

BIFACIAL PHOTOVOLTAIC MODULE RESEARCH EXPERIMENT. PART 1: DESIGN AND CONSTRUCTION

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Abstract: The present study concerns the construction of a bifacial photovoltaic module research experiment in Bucharest, as well as the reporting of the first monitoring results. This paper presents a comparative study of monofacial and bifacial photovoltaic (PV) modules, with a focus on the role of the reflective surface materials (albedo) in enhancing the backside irradiance and overall system performance. The research was conducted at the Technical University of Construction Bucharest (UTCB) and combines numerical simulations performed with Dialux Evo and PV Sol with real experimental measurements. The results demonstrate that bifacial panels outperform conventional monofacial panels under diffuse irradiance conditions, with energy gains of up to 34% on certain measurement days and a cumulative monthly surplus of 4.43%. The study also addresses critical installation parameters, such as tilt angle, mounting height and selection of reflective surface materials, providing practical guidelines for integrating bifacial systems into passive and energy-efficient buildings.

Keywords: albedo; reflective surfaces; solar energy; building-integrated photovoltaics; energy efficiency

1. Introduction

One important technology used today to increase the specific production of the photovoltaic modules is to use not only the front side, but also the back side of a PV module (bifacial technology), so more energy can be collected for the same installed area. It has to be noted that the International Technology Roadmap for Photovoltaic (ITRPV) has projected a market share of 85% for bifacial PV cells by 2032.

Systematic literature reviews of the bifacial photovoltaic module and its applications have recently been presented ([1, 2]). Another important comprehensive review has been published [3], presenting bifacial photovoltaic technology working principle, basic structure, cell categories, energy losses, merits and demerits. By increasing ground reflectance (albedo), the gain of bifacial modules becomes relevant especially on cloudy days. It has been emphasized the fact that, under optimum conditions, used in conjunction with reflective surfaces, bifacial modules can offer up to 15-30% more energy than fixed mono-facial modules. The bifacial photovoltaic module are especially suitable for large-scale installations in rooftop or open areas.

The key quantity in the study of bifacial PV modules is the backside irradiance, which depends on many factors related not only to the climatic conditions, but also to the installation and operation of the system. Therefore, the performance of bifacial systems has to be established and validated by further research, based on measurement and monitoring systems that could provide long-term field data.

The performance of bifacial PV modules, as a direct function of the front and backside irradiance, depends also on location. Therefore, studies have been performed in different locations of the world and for different climatic conditions (India [4], Nigeria

[5], Arizona [6], China [7], UK [8]), even at high latitudes (Nordic countries [9, 10]) or in the presence of the snow (Japan [11], Michigan [12]). Those studies report different rates of the increase of the power at the maximum power point of the bifacial operation, in the comparison between the bifacial and mono-facial modules operation.

The present study concerns the construction of a bifacial photovoltaic module research experiment in Bucharest, as well as the reporting of the first monitoring results.

The present research has the general objective to evaluate the efficiency of bifacial photovoltaic systems and to investigate the influence of reflective surfaces on their performance. This type of photovoltaic panels represents an important innovation in the field of solar energy due to their ability to capture radiation on both sides.

Bifacial photovoltaic technology has emerged as a promising approach, as it enables electricity generation on both the front side (direct irradiation) and the rear side (reflected irradiation) of a solar module. This feature provides a competitive advantage over monofacial panels, as it allows for higher efficiency and better adaptability in various environments.

The research aims to combine numerical and experimental analysis to contribute to the development of existing methodologies for sizing and using bifacial systems. Additionally, through the construction of an experimental stand, the research seeks to compare different reflective materials and identify those that maximize energy production.

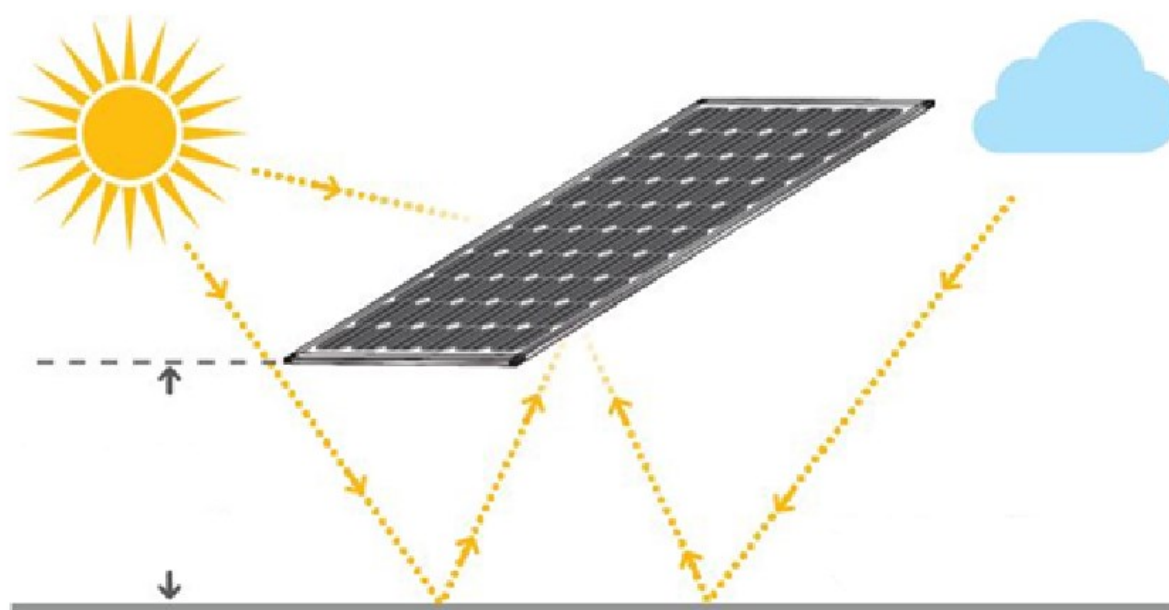


Fig. 1 - Schematic representation of a bifacial photovoltaic system capturing both direct and reflected solar radiation.

The main objective of this study is to investigate how different reflective substrate materials influence the overall performance of bifacial PV systems and to establish an optimal sizing methodology applicable to passive and energy-efficient buildings.

The expected results may be integrated into a set of recommendations applicable to the design of photovoltaic installations for passive and energy-efficient buildings, following a sufficiently large number of measurements covering the most common solar radiation scenarios.

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2. Design of the experimental stand

2.1. Theoretical study on the functioning and efficiency of bifacial panels: installation of the panels in the testing stand

The efficiency of a bifacial PV system depends not only on the quality of the panels but also on the geometric installation parameters. The research project carried out at UTCB established the following design criteria for evaluating system performance: tilt angle and mounting height.

2.1.1. Tilt angle

The tilt angle is chosen by prioritizing the efficiency of the front side, which provides the largest share of total energy production, regardless of the reflective properties of the mounting surface. Optimal tilt angles are determined based on geographic latitude and annual solar trajectory analysis.

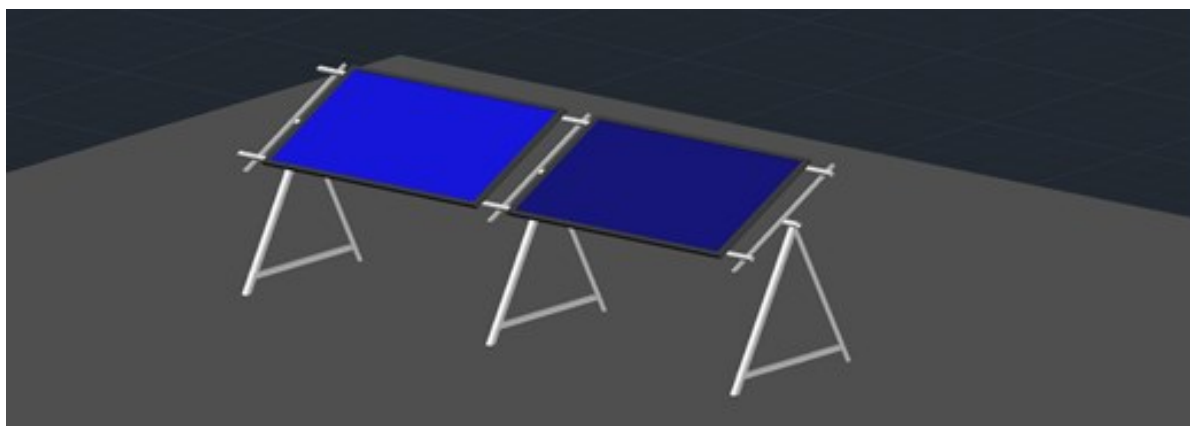


Fig. 2 - Design stage of the experimental stand.

To diversify the experimental conditions, the photovoltaic system was designed with the capability to rotate around one axis, allowing the tilt angle of the photovoltaic modules to be varied in a controlled manner and thus enabling more testing scenarios.

2.1.2. Mounting height

The energy contribution of bifacial photovoltaic systems depends, among other factors, on the mounting height of the modules above the roof surface, measured at their lower edge. The greater this distance, the more uniformly the reflected solar radiation reaches the rear side of the panels, contributing to increased energy production.

A minimum mounting height of 0.5 m above the roof surface is recommended. A greater height results in a more uniform distribution of irradiation on the back side of the module, thus increasing the energetic contribution of the rear side.

2.2. Theoretical study on the functioning and efficiency of bifacial panels: installation of the panels in the testing stand

To evaluate the performance of a wide range of reflective surface materials before physical implementation, the study uses two complementary simulation platforms: Dialux Evo for detailed optical and luminance analysis of the mounting surface, and PV Sol for energy yield simulations of the complete photovoltaic system.

This dual simulation methodology enables systematic evaluation of candidate materials and installation configurations, significantly reducing the time and costs associated with experimental prototype testing.

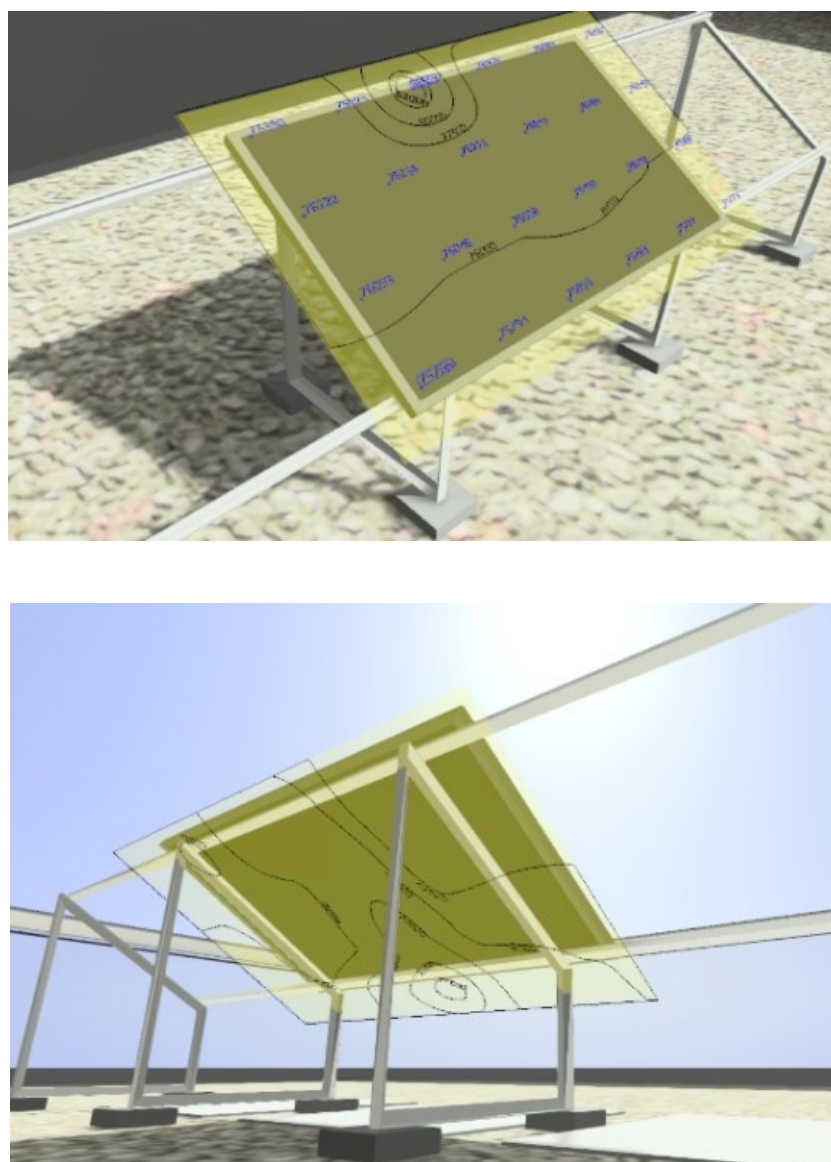


Fig. 3 - Simulation of solar radiation distribution on the surfaces of the photovoltaic panel

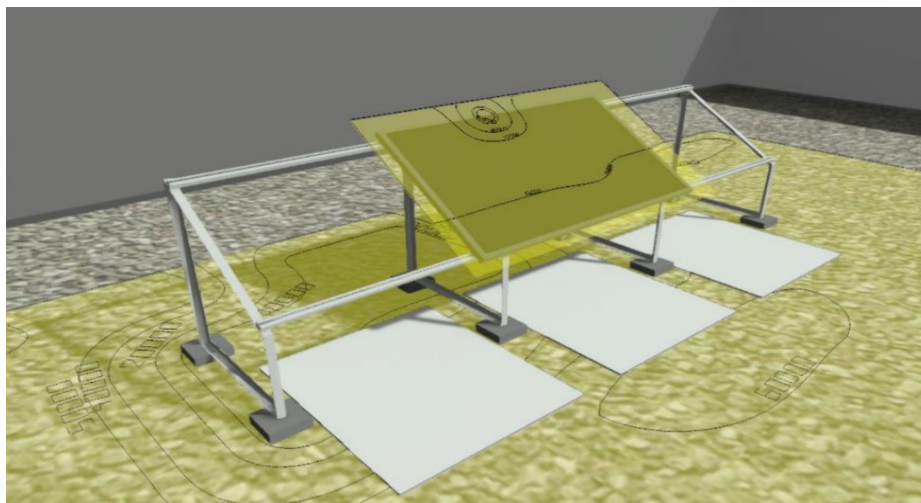
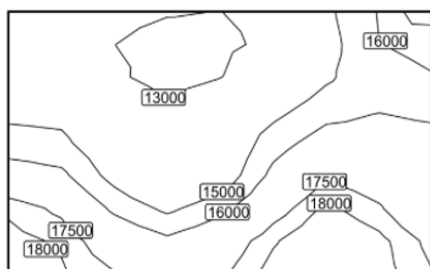


Fig. 4 - DIALux Evo simulation interface showing the configuration of the bifacial system and the estimated energy production

Fa $\square$ ă inferioară panou fotovoltaic:
Scena luminii: Light scene 1
Mediu: 15401 lx, Min: 12838 lx, Max: 18561 lx, Min/mediu: 0.83, Min/Max: 0.69

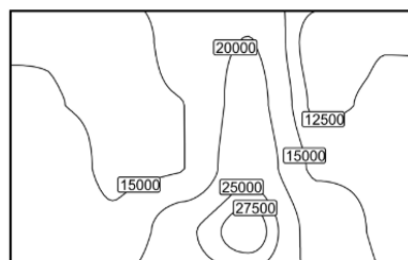
Izolinii [lx]



Scară: 1 : 25

Fa $\square$ ă inferioară panou fotovoltaic:
Scena luminii: Light scene 1
Mediu: 16616 lx, Min: 11078 lx, Max: 29320 lx, Min/mediu: 0.67, Min/Max: 0.38
Înălțime: 0.750 m

Izolinii [lx]



Scară: 1 : 25

Fig. 5 - DIALux Evo optical simulation of irradiance distribution on the reflective surface

From the simulation results, using only the bituminous terrace surface, the average perpendicular illuminance on the rear side of the panel had a value of 9707 lux, representing 12.7% of the average illuminance of the front side.

Using aluminum plates with a high reflectance of 80%, simulations showed a significant increase in illuminance on the rear side - from 9707 to 16616 lux, a 58.4% increase, reaching 21.7% of the front-side illuminance.

3. Construction of the experimental stand and testing of reflective surfaces

An important aspect of the experimental stand is its ability to rotate along one axis, achieved through an upper pivot bar that allows manual adjustment of the panel tilt angle depending on the season.



Fig. 6 - Mounting structure of photovoltaic modules with one-axis pivot bar



Fig. 7 - Panel fastening elements

The mounting structure is designed using aluminum profiles to ensure mechanical strength (as presented in Fig. 7).

A market study was carried out and offers were requested for the necessary equipment and materials.

For constructing the albedo surface, several light-colored materials were used, such as ceramic tiles, white painted metal sheets, and other construction materials placed between the structure supports, with the purpose of reflecting solar radiation toward the rear side of the bifacial panels to maximize captured energy – examples are given in Fig. 8.



Fig. 8 - Example of materials used to create the albedo surface

Conclusions

The present paper presented the design and construction of a bifacial photovoltaic module research experiment in Bucharest.

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