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Comparative Performance Analysis of Photovoltaic Systems with Bifacial and Monofacial Panels

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Abstract:

The search for more effective and at the same time cost-effective solutions in the PV industry causes the creation of an increasing number of installations using bifacial modules. This article presents a comparison of the energy gains of two photovoltaic farms - the first with bifacial modules, and the other with mono-facial modules. Moreover, the market of bifacial modules is discussed along with development prospects in the coming years, the technologies are characterized and the main factors influencing the improvement of energy gains from the operation of panels.

Keywords:- Bifacial module, PVSyst symulation, Photovoltaic.

Introduction:

The search for more effective solutions in obtaining energy from renewable energy sources influences the growth of types of photovoltaic panels available on the market and their efficiency all over the world. Current development works concern the improvement of their efficiency, the development of bifacial technology and the optimization of cell production. Double-sided panels have two sides covered with toughened glass or foil, which allows them to absorb light both on the front and back of the panels. In bifacial panels, photons are absorbed on both sides, which means that the energy produced is 30% higher compared to traditional single-sided panels. As the International Technology Roadmap for PV shows in its studies, the future belongs to bifacial technology. It is assumed that bifacial cells will dominate the market in the coming years (Figure 1). However, it should be emphasized that the development of this technology is still required at the cellular, modular or system level [1, 2, 3, 4]

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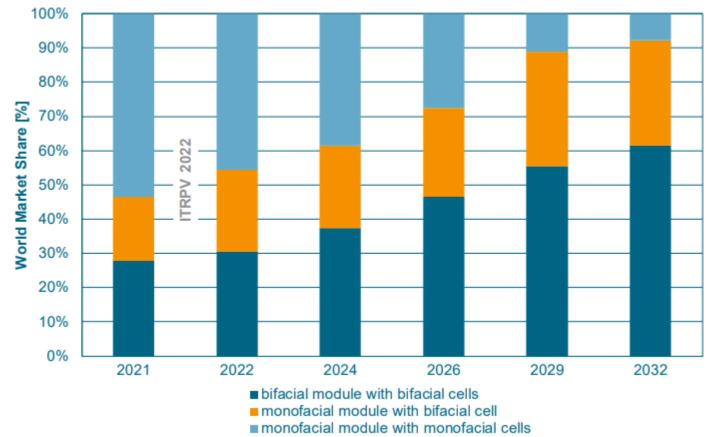

Fig. 1. Forecasts of the Share of Bifacial and Monofacial Panels in the Photovoltaic Market According to ITRPV 2022

Theoretical Part:

Bifacial panels, unlike monofacial ones, are characterized by the possibility of generating electricity both on the front and rear side of the PV module (Figure. 2). In addition, the radiation dose received by the rear part of the module means that more current is generated, which allows for obtaining more power from cells with the same surface area [2, 5, 6].

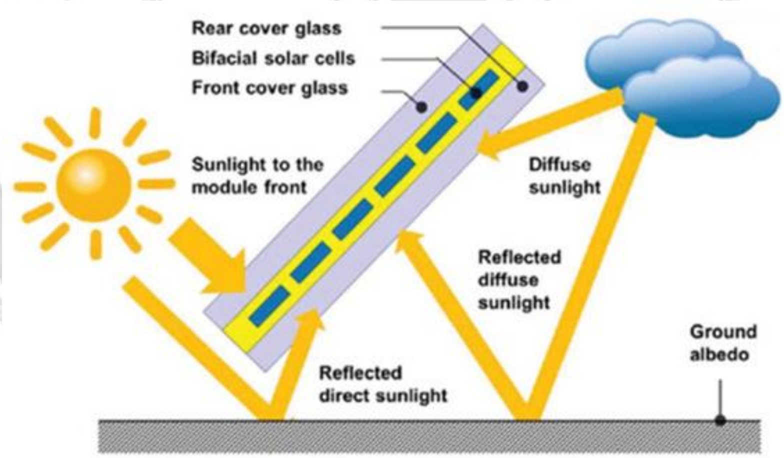

Fig. 2. Bifacial Panels Operation Diagram [13]

According to many experts, this technology is currently on the right track as the newest trendin the PV industry and will soon become the dominant standard. PV installations in the world with two-sided modules in 2016, they had a capacity of only 97 MW in the world. In 2019, this power increased to almost 6 GW. As the price difference between the double-sided module technology and the single-sided technology decreases, it is expected that the market share of this technology will increase [7, 8, 4]

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Bifacial panels, according to the research carried out so far, are considered to be more efficient compared to their traditional counterparts. Due to double-sided modules, you can get up to 20-25% more energy. Much depends on how much sunlight is reflected from a special surface. All shading elements also have a particularly large impact on performance. To increase the efficiency of bifacial panels, the parameters that should be taken into account during assembly are important. These parameters include the presence of shade, the angle of inclination of the panels, the type of surface, the presence of specific weather conditions or the orientation of the installation. Very important for the efficiency of two-sided modules is the so-called the albedo factor, which shows the ability to reflect light from a given surface. The brighter the surface, the more light it can reflect and the better for energy recovery from the back surface of the module. The table below shows the factors for each type of surface:

Tab. 1. Albedo Values of Selected Surfaces *خطأ! لم يتم العثور على مصدر المرجع.*

Type of surface	**Albedo**
Black ground	0,08-0,14
Grass	0,14-0,37
Dry sand	0,35-0,45
Wet sand	0,20-0,30
Concrete	0,20-0,35
Asphalt	0,05-0,20
Fresh snow	0,80-0,95

In Poland, the annual amount of insolation amounts to an average of 1000 kWh / m^2. About 77% of the annual radiation energy is obtained in the summer half-year, while only 23% in the winter half-year from October to April. The months of June, July and August are the sunniest, where about 43% of the annual radiation is obtained [10, 11, 12, 3, 5, 13].

Materials and Methods:

For this analysis, a grid connected photovoltaic system is modelled and simulated using PVsyst software. The main purpose of this analysis is to compare the annual energy efficiency of 0,48 MW farms with bifacial and monofacial panels located in Poland. The article compares two farms. The first PV plant that is described in this study comprises RSM-144-6-405-BMDG-Bifacial PV modules. The farm contains 1200 modules of power 405 Wp and three inverters Sun2000-125KTL-M0. The grass was taken as a substrate under the panels with albedo 20%. The panels are arranged in 18 rows in south direction at an angle 25º and a pitch 3,5 m (Figure. 3).

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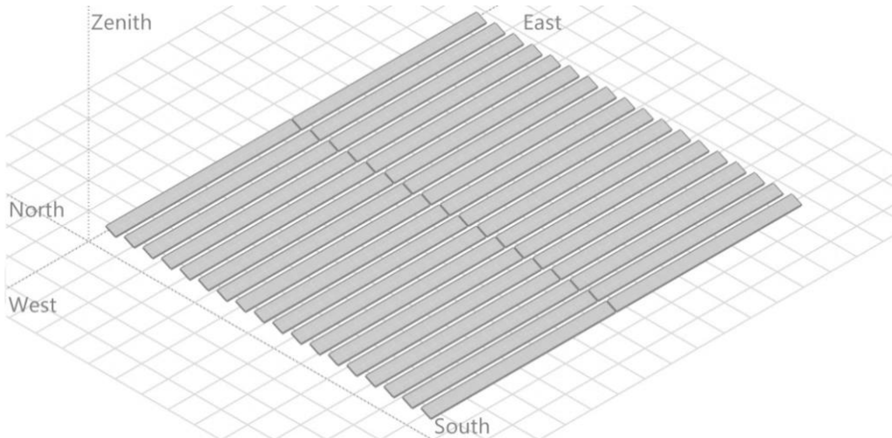

Fig. 3. The Visualization of Sample PV Farm with Bifacial Panels Arranged on the South (source: PVsyst, own elaboration)

The second PV farm that is described in this study comprises RSM-144-6-405-M PV modules. The farm contains 1200 modules of power 405 Wp and three inverters Sun2000-125KTL-M0. The panels are arranged in 18 rows in south direction at an angle 25º and a pitch 3,5 m (Figure. 4).

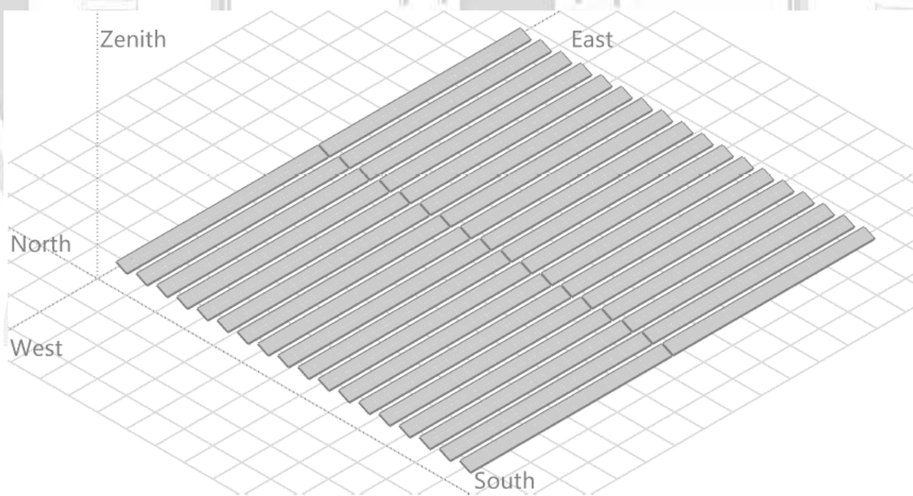

Fig. 4. The Visualization of Sample PV Farm with Monofacial Panels Arranged on the South (source: PVsyst, own elaboration)

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Results and Discussion:

A. The farm with bifacial modules

The most important results of the simulation for a farm with bifacial panels are presented in the (Table 2.) For the study location, annual global irradiance on horizontal plane is 1057,0 kWh/m^2. Annual DC Energy produced from the PV array and annual AC energy injected to grid are 547,78 MWh and 540,01 MWh respectively.

Tab. 2 Simulation Results for Farm with Bifacial Modules (source: PVSyst)

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	18.6	13.72	-1.56	28.7	22.0	11.15	10.97	0.786
February	35.5	21.43	-0.46	52.8	46.1	23.12	22.79	0.888
March	78.8	41.57	3.28	102.7	97.5	47.65	47.00	0.942
April	122.4	59.20	8.93	143.7	137.7	66.14	65.22	0.934
May	158.2	78.15	14.18	167.3	159.9	76.04	74.96	0.922
June	160.9	86.44	16.98	162.7	154.9	73.59	72.55	0.917
July	159.2	80.29	19.35	164.2	156.5	73.45	72.38	0.907
August	139.9	66.86	18.72	156.0	149.6	69.49	68.47	0.903
September	94.3	49.05	13.66	116.3	111.0	52.44	51.73	0.915
October	54.3	30.73	8.91	76.9	70.2	33.59	33.14	0.887
November	21.6	15.65	4.52	31.9	25.6	12.70	12.51	0.806
December	13.3	8.17	0.69	25.1	17.1	8.44	8.29	0.679
Year	1057.0	551.26	8.99	1228.4	1148.1	547.78	540.01	0.905

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

As part of the simulation, it was determined normalized productions such as collection losses, system losses and produced useful energy per installed kWp/day (Figure. 5). Lc is the Collection losses or the PV array capture losses i.e. 0,28 kWh/kWp/day. Ls is the system loss i.e. 0,04 kWh/kWp/day and the Yf is the produced useful energy i.e. 3,04 kWh/kWp/day.

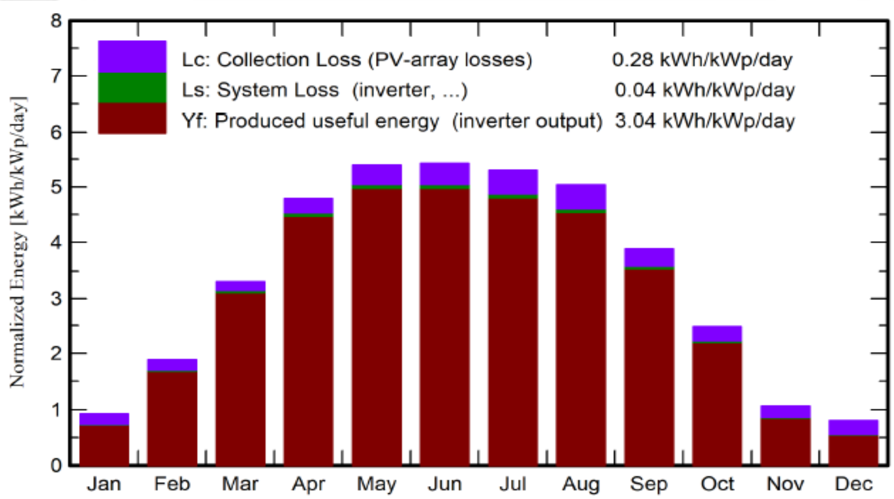

Fig. 5. The Visualization of Sample PV Farm with Bifacial Panels Arranged on the South (source: PVsyst, own elaboration)

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B. The farm with monofacial modules

The results of the simulation for a farm with monofacial panels are presented in the (Table 3.) For the study location, annual global irradiance on horizontal plane is 1057,0 kWh/m^2. Annual DC Energy produced from the PV array and annual AC energy injected to grid are 518,30 MWh and 510,89 MWh respectively.

Tab. 3 Simulation Results for Farm with Monofacial Modules (source: PVSyst)

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	18.6	13.72	-1.56	28.7	22.0	10.67	10.49	0.751
February	35.5	21.43	-0.46	52.8	46.0	22.42	22.10	0.861
March	78.8	41.57	3.28	102.7	97.4	45.95	45.32	0.908
April	122.4	59.20	8.93	143.7	137.4	62.84	61.97	0.887
May	158.2	78.15	14.18	167.3	159.5	71.21	70.19	0.863
June	160.9	86.44	16.98	162.7	154.5	68.39	67.41	0.852
July	159.2	80.29	19.35	164.2	156.1	68.34	67.34	0.844
August	139.9	66.86	18.72	156.0	149.3	65.47	64.52	0.851
September	94.3	49.05	13.66	116.3	110.8	50.13	49.45	0.875
October	54.3	30.73	8.91	76.9	70.2	32.56	32.13	0.860
November	21.6	15.65	4.52	31.9	25.6	12.16	11.97	0.771
December	13.3	8.17	0.69	25.1	17.1	8.16	8.02	0.657
Year	1057.0	551.26	8.99	1228.4	1145.9	518.30	510.89	0.856

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

For second farm collection losses is 0,44 kWh/kWp/day, the system loss is 0,04 kWh/kWp/day and produced useful energy - 2,88 kWh/kWp/day. These values are shown in (Figure 6).

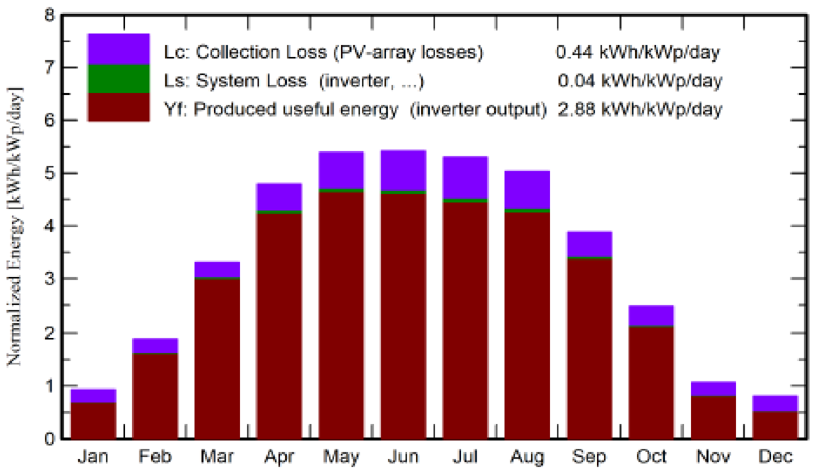

Fig. 6. The Visualization of Sample PV Farm with Monofacial Panels Arranged on the South (source: PVsyst, own elaboration)

Conclusions:

The following conclusions were drawn from the comparative analysis of two photovoltaic installations with the same power connected to the grid:

- ✓ with the specified installation parameters, the farm with bifacial panels annually produces about 6% MWh per year,
- ✓ maximum energy injected into the grid is in the month of June for both installation,
- ✓ in simulated farms the average performance ratio (PR) of the bifacial system is operated at 90,45% and 85,58% for monofacial system.

Additional energy profit with a slightly higher financial outlay contributes to the growing interest in bifacial technology all over the world. In the case of installation of bifacial panels, it is important to provide a suitable substrate with the highest ALBEDO coefficient, control of substrate pollution, installation of double-sided photovoltaic panels much higher than traditional ones.

References

[1] Kopecek R., Libal J. „Bifacial Photovoltaics 2021: Status, Opportunities and Challenges", *Energies 2021*, *14*, *2076*, *2021*.

[2] Y. Seo et al. (2019) „Effect of Front Irradiance and Albedo on Bifacial Gain in 1.8kW Bifacial Silicon Photovoltaic System", *2019 IEEE 46th Photovoltaic Specialists Conference (PVSC), pp. 1298-1301, 2019.*

[3] https://www.esoleo.pl/baza-wiedzy/poradnik-fotowoltaika-esoleo/panele-fotowoltaiczne-bifacial-czym-sie-charakteryzuja-i-jak-dzialaja/ (Accessed: October 5, 2022)

[4] https://zenerisprojekty.pl/dwustronne-panele-fotowoltaiczne-bifacial/ (Accessed: October 5, 2022)

[5] https://blog.ongeo.pl/liczba-godzin-slonecznych-uslonecznienie (Accessed: October 5, 2022)

[6] https://www.dsneg.com/info/bifacial-solar-panels-give-increased-power-out-36005894.html (Accessed: October 5, 2022)

[7] D. Kurz, K. Lewandowski, M. Szydłowska, „Analiza uzysku energii z fotowoltaicznych ogniw bifacjalnych. część 1 – budowa i parametry ogniw bifacjalnych", *Poznan University of Technology Academic Journals, No 94 Electrical Engineering, 2018.*

[8] Sunanda Sinha, S. S. Chandel. „Review of software tools for hybrid renewable energy systems". *Renewable and Sustainable Energy Reviews 2014; 32: 192-205, (2014).*

[9] http://www.instsani.pl/450/wielkosc-energii-docierajacej-do-kolektora (Accessed: October 5, 2022)

[10] Stanley Wang, Oscar Wilkie, Jenny Lam, Rob Steeman, Wilson Zhang, Kah Sing Khoo, Sim Chun Siong, Hannes Rostan, „Bifacial Photovoltaic Systems Energy Yield Modelling", *Energy Procedia*, *Volume 77*, *2015*, *Pages 428-433, ISSN 1876-6102,1, 2015.*

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[11] Gostein M., Marion B., Stueve B. (2020) „Spectral Effects in Albedo and Rearside Irradiance Measurement for Bifacial Performance Estimation”, *2020 47th IEEE Photovoltaic Specialists Conference (PVSC), 2020, pp. 0515-0519, 2020.*

[12] B. Shiva Kumar, K. Sudhakar. „Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India”. *Energy Reports 2015; 1: 184-192.*

[13] https://www.kippzonen.com/News/847/Albedo-measurement-for-bifacial-PV-modules#.X9pW0NhKjcv (Accessed: October 5, 2022)

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مقارنة لتحليل أداء الأنظمة الضوئية مع الألواح أحادية وثنائية الوجه

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الخلاصة

البحث عن أكثر فعالية وفي نفس الوقت فعالية من حيث التكلفة في صناعة الكهروضوئية إلى إنشاء عدد متزايد من التركيبات باستخدام وحدات ثنائية الوجه. تقدم هذه الدراسة مقارنة بين فوائد الطاقة لمزارعين من الخلايا الكهروضوئية – الأولى بوحدات ثنائية الوجه ، والأخرى بوحدات أحادية الوجه, علاوة على ذلك، تتم مناقشة سوق الوحدات ثنائية الطور جنبًا إلى جنب مع آفاق التطوير في السنوات القادمة، ويتم وصف التقنيات والعوامل الرئيسية التي تؤثر على تحسين فوائد الطاقة من حيث تشغيل الألواح.

الكلمات الدالة: وحدة ثنائية الوجه، محاكاة PVSyst ، كهروضوئية.

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