Study on photovoltaic characteristics of bifacial solar panels

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Abstract. In the work optimum angles of orientation of solar panels with bifacial silicon solar cell, essentially different from traditional solar panels with simple silicon solar cells are experimentally defined. Are shown optimum distance from a back vertical wall and height from horizon, and also color of a horizontal surface reflecting them for achievement of high efficiency of solar panels with bifacial solar cells. Temperature factors of the main basic photovoltaic parameters of power stations with simple and bifacial silicon solar cells shown. Advantage of use of photovoltaic power stations with bifacial silicon solar cells in the hot climate conditions is revealed.

1. Introduction

The role of photovoltaic conversion of solar energy among various types of renewable sources is significant [1, 2, 3]. The efficiency of photoelectric conversion significantly depends on the electrophysical properties of the semiconductor material from which the solar cell (SC) is made and the design of the solar cell itself [3]. Various methods have been proposed and developed to increase the efficiency of SCs and solar panels (SP), in particular with texture on the front surface [4, 5, 7] and metal nanoparticles [6, 8]. One of the promising ways to increase the output power of SCs is the use of double-sided illuminated (DS) SCs and SPs [4]. One of the promising ways to increase the output power of SCs is the use of double-sided illuminated (DS) SCs and SPs [4].

Although bifacial technologies have been around for as long as monofacial technologies, their increased efficiencies and decreased levelized costs of electricity (LCOE) have made bifacial solar modules more popular in the market recently. As to a Wood Mackenzie Power & Renewables report, the installed capacity of photovoltaic modules increased from 97 MW in 2016 to over 2,600 MW in 2018. It is anticipated to reach 20,000 MW in 2024, which would account for 17% of the worldwide PV module industry. The International Technology Roadmap for Photovoltaics, or ITRPV, has also projected that by 2030, the market share of these modules will rise by a minimum of 35%. Global bifacial demand is predicted by Infolink to reach 12GW by 2020. The proper rear surface reflector design is a major obstacle to the efficient use of bifacial solar cells. For residential applications, such as reflection from walls, capturing energy reflected back by windows, and terrestrial reflection in parking lots, the impact of an exterior rear surface reflector for bifacial solar cells has been studied [9, 10]. In these kinds of applications, having the right reflector is essential to significantly raising the amount of solar energy incident on the back surface. Nevertheless, bifacial solar panels can function well even in the absence of a reflector in many situations.

Therefore, in this work, silicon solar panels are considered as power plants. Analysis and comparative study of the photoelectric characteristics of two types of solar panels, including when directing sunlight to the front and rear sides, was carried out under natural conditions.

2. Methodology

The characteristics of solar panels were measured under natural conditions on sunny days at different times of the year [11, 12]. A comparison of the current-voltage characteristics and the main photoelectric parameters of silicon one-sided and two-sided illuminated SCs was carried out. When measuring the current-voltage characteristics of bilaterally sensitive (BS) SPs, the direction of sunlight is perpendicular to both the front and rear surfaces.

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3. Results and Discussion

The current-voltage characteristics of the studied joints were measured at different illumination levels. In Fig. Figure 1 shows the current-voltage curves of a double-sided solar panel with a maximum power P_m = 545 W under various lighting conditions front surface W=95; 450; 630; 700; 740; and 760 W/cm^2.

In Fig. 2 shows power versus voltage curves of a double-sided solar panel with a maximum power P_m=545 W at different values of the front surface illumination power, i.e. W = 95; 450; 630; 700; 740; and 760 W/cm^2. Comparison of the given data in Fig. 1 and fig. 2 with similar data for individual silicon solar cells with solid rear contacts indicates the preservation of the mechanism for changing the main photoelectric parameters depending on an increase in the illumination level.

If we take into account the design features of double-sidedly illuminated SCs, then we would expect some deviation in the pattern of changes in the photoelectric parameters of SCs from similar data for SCs. Due to the high transmittance of IR radiation, double-sided illuminated solar cells should have a lower operating temperature than one-sided illuminated solar cells.

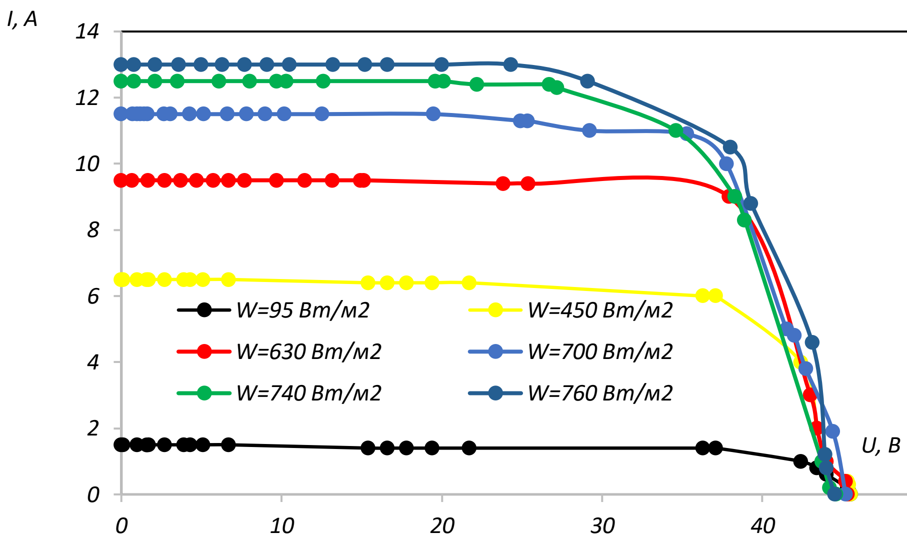

Fig. 1. I-V curves of a double-sided solar panel with a maximum power P_m= 545 W under different conditions of illumination of the front surface

Double-sidedly illuminated SPs are assembled from precisely such SCs. However, the change in the current-voltage characteristics and other basic photoelectric parameters with increasing illumination intensity are identical both for the BS SPs when illuminated from the front side and for the BS SCs. Apparently, some structural parts, namely the metal frame, contact grid, anti-reflective coating and protective glass of the joint venture, absorb IR radiation.

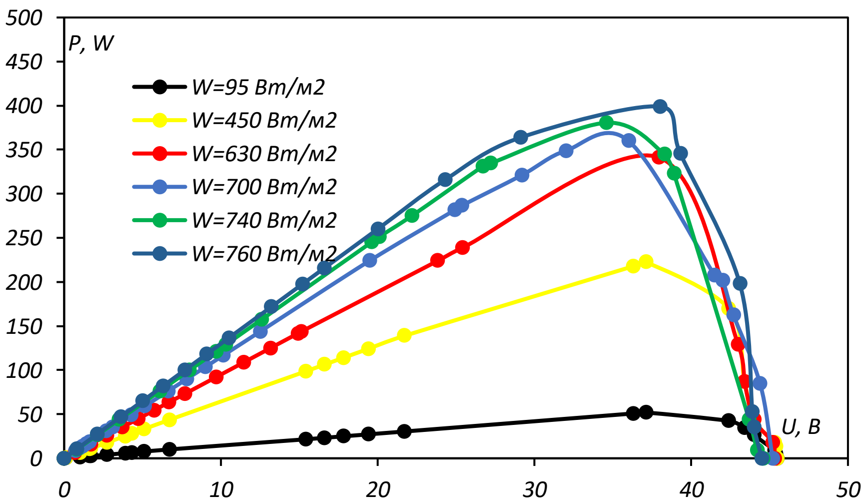

Fig. 2. Curves of power versus voltage of a double-sided solar panel with P_m = 545 W under various conditions of illumination of the front surface

This causes the SC heating process to persist and compensates for the temperature gain achieved by transmitting IR radiation by the SCs themselves. Therefore, it is necessary to control changes in the surface temperature of the solar cells and solar panels themselves, as well as the structural elements of the solar panels.

Experiments were carried out to measure the current-voltage characteristics and the dependence of power on voltage of a double-sided solar panel when the back side was illuminated with sunlight of varying intensities. The measurement results are shown in the form of graphs in Fig. 3 and fig. 4.

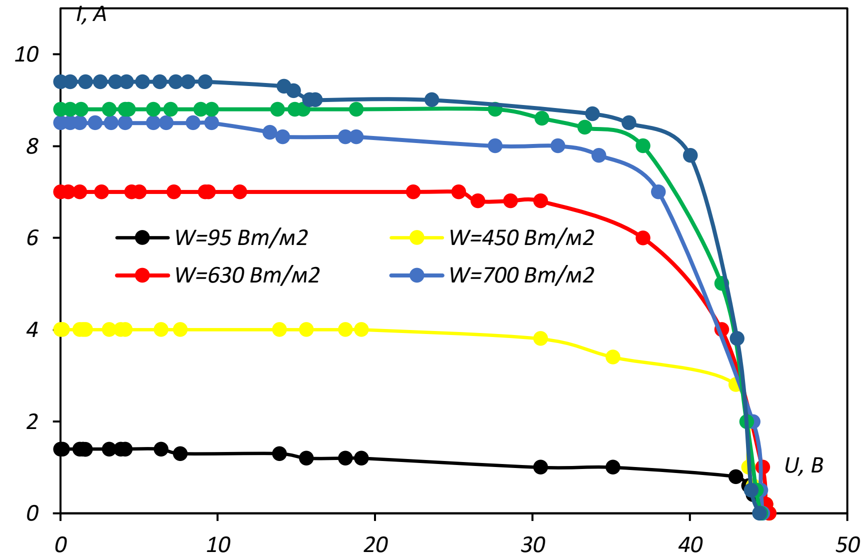

Fig. 3. I-V curves of a double-sided solar panel with Pm = 545 W under different conditions of illumination of the rear surface

As follows from the data in Fig. 3 and fig. 4, the color of the horizontal plane under the BS SP plays an important role in the values of the total output energy.Short-circuit current values and output power take the greatest values with green and yellow colors of the horizontal plane under the BS SP.

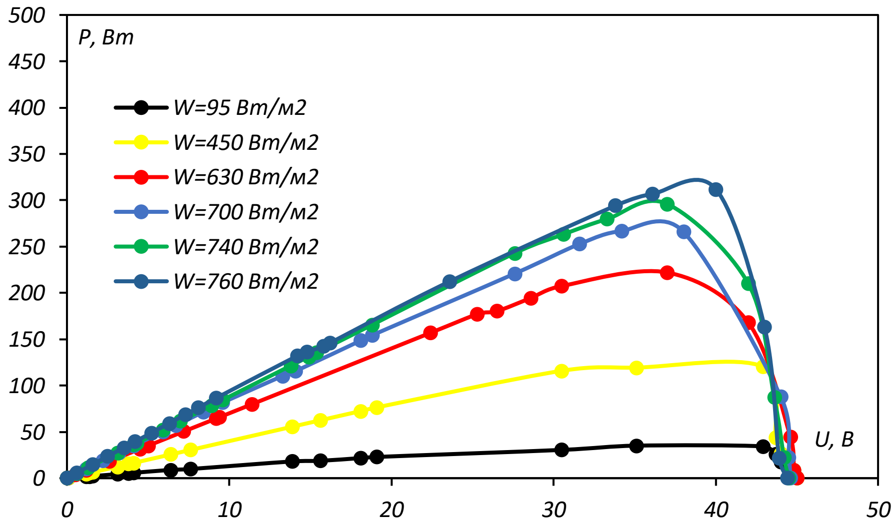

Fig. 4. Curves of power versus voltage of a double-sided solar panel with Pм=545 W under different conditions of illumination of the rear surface

Naturally, in such cases, the contribution of the rear surface to the overall value of the output parameters of the BS SP increases. From here it also becomes clear that if you use specularly reflective surfaces under or behind BS SP should show even better results. To clarify the contribution of such ideas, it is necessary to carry out separate research works in the form of scientific, technical, design or innovation projects. Because such studies make it possible to obtain results for specific areas (on the ground or on the roof), taking into account the architecture and location of various buildings and the colors of their external surface. It is also possible to propose the use of BS SP in agricultural fields, for example, where alfalfa is grown (always green fields). It is of interest to test the PM SP with different colors of the background horizontal surface, the results of which are shown in Fig. 5. With the same inclination of one-sided (OSO) and double-sided (DSO) illuminated objects, the best output parameters have the OSO, naturally due to the contribution of the back side, where randomly scattered light falls.

The formation of green and white background colors under the BS SP provides a significant improvement in the output characteristics (DSO (zf) and DSO (bf) curves, Fig. 5).

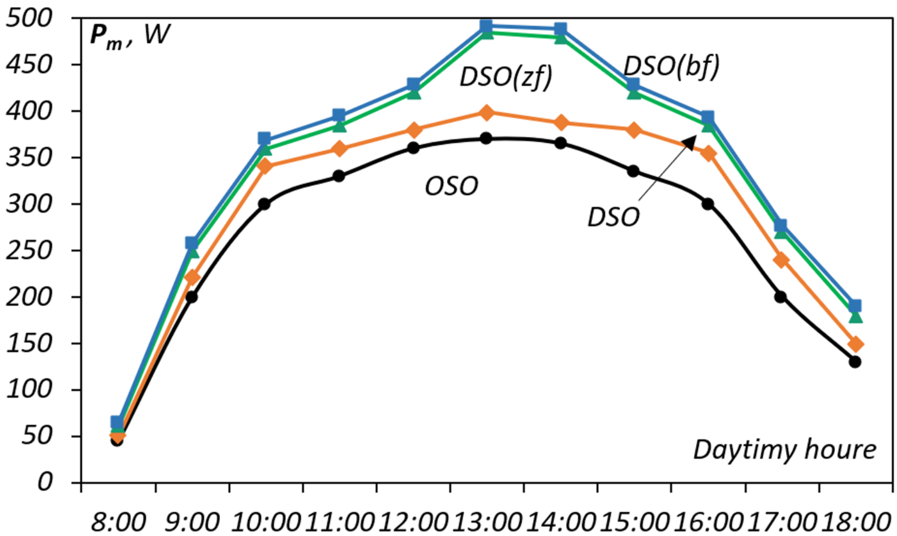

Fig. 5. Power versus time curves of one-sided OSO and double-sided DSO solar panels with green DSO(bf) and white DSO(bf) background colors of the horizontal surface

The importance of color and distance from the horizontal surface under the DS SP to the SP itself is revealed, and also if it is installed in front of a vertical fence (wall), then the color of its surface and the distance between them also play an important role in determining the output parameters.

Therefore, targeted experiments were carried out (Fig. 6) on the influence of the above physical parameters on the output photoelectric and energy parameters of the BS SP. It should be taken into account that the color of the horizontal surface in front of the BS SP can also make its contribution due to the incidence of reflected (scattered) light on the front surface.

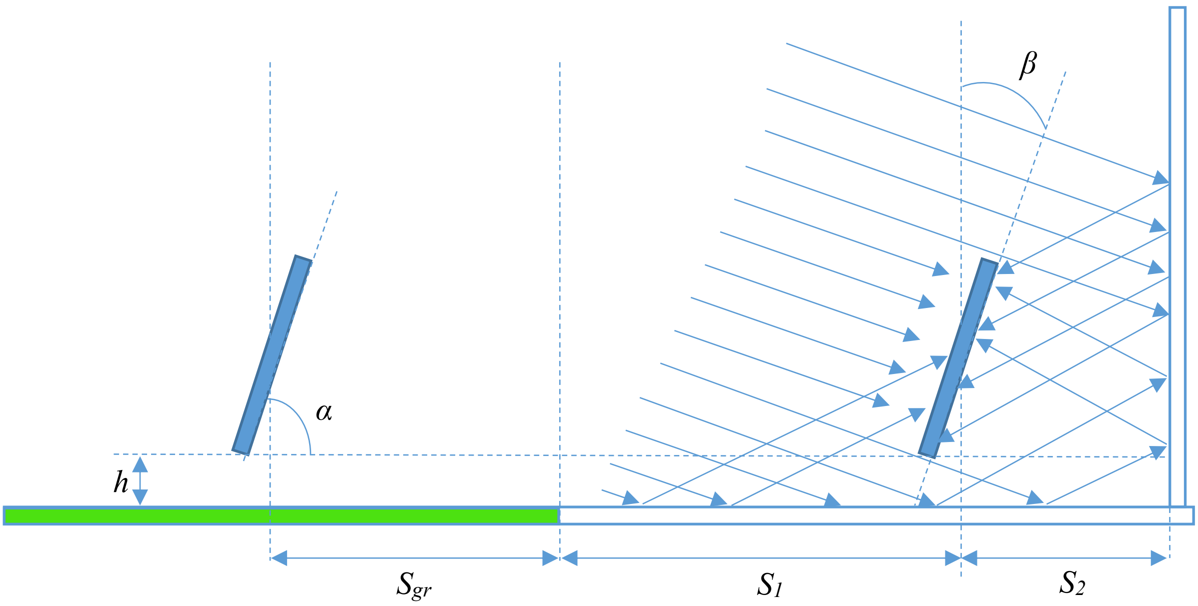

Fig. 6. Diagram for determining the optimal location of a two-way illuminated solar panel

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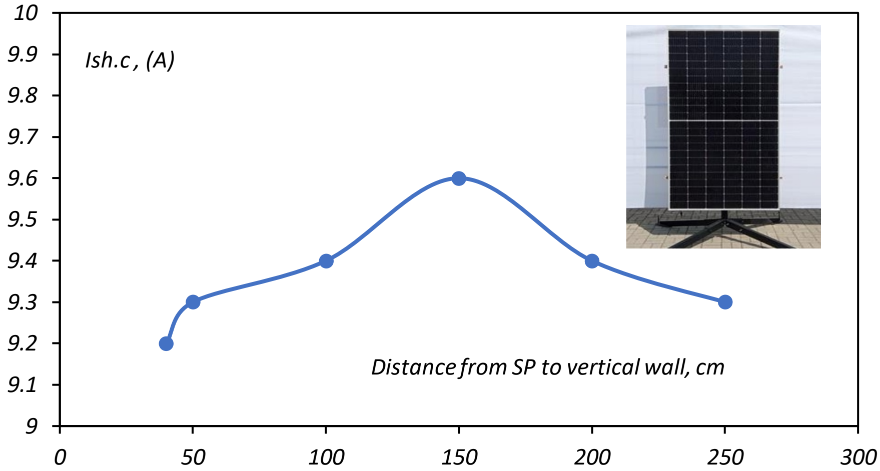

Fig. 7. Dependence of short-circuit current double-sided solar panel (2.28×1.14 m^2), installed vertically (α = 90^o) subject to illumination W = 650 W/cm^2 from the distance of a white vertical wall

Figure 7 shows the data in the form of a graph of the dependence of the short-circuit current of a double-sided solar panel (2.28 × 1.14 m^2), installed vertically (α = 90°) under the condition of illumination W = 650 W/cm^2, from the distance to a vertical white wall. As follows from the graph, there is a clearly defined maximum on the curve, which corresponds to 150 cm.

In Figure 8 shows the dependence of the short-circuit current. double-sided solar panel (2.28×1.14 m^2), installed at a distance of 150 cm from a vertical wall of white color from the angle of inclination (α = 0 ÷ 90 degrees) in relation to the horizon (Fig. 8) under illumination conditions W = 650 W /cm^2. From the graph you can see that the optimal tilt angle from the horizontal is 45 degrees. For such an identical case, using the example of a one-sided joint venture, the optimal angle of inclination is 39 degrees. It is precisely due to the contribution of the back side of the BS SP to the overall values of the main photoelectric parameters that there is a significant difference in the values of the optimal inclination angle of the two types of SP.

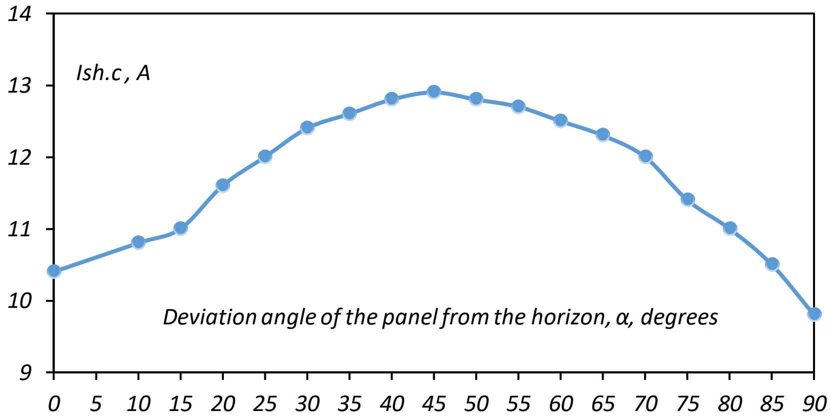

Fig. 8. Dependence of short-circuit current double-sided solar panel (2.28 × 1.14 m^2), installed at a distance of 150 cm from a vertical wall of white color from the angle of inclination (α = 0 ÷ 90 degrees) in relation to the horizon (Fig. 7) under the condition of illumination W= 650 W/cm^2

According to Fig. 9, which shows the dependence of the short-circuit current of a double-sided solar panel (2.28 × 1.14 m2), installed at a distance of 150 cm from the rear vertical wall, with illumination W = 700 W/m^2 and tilt angle α = 45° relative to the horizon from angle of inclination from the vertical in the range β = -90^o ÷ +90^o. At values β = -10^o ÷ +10^o the highest values of short-circuit current are achieved BS SP. From the graph you can see that the plus (right) side corresponds to the front, minus (left) side corresponds to the back side of the B SP.

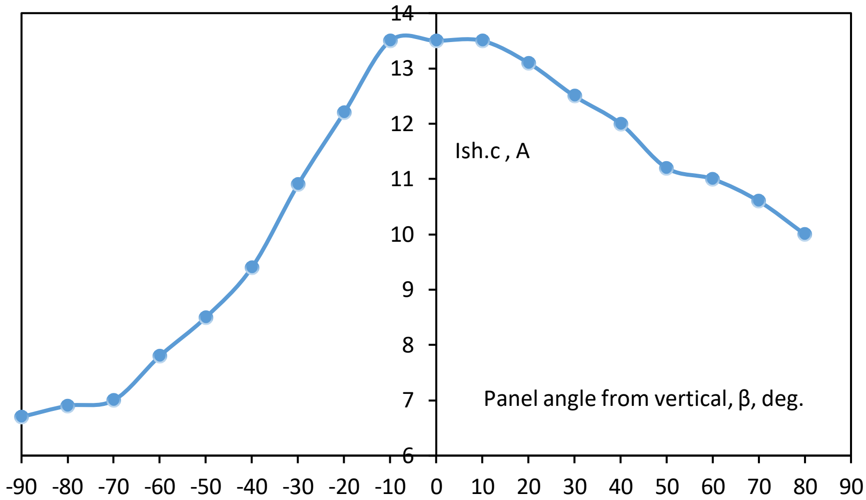

Fig. 9. Dependence of short-circuit current. double-sided solar panel (2.28×1.14 m2), installed at a distance of 150 cm from a vertical wall, with illumination W = 700 W/m2 and tilt angle α = 45° from the tilt angle from the vertical β = -90° ÷ + 90°

Unlike single-sided SPs, BS SPs can be installed in a vertical position. Examples of the possibilities of vertically installing BS SPs include their installation along the road and in rows with certain distances between rows on green fields. From the obtained preliminary results of the vertical installation of the BS SP, it can be noted that there are two options for their installation with a front/rear orientation in the form of east/west and south/north. The total power generated by the BS SP and its distribution over time during the day have significantly different curves from each other. The experimental results obtained made it possible to formulate new and energetically useful practical recommendations for the use of BS SPs, which differ from the procedures for using one-sidedly illuminated SPs.

4. Conclusion

Thus, the optimal orientation angles of solar panels with two-sidedly illuminated silicon solar cells have been determined, which are significantly different from traditional solar panels with one-sidedly illuminated silicon solar cells. The optimal distance from the rear vertical wall and height from the horizon, as well as the color of the surface reflecting them, were determined to achieve high efficiency of solar panels with bilaterally illuminated silicon solar cells. The temperature coefficients of the main photovoltaic parameters of power plants with one- and two-sided illuminated silicon solar cells have been determined. The advantage of using photovoltaic power plants with two-sidedly illuminated silicon solar cells in hot climates is shown.

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