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Energetic effectiveness of photovoltaic modules operating with the follow-up systems

Summary: *The paper presents the results of the research carried out in summer periods in 2011 and 2012 for two geographical locations, i.e. Poznań (Poland) with geographic coordinates 52°24'30"N, 16°56'3"E and Playa del Ingles (Gran Canaria, Spain) - 27°45'24"N and 15°34'43"W, and for various time coordinates (within day and year scale), with consideration of the angle of receiver inclination with respect to the horizon and with various azimuth angles. Differences in solar radiation were considered in the research. The results so obtained give evidence of usefulness of the use of the follow-up systems in our weather conditions in order to achieve optimal values of power density of the radiation.*

Streszczenie. *W pracy przedstawiono wyniki badań przeprowadzonych w okresie letnim 2011 i 2012 roku dla dwóch lokalizacji geograficznych Poznań (Poland) o współrzędnych geograficznych 52°24'30"N i 16°56'3"E oraz Playa del Ingles (Gran Canaria Spain) - odpowiednio - 27°45'24" N i 15°34'43" W oraz różnych współrzędnych czasowych (w skali dnia i roku), z uwzględnieniem zmian kąta pochylenia odbiornika do horyzontu jak i zmian kąta azymutu. Uwzględniono przy tym zróżnicowaną intensywność promieniowania słonecznego. Uzyskane wyniki wskazują na celowość stosowania układów nadążnych w naszych warunkach klimatycznych dla uzyskania optymalnych wartości gęstości mocy promieniowania("Energetyczna efektywność modułów fotowoltaicznych pracujących w systemach nadążnych").*

Słowa kluczowe: konwersja fotowoltaiczna, efektywność, dwuosiowy tracker, zysk energetyczny.
Keywords: photovoltaic conversion, effectiveness, double - axis tracker, energetic gain.

Introduction

Apparent Sun motion is a reason why the incidence angle of solar radiation on the energy receiver surface changes. The follow-up systems have in photovoltaics the advantage over the stationary ones because of permanent adjustment of spatial orientation of the receiver to current situation on the sky. Positioning (in one or two axes) is carried out according to astronomical parameters, automatically or manually e.g. based on location of a selected star in predefined time intervals. Finally, power density of solar radiation available to the customer is a function of many variables, inclusive of geographic and time coordinates [1,2,3,4,5,6]. Other parameters, as radiation intensity and coefficient of atmospheric transparency, are significant too. In the countries of high predictability of insolation the stationary systems adjusted at optimal angle with respect to the horizon, or uni-axial solutions may be used.

Figures 1, 2 present examples of the trackers: with concentration–El Medano and without concentration–Leżajsk. The trackers with concentrators, in Phot. 1, are provided with monitoring with data acquisition, that enables current read-out of the gained energy.

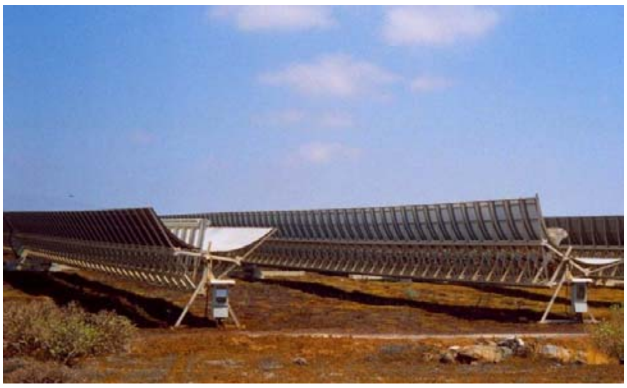


Fig. 1. Example of photovoltaic installation provided with Sun follow-up (1-axis); with concentration system, ITER, El Medano on Teneriffe phot. Grażyna Frydrychowicz-Jastrzębska

Fig. 3 shows example records of monitoring of a follow-up system operating in Leżajsk [1].

Fig. 2. Example of photovoltaic installation provided with Sun follow-up; the tracker with PV modules without the concentration system 2-axis, the Communication Plant of Alarm System PHU, Leżajsk (Poland), with approval of Mr. Stanisław Krupa

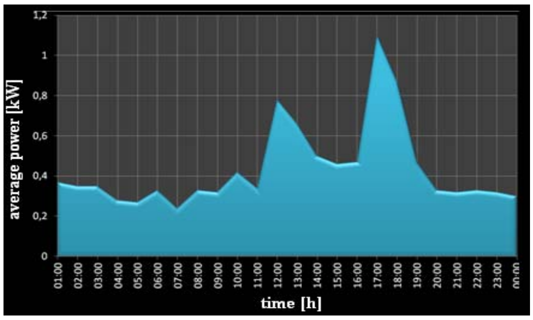


Fig. 3. Read-out from the solar radiation power monitoring obtained by Communication Plant of Alarm System PHU, Leżajsk, on May 17, 2012

Effectiveness of follow-up systems in uni- or two axial solutions

The highest effectiveness occurs for two axial solutions, as in result of variations of spatial orientation of the receiver the angle of receiver inclination with respect to the horizon and the azimuth angle may be properly adjusted. The power required for the drive is insignificant (0.1 to 3 per cent) as compared to possible power gain resulting from optimization of the receiver adjustment [3]. Good results may be obtained already in case of receiver adjustment only in one plane (uni-axial systems) [5,6,7,8].

Effectiveness of the follow-up systems may be improved by installation of concentrators (however, only in geographical locations of significant predominance of direct radiation component). On the other hand, the use of concentrators in the countries where the diffusion radiation component predominates is not advantageous (except for plane concentrators) [1].

Permanent adaptation of spatial orientation of the receiver (inclination angle with respect to the horizon and azimuth angle) with regard to apparent Sun motion enables increasing the gained energy as compared to a stationary solution. An uni-axial system follows-up the Sun from east to west (mapping Sun daily motion at the sky hemisphere). A two axial system additionally follows-up the Sun motion between north and south (i.e. reflects the angular height of the Sun). In the [6] is presented possible gain of solar power in uni- and two axial systems, as compared to stationary ones, for several settings and over a dozen geographical locations.

Justness of the use of two axial trackers in photovoltaic is emphasized by many authors, among others [2,3,5]. The advantages obtained this way is estimated to 30-50 per cent. Particularly spectacular success was achieved in the tests carried out in Toledo (Spain). The highest power gain obtained in case of a stationary system inclined at the angle 30° to the horizon amounted to 57 percent of the output value, which is shown in Fig. 4 [9], in [2] gain equals 64%, in - [4] - 48%.

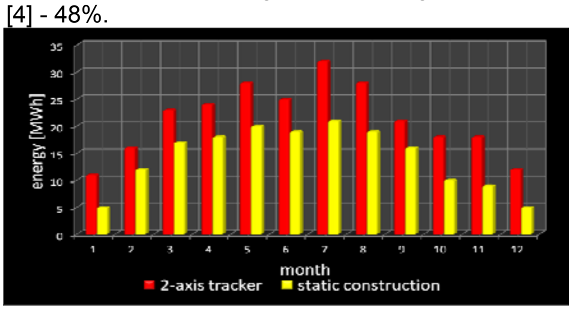


Fig. 4. The highest power gain obtained in result of the use of two axial tracker as compared to stationary construction inclined at the angle 30° to the ground in Toledo, own elaboration based on [9]

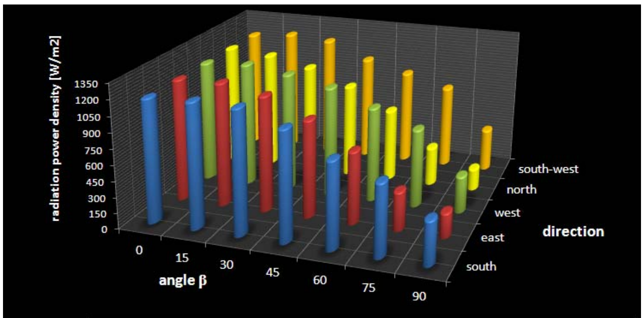
Measurement stand and results of the research

In summer periods in 2011 and 2012 the density of solar radiation was measured in two geographical locations: Poznań (Poland) with geographic coordinates 52°24'30"N, 16°56'3"E and Playa del Ingles (Gran Canaria Spain) - 27°45'24"N and 15°34'43"W, with consideration of the angle of receiver inclination with respect to the horizon and with various azimuth angles.

Figure 5 presents the measurement stand for researching the effect of spatial orientation of the modules on possible increase in the energy obtained and on the pattern of their characteristic parameters as compared to stationary solution.

Fig. 5. The measurement stand – phot. Artur Bugała

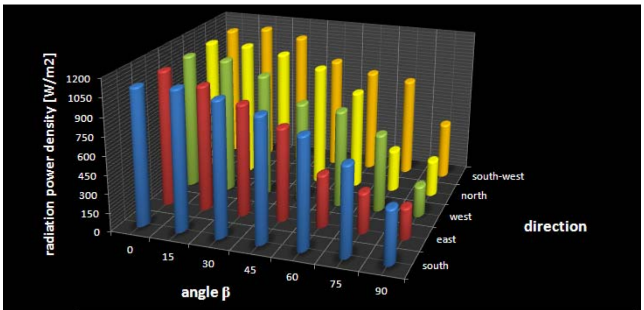
Figures 6 and 7 show example measurement results of the power density of solar radiation in Playa del Ingles, obtained each time at 2:00 p.m. on August 6, 2011 and August 6, 2012, as the function of spatial orientation of the module (i.e. inclination angle and geographical direction).



	0	15	30	45	60	75	90
south	1175	1188	1179	1045	822	683	413
east	1175	1185	1109	932	691	369	233
west	1175	1200	1144	1058	908	748	350
north	1175	1138	1054	902	699	370	207
south-west	1175	1215	1181	1021	917	802	407

Fig. 6. Power density of solar radiation vs. the angles of spatial orientation in Playa del Ingles, on August 6, 2011 at 2:00 p.m.

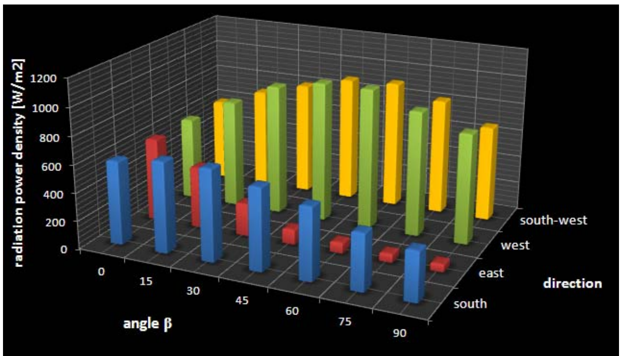
Figures 8 and 9 present the measurement results of the radiation power density in two locations: Playa del Ingles and Poznań, as a function of spatial orientation, defined both by inclination angle with respect to the horizon and azimuth angle.



	0	15	30	45	60	75	90
south	1102	1122	1075	996	885	712	432
east	1102	1014	904	755	422	325	252
west	1102	1095	999	804	779	627	247
north	1102	1101	1060	970	797	340	292
south-west	1102	1143	1091	912	840	801	457

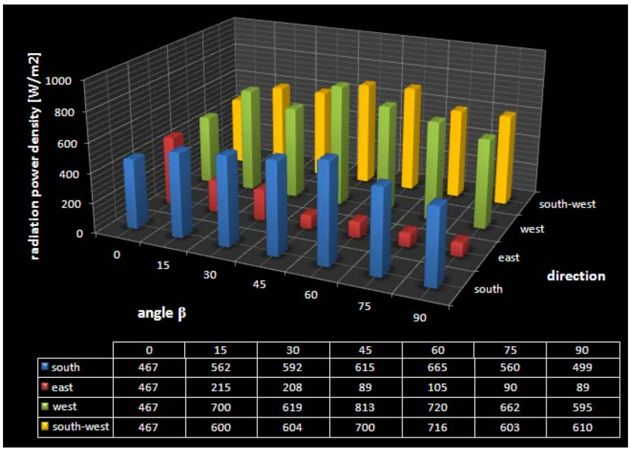
Fig. 7. Power density of solar radiation vs. the angles of spatial orientation in Playa del Ingles, on August 6, 2012 at 2:00 p.m.

The comparative specification includes the measurement trials made on August 6, 2012 at 6:00 p.m.



	0	15	30	45	60	75	90
south	600	653	658	588	517	402	349
east	600	444	234	106	75	60	55
west	600	780	940	1009	1011	899	792
south-west	600	722	816	904	919	834	686

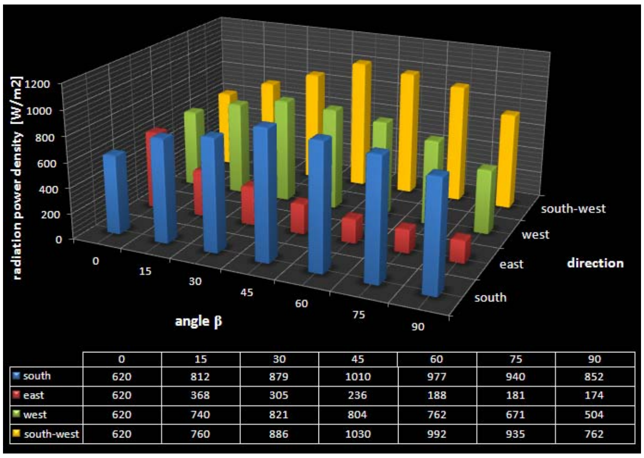
Fig. 8. Power density of solar radiation vs. the angles of spatial orientation in Playa del Ingles, on August 6, 2012 at 6:00 p.m.



	0	15	30	45	60	75	90
south	467	562	592	615	665	560	499
east	467	215	208	89	105	90	89
west	467	700	619	813	720	662	595
south-west	467	600	604	700	716	603	610

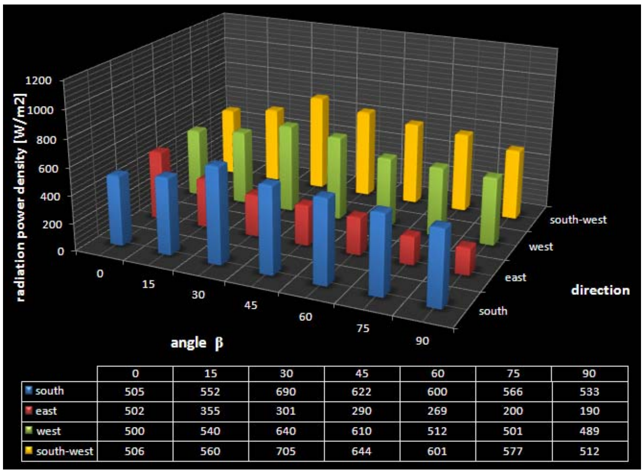
Fig. 9. Power density of solar radiation vs. the angles of spatial orientation in Poznań, on August 6, 2012 at 6:00 p.m.

Further two plots shown in Figures 10 and 11 depict the results of the measurements carried out on September 11, 2011, and September 9, 2012, at 2:00 p.m. in Poznań.



	0	15	30	45	60	75	90
south	620	812	879	1010	977	940	852
east	620	368	305	236	188	181	174
west	620	740	821	804	762	671	504
south-west	620	760	886	1030	992	935	762

Fig. 10. Power density of solar radiation vs. the angles of spatial orientation in Poznań, on September 11, 2011 at 2:00 p.m.



	0	15	30	45	60	75	90
south	505	552	690	622	600	566	533
east	502	355	301	290	269	200	190
west	500	540	640	610	512	501	489
south-west	506	560	705	644	601	577	512

Fig. 11. Power density of solar radiation vs. the angles of spatial orientation in Poznań on September 9, 2012 at 2:00 p.m.

Recapitulation

Based on the measurements of power density of radiation reaching the receiver vs. its spatial orientation, time of the day, day of the year, and location, it was found that:

1. Figures 6 to 11 show significant relationship between available power density of the radiation on spatial orientation of the receiver.
2. Measurement results of power density of solar radiation in Playa del Ingles (Gran Canaria, Spain) give evidence of nearly full repeatability for respective days, hours of the day, and receiver settings, as shown in Figs 6 and 7.
Such a stability allows for significant predictability of optimal receiver settings with a view to achieve proper energetic gain. Unfortunately, this is not a case of all the locations.
3. The plots shown in Figures 8 and 9 are differentiated because of various locations (latitudes). Maximum values of power density of the radiation reaching the receiver approximate each other, although, in case of some settings the differences exceed 25 percent. Nevertheless, longer day duration in Poznań should be considered. This gives evidence of possible use of the potential and profitability of photovoltaic installations in the Polish conditions.
4. The measurement results for Poznań, shown in Figures 10 and 11, are characterized by large differentiation of power density of the radiation reaching the receiver, in spite of similar time conditions (day of the year, hour of the day). They are not repeatable as is the case of the measurements in Playa del Ingles, which is a consequence of impossibility of prediction of optimal receiver setting, even for multi-years data. Hence, it is difficult to program automatic or manual adjustment of the receiver setting changes or to confine the adjustment only to one axis.
5. In consequence, in Polish conditions it seems advisable to use the two axis follow-up systems, particularly taking into account the fact that the power used by the system drive is negligible.

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