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The impact of selected parameters on the efficiency of a photovoltaic installation with bifacial modules in local conditions

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Abstract: The article presents a comparison of the results of simulation by a photovoltaic installation with bifacial modules. The analyzed 20 kWp PV installation was located in the Kuyavian--Pomeranian Voivodeship. The article compares how the energy production of installations with bifacial modules changes depending on the angle of inclination, the distance between the rows of modules and the orientation. The results obtained in the study indicate that albedo is an important, but not the only parameter to be considered when designing a farm with bifacial modules.

Keywords: photovoltaic, efficiency, bifacial module, PVsyst

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Introduction

Bifacial panels have two sides covered with tempered glass or foil, which can absorb light from the front and back of the panels. In bifacial panels, there is a double-sided absorption of photons, which results in 30% more energy produced compared to traditional one-sided modules. As indicated in its International Technology Roadmap for PV, the future belongs to bifacial technology. It is assumed

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that bifacial solar panels with bifacial cells will dominate the market in the coming years (Fig. 1). However, it should be emphasized that the development of this technology at the cellular, modular or system level is still required (Gallardo-Saavedra & Karlsson, 2018).

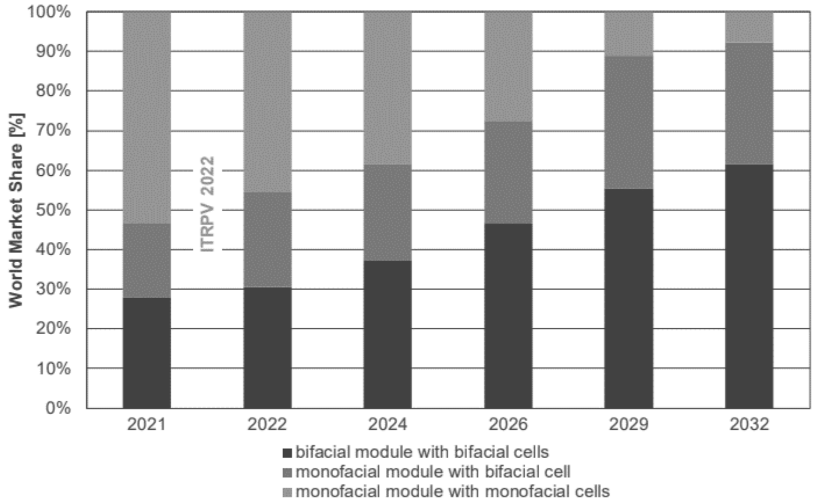

Fig. 1. Forecasts of the share of bifacial and monofacial panels in the photovoltaic market according to ITRPV 2022 (source: IHS Markit Report Global PV Tracker Market Report)

Bifacial modules offer certain advantages over conventional modules, such as higher energy efficiency, higher energy density and lower operating temperature. The most important factors affecting the coefficient of increased energy yield in PV systems with double-sided modules include:

– albedo, i.e. the ability of the surface of the substrate on which the system is installed to reflect solar radiation,
– degree of soil contamination,
– the height of the modules above the ground,
– orientation of the module plane,
– angle of inclination of the module,
– distance between rows of modules,
– ground-coverage ratio (GCR),
– DHI diffuse radiation,
– shading (includes self-shading) and uneven illumination of the rear surface of the modules (junction box, elements of the assembly structure, etc.).

One bifacial module that was placed in a PV system designed with the correctly selected parameters mentioned above can produce more electricity, thanks to its back side absorbing the radiation reflected from the ground (Kopecek & Libal, 2021; Oliveira-Pinto & Stokkermans, 2020; Porter, 2019; Rodríguez-Gallegos et al., 2018; Walichnowska et al., 2022).

1. Methodology

In this study, PVSyst software version 7.2 is used to analysis the impact of selected parameters on the efficiency of a photovoltaic installation with bifacial modules in local conditions. The simulated farm with a capacity of 6.3 kWp was designed in a stationary system and located in the Kuyavian-Pomeranian Voivodeship. The designed PV farm has 20 bifacial modules arranged at 2x2 with a unit power of 315 Wp and an inverter Solar Edge SE10K. The lower edge of the bifacial modules is located at a height of approx. 60 cm from the ground. The article compares the energy gains of the installation depending on the albedo, the angle of inclination, the orientation and the distance between the rows of modules.

A. Albedo

An important parameter affecting higher energy yields from the installation of bifacial modules is the type of substrate on which the panels are mounted. The sun's rays from different surfaces are reflected in different percentages. The efficiency of bifacial panels depends on the albedo coefficient of the given surface under the modules. The brighter the surface, the more light it reflects, which in turn translates into higher values of energy yield from the installation (Gostein et al., 2020; Russell et al., 2017).

B. Angle of inclination

The incorrect angle of inclination of the panels reduces the amount of energy produced, which in turn is associated with a decrease in the profitability of the entire PV installation (Aryal & Bhattarai, 2018).

C. Orientation

Another important parameter affecting the efficiency of a PV installation is the orientation. It is best to direct a photovoltaic installation towards the south, to obtain the best conditions to convert solar radiation into electricity thanks to the photoelectric effect (Kurz et al., 2018; Boddapati & Daniel, 2020).

D. The distance between the rows of modules

When installing bifacial panels on the ground, it is important to leave appropriate distances between the rows so that individual rows of panels do not shade each other and the ground beneath them. The shadow falling on the surfaces under the modules affects the limited access to the light of the rear side of the modules. To avoid losses due to shading, the rows of panels should be spaced far enough apart that the surface under the row and the row of PV panels will not be shaded (Branker et al., 2011; Idzikowski et al., 2022).

2. Results of the simulation

To assess how the amount of energy produced changes depending on the angle variation, simulations were conducted using the PVSyst program for the specific photovoltaic installation. The analysis employed an orientation of 0°, a panel row spacing of 5 m, and an albedo of 0.2. The results are presented in Table 1.

Table 1. The amount of energy produced depending on the change in the angle of inclination of the PV panels (*own elaboration based on simulations in the PVSyst program*)

Angle of inclination	15°	20°	22°	25°	27°	30°	35°	40°	45°
Produced energy [MWh/year]	6.584	6.722	6.766	6.823	6.856	6.896	6.941	6.939	6.935

The obtained values show that for the angle of 35° the installation achieves the highest values of the energy produced, which confirms that this is the optimal angle for Poland. It is assumed that this angle allows for the highest efficiency of the installation both in the summer and winter months. However, it should be emphasized that setting the modules at such an angle is only possible in ground systems and on flat roofs through a specially designed supporting structure.

Table 2 presents the results of the simulation for the farm when changing the direction of its foundation, decreases in energy profit are visible with the change of direction – the more the installation is turned from the south, the less energy is produced. The angle for the analysis was 35° and the distance between rows of panels was 5 m. The albedo was 0.2.

Table 2. Values of energy yield depending on the change of the system orientation (*own elaboration based on simulations in the PVSyst program*)

Orientation	Produced energy [MWh/year]
0°	6.941
45°	6.578
90°	5.671
180°	3.979

In order to verify the effect of the distance between the rows of panels (Fig. 2), simulations of the photovoltaic installation in question were carried out. The analysis used an orientation of 0, an albedo of 0.2 and the angle 35°.

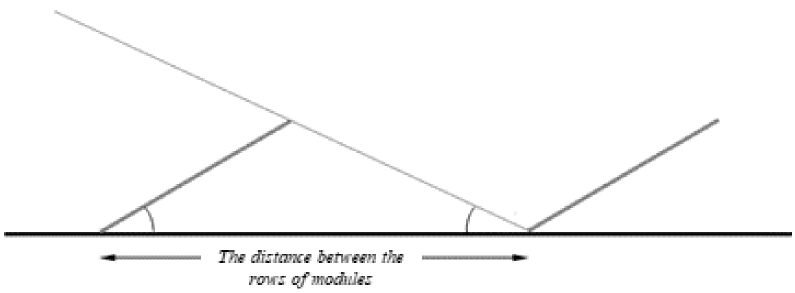

Fig. 2. Scheme with indication of the distance between the modules (*own elaboration*)

The simulation results in the form of annual energy production and the efficiency index of the photovoltaic installation for individual distances between the rows of panels are presented in Table 3.

Table 3. Energy yield values depending on the change in the distance between the rows of panels (*own elaboration based on simulations in the PVSyst program*)

The distance beetwen the rows of modules [m]	4	4.5	5	5.5	6	6.5	8	10
Produced energy [MWh/year]	6.659	6.824	6.941	7.031	7.101	7.149	7.245	7.303

The obtained values show that the greater the distance between the rows, the greater the energy gains. This is caused by the fact that the row of modules not only avoids shading the next row behind it, but also the ground in front of it. The solar reflecting surfaces act on the rear side of the module not only from the area below and behind the modules, but also from the area in front of the modules.

The energy yields of the installation with bifacial modules were compared to installations with a variable substrate. The adopted parameters for the comparison were an angle of 35°, south orientation, and a distance of 5 m between rows of panels. Simulations were conducted for three types of substrate: grass (albedo 0.20), concrete (albedo 0.35), and dry sand (albedo 0.45). Table 4 presents the energy yields in individual months for the three tested cases, expressed in MWh.

Table 4. Monthly energy production at different albedo coefficients (*own elaboration based on simulation data in the PVSyst Program*)

Month	Monthly energy production for an albedo of 0.20 [MWh]	Monthly energy production for an albedo of 0.35 [MWh]	Monthly energy production for an albedo of 0.45 [MWh]
January	0.169	0.173	0.175
February	0.324	0.330	0.334
March	0.619	0.630	0.637
April	0.831	0.851	0.864
May	0.924	0.956	0.977
June	0.884	0.919	0.941
July	0.883	0.916	0.938
August	0.856	0.880	0.897
September	0.668	0.681	0.690
October	0.452	0.460	0.465
November	0.186	0.190	0.192
December	0.145	0.147	0.148
The sum	**6.941**	**7.132**	**7.259**

The simulation shows that the substrate in the form of dry sand, for which the albedo is 0.45, has the best ability to reflect sunlight from the presented variants (Fig. 3).

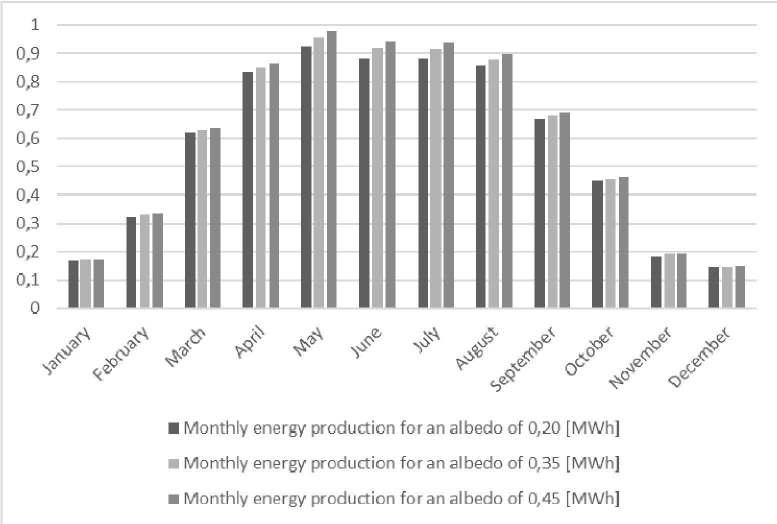

Fig. 3. Monthly energy production at different albedo coefficients (*own elaboration*)

However, it should be emphasized that the differences in the results are small. This raises the question of whether it is necessary to intervene with the natural ground when investing in above-ground PV installations, especially since these systems often utilize green meadows as the base. It may be more beneficial to explore alternative options, such as changing the panel assembly system, to achieve higher energy production.

Conclusion

Based on the analysis, it can be concluded that albedo is an important, but not the only parameter to be considered when designing a farm with bifacial modules. To increase the efficiency of the installation, it is worth choosing the angle of inclination of the module's orientation correctly and the distance between the rows of modules. In summary, the research shows that:

a) when choosing the best substrate for a photovoltaic installation, it is not always worth choosing the highest albedo value, as the extra cost of a substrate with a higher albedo may not be financially viable,
b) the conducted analysis confirms that the panels should be mounted in the southerly direction. According to the data obtained, the more the panels are orientated in a northerly direction, the lower the annual energy production,
c) natural energy resources, including energy obtained from the Sun, provide real opportunities for the development of distributed energy and a significant reduction in the use of fossil fuels for energy production in Poland.

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