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THE IMPACT OF SELECTED PARAMETERS ON THEEFFICIENCYOF PV INSTALLATIONS - SIMULATION TEST OF THE 1 MW PV FARM IN THE PVSYST PROGRAM

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Abstract: Nowadays, more and more solar farms are being created in Poland. This is due to the development of PV technology, the appearance of more efficient systems on the market, but also the need for Poland to achieve a 50% share of energy production from zero-emission sources. In designing PV farms, an important issue is the selection of the right angle, but also the distance between individual rows of panels. The article shows the work analysis of the 1 MW PV farm consisting of 2000 units of 500 Wp panels with dimensions of 2220 mm x 1108 mm x 40 mm and a weight of 28.60 kg and 8 inverters SUN2000-105KTL-H1. The panels are arranged in 10 rows in two directions: south and south-west. The analysis was performed for the angles of 10°, 20°, 25° and 30°. The investigation was carried out in order to evaluate the effect of changing the angle of the panels and the distance between the rows on the PV farm efficiency.
Keywords: renewable energy, photovoltaics farm, efficiency

1. INTRODUCTION

A large amount of energy consumed by European countries has a huge impact on the implementation of clean energy programs by the European Union. Nowadays, Poland is in fourth place in terms of the increase in new photovoltaic capacity. The dynamics of the development of the Polish PV market remains high. If Poland manages to maintain the current growth trends and financial support systems, further development is possible, which will allow to maintain a high position among European countries. Unfortunately, the technical capabilities of Polish networks are still a big problem in the development of the PV industry energy. According to available information sources, operators are often forced to refuse to connect to the electricity grid (Krawczyk, 2020; Świderski et al., 2020; Zdyband Gulkowski, 2020).

Currently, when solar farms are designed, it is important to choose the optimal angle and the distance between the rows of panels. This affects not only the farm's energy profit, but also shade and soil. The shading occurs when a part of a photovoltaic panel is temporarily or permanently cut off from solar radiation. The shading can be permanent or periodic. Permanent shading results from the existence of objects close to the farm, similar in size to the panel, which cast the shadow regardless of the movement of the sun. Periodic shading depends on the movement of the Sun and the movement of the shadow-producing objects for example: snow, leaves, dust or steel antenna mast. The worst sun conditions and also the longest shadows occur during the winter. The article analyzed a farm with a capacity of 1 MW depending on the angle and the distance between the rows of panels. The analysis shows the impact of selected parameters on the efficiency of simulated PV farm (Daliento et al., 2016; Trzmiel et al, 2020; Świderski et al., 2020; Walichnowska and Idzikowski, 2021; Mayfield, 2021; Idzikowski et al., 2022).

2. METHODOLOGY OF RESEARCH

The analysis has been carried out in the program PVSyst. This program is used in the renewable energy industry to assess the efficiency and applicability of photovoltaic systems to convert sunlight into electricity. PVsyst can quickly and reliably model possible layout formats for PV systems, crateful reports, visual charts and detailed data tables that are ready for export and use in other software. In the article for simulation used a high-efficiency PV modules which are using currently. The possibility of shading PV modules and related losses was assumed. Only classic ground assembly systems for PV farms without solar tracking systems were analyzed. The simulations were carried out with the assumption that we are dealing with flat area. A farm with a capacity of 1 MWp was simulated. Designed PV farm has 2000 modules arranged at a certain angle with a unit power of 500Wp, dimensions 2220 mm x 1108 mm x 40 mm and a weight of 28.60 kg and 8 inverters SUN2000-105KTL-H1 (pic. 1). The panels are arranged in 10 rows in two directions: south and south-west. The analysis was performed for the angles of 10°, 20°, 25° and 30° and also for the distance between the rows of panels from 4 to 10 m (Szymański, 2021; Dębowski et al.,2021; www.pvsyst.com).

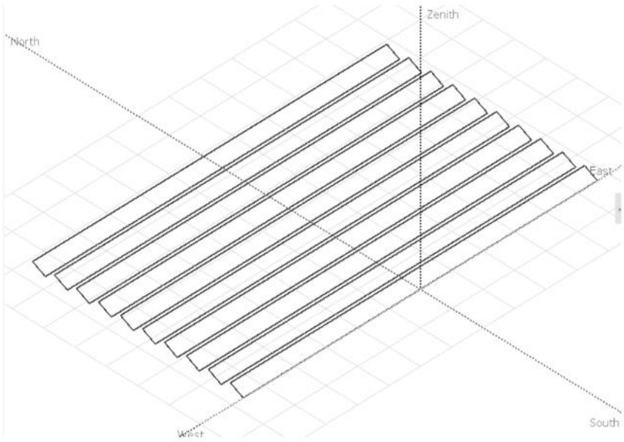

Fig. 1. The visualization of sample PV farm with panels arranged at a certain angle on the south (source: PVsyst, own elaboration)

3. RESULTS

In the first step of analysis has been determined the theoretical area of the photovoltaics farm depending on the distance between the rows of panels without area of the access road to the farm, technical building, distance from the fence and other infrastructure (Fig. 2 and 3).

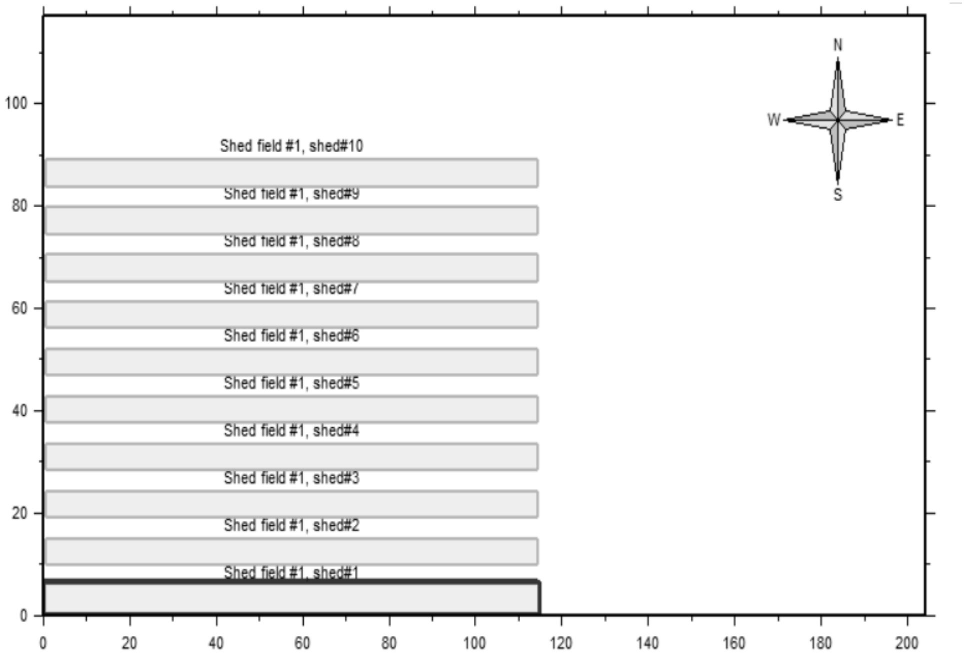

Fig. 2. The area of the sample farm with panels at a certain angle on the direction: south. (source: PVsyst, own elaboration)

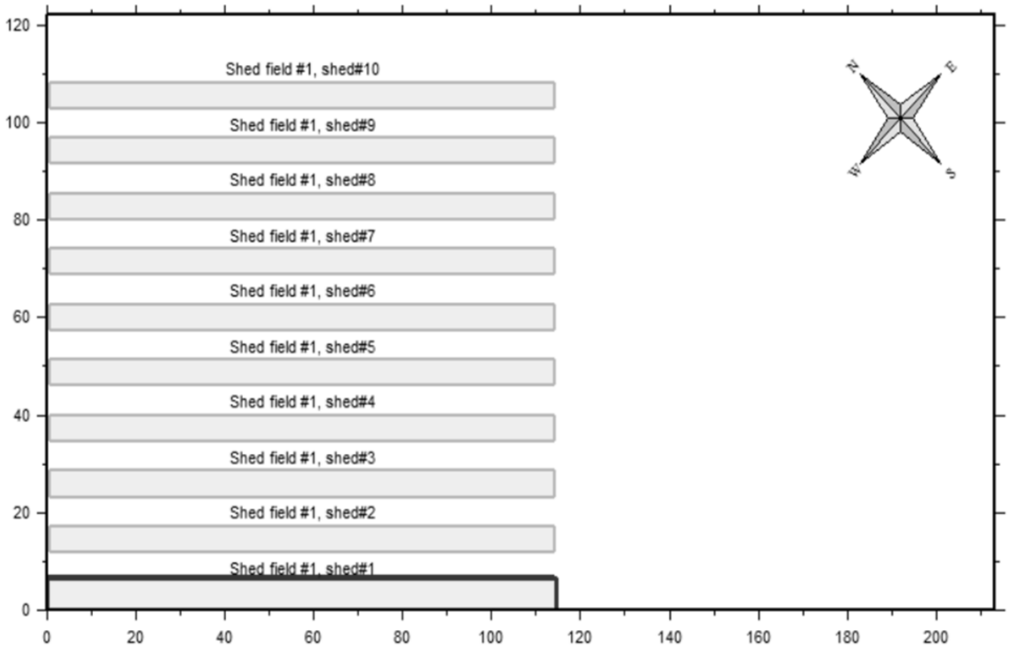

Fig. 3. The area of the sample farm with panels arranged at a certain angle on the direction: south-west. (source: PVsyst, own elaboration)

It was assumed that the additional infrastructure is 20-30% of the PV farm. The individual areas depending on the distance between the rows of panels are presented the table below (Table 1).

Table 1
The areas of PV farms on the directions south and south-west

The distance between the rows of panels [m]	**The area without additional infrastructure [ha]**	**The area with additional infrastructure [ha]**
4	0.452	0.588
5	0.554	0.720
6	0.655	0.852
7	0.757	0.984
8	0.858	1.116
9	0.960	1.248
10	1.061	1.380

Source: own study

PV farms are rightly advertised as a green and environmentally friendly alternative coal and nuclear power. However can still cause problems for the local community the environment in the form of severe erosion and runoff, the second very important aspect. Analyzing the effects of modules in densely stacked modules on a PV farm are issues blocking the access of natural light and rainwater to the ground under the modules. That is why it is so important to choose the right farm parameters. The increase in the number of large-scale PV farms focuses attention on the environmental and land-use impact of PV systems (Trzmiel et al, 2020; Szymański, 202).]In the second step has been compared the years production from farm depending on the angle, distance between the rows of panels and the azimuth. The angles 10º, 20º, 25º and 30º were selected in the analysis. As part of the simulation studies carried out to determine the impact of selected parameters on productivity and losses for a farm with a capacity of approx. 1 MW together with the necessary technical infrastructure, the PVsyst program determined that for all farm variants adopted in the study 20° can be assumed as the optimal angle. Taking a smaller value of the spacing between the rows of panels will result in bigger shading of individual rows, and therefore bigger losses for the farm. The optimal area in the azimuth of south and south-west is 1,1-1.25 ha. The annual production for the farm with azimuth south for 8 m of the distance between the rows of panels and angle 20º was 1055 MWh and for 9 m – 1061 MWh (Tab. 2). However for the farm with azimuth south-west for 8 m of the distance between the rows of panels and angle 20º was 1004 MWh and for 9 m – 1011 MWh (Tab. 3). According to these values for azimuth south-west are smaller energy production during the year.

Table 2
Losses and production of the system depending on the row spacing and the angle of inclination of the panels in the variant of modules arranged at a certain angle and azimuth south

The area with additional infrastructure	The distance between the rows [m]	10°		20°		25°		26°		30°	
		The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr
0.588	**4**	18.7	855	27.6	837	31.2	826	34.2	813	18.7	855
0.720	**5**	4.5	979	12.7	967	16.5	954	19.8	939	4.5	979
0.852	**6**	1.6	1004	6.5	1021	9.4	1015	12.2	1004	1.6	1004
0.984	**7**	0.8	1012	4.0	1043	6.2	1043	8.4	1037	0.8	1012
1.116	**8**	0.5	1014	2.8	1055	4.4	1060	6.2	1057	0.5	1014
1.248	**9**	0.4	1015	2.0	1061	3.4	1070	4.9	1070	0.4	1015
1.380	**10**	0.3	1016	1.6	1066	2.7	1076	4.0	1078	0.3	1016

Source: own study

Table 3
Losses and production of the system depending on the row spacing and the angle of inclination of the panels in the variant of modules arranged at a certain angle and azimuth south-west

The area with additional infrastructure [ha]	The distance between the rows [m]	10°		20°		25°		26°		30°	
		The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr	The losses [%]	The production MWh/yr
0.588	**4**	17.3	840	25.7	804	29.2	784	29.9	779	32.4	762
0.720	**5**	4.9	948	13.4	911	17.2	888	17.9	883	20.7	864
0.852	**6**	1.7	976	6.9	967	9.9	950	10.6	946	13.0	929
0.984	**7**	0.9	984	4.1	992	6.3	982	6.8	980	20.7	967
1.116	**8**	0.6	986	2.9	1004	4.5	999	4.9	998	13.0	988
1.248	**9**	0.5	987	2.2	1011	3.5	1009	3.8	1008	8.8	1002
1.380	**10**	0.4	988	1.7	1015	2.8	1016	3.1	1015	4.1	1010

Source: own study

4. CONCLUSION

The simulation showed that parameters such as angle, azimuth and distance between the rows of panels have an impact on the annual energy production. The selection of appropriate parameters has a significant impact on the efficiency of the installation. According to the conducted analysis, it is possible to arrange a PV farm with a capacity of 1 MW on an area about of 1 ha. Such installations are already implemented in Poland and in Europe. The indicated value is therefore not only a simulation value, but results from market reports. It seems that the literature indication of 1ha to 0.5MW is a classic value, which, taking into account the dynamic progress in the field of PV module technology and trends in the design of PV farms (type, angle, azimuth), taking into account the investor's space limitation and the expectations of specific production plans (morning and afternoon production in the max system) can be adjusted more and more often in individual cases. For the chosen orientations of the farm, the optimal angle can be assumed to be 20° - increasing the angle increases losses, which reduces the annual profits of the system. If a smaller angle is selected, the production of the system is significantly lower. It should also be emphasized that if a smaller angle is selected, the substrate under the farm structure is exposed to insufficient sunlight during the farm's exploitation, which in turn causes deterioration of the soil condition in this place. The environmental aspect should be taken into account in further analysis. Very often, agricultural land is leased for photovoltaic projects. Leases are typically 20-30 years. During this time, the soil may not be properly exposed to sunlight, as a consequence of which the quality of the soil deteriorates (Flizikowski and Mroziński, 2016; Znajdek and Sibiński, 2021; Redliński and Zapałowicz, 2020; Trzmiel et al., 2020; Idzikowski and Cierlicki, 2021; https://environment-review.yale.edu/reducing-land-use-impact-solar-energy-triple-win-climate-agriculture-and-biodiversity; https://www.hydrograsstech.com/5-factors-that-complicate-erosion-control-on-solar-farms).

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