

The impact of shading on solar cell electrical parameters

BARBARA SWATOWSKA^{1*}, PIOTR PANEK²

¹AGH – University of Science and Technology, Department of Electronics,
al. Mickiewicza 30, 30-059 Kraków, Poland

²Institute of Metallurgy and Material Science PAS,
ul. Reymonta 25, 30-059 Kraków, Poland

*Corresponding author: swatow@agh.edu.pl

Availability of light to solar cells is crucial for the efficiency of photovoltaic systems. For this reason, even partial shading can result in significant reduction of generated electric power (loss of current). This paper examines the changes in the efficiency of multicrystalline silicon solar cells which are caused by different kinds of shading. Full and partial shading were simulated by the use of three types of shutter-foils printed in a gray and black scale. The measurements of current-voltage characteristics show that totally or partially shaded modules can drastically reduce the generated power. Short circuit current decreases from about 8100 to 100 mA that in the case of the series connection of cells in a module, lead to the shift of the point of the maximum power and finally to the considerable reduction of nominal system photovoltaic power.

Keywords: solar cells, shading, electrical parameters, efficiency.

1. Introduction

Partial or total shading of solar cells is a very frequent phenomenon in all kinds of photovoltaic (PV) systems [1]. The reasons for this may be very different: neighboring buildings, trees, the passing clouds, improper inclination of adjacent modules or the shadow of other elements of architecture and sometimes lying snow or mud. These factors lead to nonlinearities in electric characteristics of PV systems [2, 3].

The influence of shading cells on the efficiency of the modules is directly related to the type of cells connection [4, 5]. In series connection, all the cells in a string are compelled to retain the same current even though a few cells under shade produce less current. It is very difficult to be accomplished in real conditions [6].

Main objective of this work was to explain the impact of shading on the efficiency of a silicon solar panel. The analysis was performed on the example of multicrystalline silicon (mc-Si) solar cells. Full and partial shading was simulated by the printed foil

in a gray and black scale. In addition, the distance between the shutter and the cells was changed. In the prepared conditions current-voltage characteristics were measured.

2. Shading and results of measurements

2.1. Shading model

The shading was simulated in the laboratory conditions using three types of shutters. As the shutter, 3 foils of area 625 cm^2 ($25 \text{ cm} \times 25 \text{ cm}$) were used: fully printed in gray (FG), fully printed in black (FB) and half printed in black (HB; half transparent) – see Fig. 1.



Fig. 1. Three types of shutters as solar cell shading: foil half printed black (a), foil fully printed in black (b), and foil fully printed in gray (c).

Optical transmission of shutters was measured by the use of a Perkin–Elmer Lambda 19 spectrophotometer in the range from 300 to 1700 nm. Transmission coefficient in the effective photosensitivity scope of silicon solar cells (400–1100 nm) was equal to 45% and 5% for the FG and FB foils, respectively.

2.2. Measurements of solar cells

The measurements and analysis of the current-voltage characteristics of all kinds of solar cells are one of the most important diagnostic methods in photovoltaics [7].

In our experiments, current-voltage characteristics of mc-Si solar cells of area 243.36 cm^2 ($156 \text{ mm} \times 156 \text{ mm}$) and thickness $210 \mu\text{m}$ were measured under the AM1.5 (1000 W/m^2) using a global spectrum sun simulator, in temperature 25°C (STC – standard test conditions). All examined cells had the efficiency of about 14%. The results for selected cells are shown in Fig. 2.

The current-voltage characteristics of solar cells measured with fully and partially shading are presented in Fig. 3. The shutter was positioned approximately 15 cm over the cell.

The highest value of the short circuit current I_{sc} , 8123 mA, was observed for the solar cell without shading. Significantly lower values of I_{sc} were found for the shading cells: 2691 mA (FG shutter) and 3227 mA (HB shutter). The reason for the difference between these two values is the fact that a full-gray shutter decreases to 445 W/m^2 the

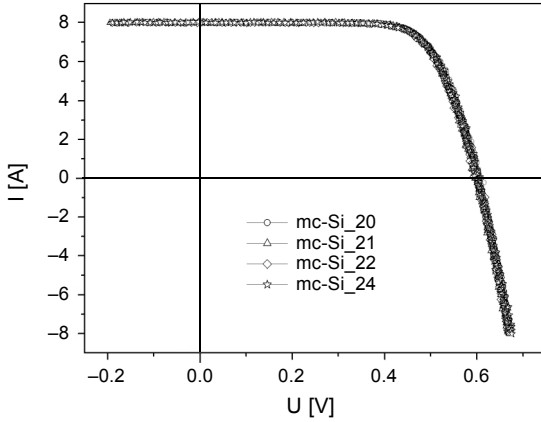


Fig. 2. Current-voltage characteristics under the AM1.5 illumination of selected multicrystalline silicon solar cells used in experiments.

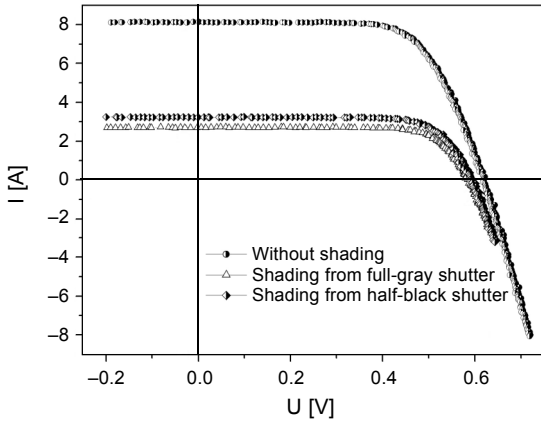


Fig. 3. Current-voltage characteristics of selected mc-Si solar cell under different shading.

intensity of light for the entire surface of the cell. The half-black shutter causes that the half of the cell area still receives light of 1000 W/m^2 intensity while the other half is shadowed.

The change in light intensity for different shutters is visible in Fig. 4. Additionally, in this figure, the variation of light power in relationship to the distance between the shutter and the solar cell is presented. It can be observed that for the distance above 15 cm, the light intensity is rather stable.

The Table contains the parameters of the solar cells which are the most sensitive to changes in illumination.

The application of fully black shutters reduces the light intensity up to 100 W/m^2 and the short-circuit current reaches a mere 157 mA (efficiency about 2.33%).

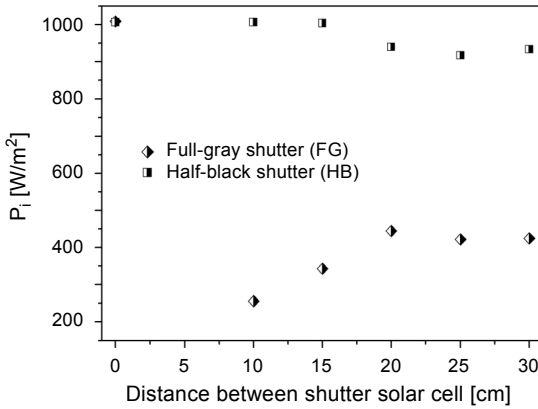


Fig. 4. Changes in power of illumination depending on the distance between the shutter and the solar cells.

T a b l e. Parameters of solar cells under different shading: P_i – light intensity, I_{sc} – short circuit current, P_{max} – maximum power, and η – efficiency.

Shading	P_i [W/m ²]	I_{sc} [mA]	P_{max} [mW]	η [%]
Without	1008	8123	3373	13.7
FG foil	444.6	2691	1176	10.8
HB foil	1003.5	3227	1406	5.7

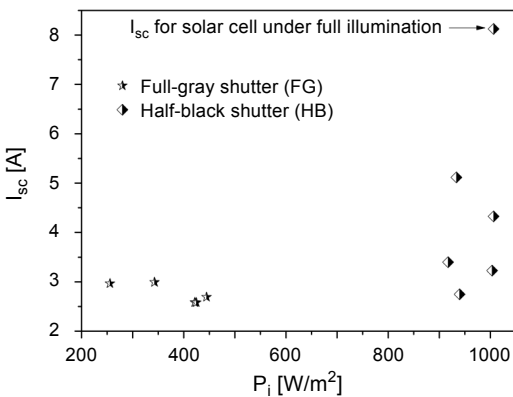


Fig. 5. The variations of short circuit current I_{sc} vs. light intensity P_i for solar cells under two kinds of shutters: FG and HB (a point for a fully illuminated solar cell is also reported).

In Figure 5 one can see the changes of I_{sc} values correlated to changes of light intensity P_i .

The application of a full-gray shutter causes a strong decrease in power of light reaching the surface of a solar cell and a strong decrease in short circuit current I_{sc} values, as well. The application of a HB shutter results in slight decrease in power of light (not more than 100 W/m²) but also a strong decrease in I_{sc} values that is similar to the

previous described case. However, the reduction of a short circuit current is stronger for the FG shutter.

Significant changes in I_{sc} mean also the significant changes in I_{max} that in consequence lead to the reduction of maximum power P_{max} and efficiency η of solar cells.

It should be remembered that in real conditions there are usually strong effects of reflection and dispersion of light which may change the dynamics of losses resulting from the shading of solar cells.

3. Conclusions

A computer controlled global spectrum sun simulator (I-V Curve Tracer For Solar Cells Qualification, v 4.1.1) was used to measure the behavior of PV modules in different shading configurations (partial and full shading). The resulting current-voltage characteristics of the solar cells clearly show the strong impact of the shading on the electrical parameters of solar cells.

The highest values of the short circuit current I_{sc} were observed for solar cells without shading: 8123 mA. Significantly lower values of I_{sc} were found for shading cells: 2691 mA (full-gray shutter) and 3227 mA (half-black shutter).

Unfortunately, the changes in electrical parameters affect both the efficiency of single cells and the modules – the efficiency can be reduced by up to 40% (relative).

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