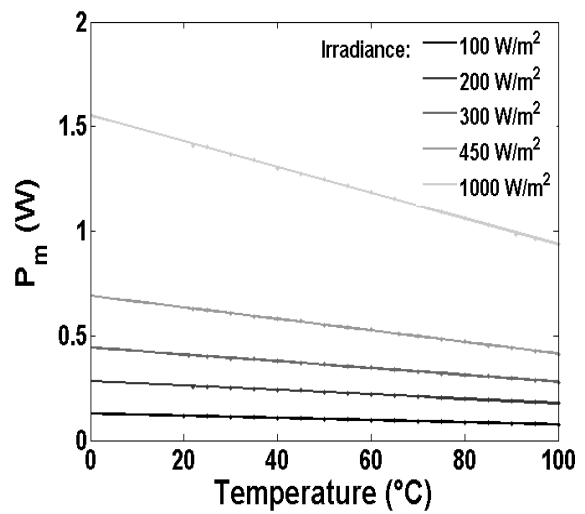

Fig. 5: Measured values of V$_{OC}$ of the PV cell as a function of the cell temperature for different irradiance.

output power increases with increasing irradiance and decreases with increasing temperature, as shown in Fig.5.

The measured decrease of the efficiency of the PV cell during the temperature increments as a function of the PV cell temperature and the irradiance is illustrated in figure 6. Here, the efficiency decreases with the temperature linearly, in average by 0,53 % / °C (for 1000 W/m^2). With decreasing irradiance, the rate of the efficiency decrease is lower.

These basic trends can be observed in practical applications. PV system efficiency is much higher during the winter months, than in the summer and, as well, this efficiency changes during the day (during sunny summer day, the total PV cell temperature difference can rise up to 45 °C), (see [3]).
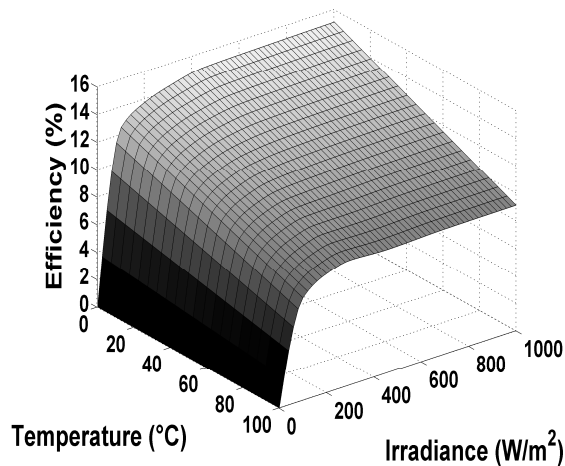

Fig. 6. : The progression of effiency of the measured PV cell as a function of the cell temperature (range from 0 to 100 °C) and irradiance (range from 0 to 1000 W/m^2).

The rest of the PV cell parameters change with the temperature as well, but their influence is not as big as it is of the parameters mentioned above. The short circuit current I_{SC} grows slightly with linear dependence on the temperature, as it is shown in the figure 1. This increase is as low as 0,05 % / °C. The rest of the basic PV cell parameters are the fill factor FF, series resistance R_s and parallel resistance R_p. The value of the fill factor decreases with increasing temperature by approximately 0,2 % / °C, the value of series resistance increases with increasing temperature almost linearly by approximately 0,32 % / °C and the value of parallel resistance decreases with increasing temperature also almost linearly by approximately 0,7 % / °C.

CONCLUSION

Because of heating of the PV cells during their utilization (heating by the solar radiation), cooling of these cells is needed. Thence it follows the requirement for as low cell temperature as possible. For each application, it is necessary to dispose of such as construction, which enables effective cooling (natural, if it possible), for example: by enabling of the surrounding air circulation that can lead to a dramatic increase of the PV system efficiency. Other possibility how to keep the PV cell temperature as low as possible is the hybrid solar cell system. Hybrid panels combine the functions of the PV panel and the photo-thermal collector for the water heating. The back surface of the solar cells is with the aid of electrically insulating but thermally conducting layer connected with a system of pipes with circulating cooling medium. This medium is instrumental for the heat transfer, which is subsequently stored in the reservoir as heated water. In this way, such a combined system for using the solar energy can operate.

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