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Comparison of the efficiency of solar modules operating with a two-axis follow-up system and with a fixed mount system

Summary: *The study compares the production of electric power and energy in the two photovoltaic systems working independently: -fixed, with one angle setting during the year, -two-axis tracking. The analyzed systems are located in Poznan, at an altitude of about 25 meters above the ground (the roof of the Faculty of Electrical Engineering building - Poznan University of Technology) and equipped with photovoltaic modules using the same polycrystalline technology and characterized by the same capacity. Distribution of power density of solar radiation on the surface of both PV modules was examined and the production of electricity from photovoltaic conversion between the two approaches was compared.*

Streszczenie. *W pracy porównano produkcję mocy i energii elektrycznej w dwóch pracujących niezależnie od siebie układach fotowoltaicznych: -stacjonarnym, o jednym całorocznym ustawieniu kątowym, - nadążnym dwuosiowym. Analizowane układy zlokalizowane są w Poznaniu na wysokości około 25 metrów nad poziomem gruntu (dach Wydziału Elektrycznego Politechniki Poznańskiej) i wyposażone w moduły fotowoltaiczne, wykonane w tej samej technologii polikrystalicznej i charakteryzujące się tą samą mocą. Zbadano rozkład gęstości mocy promieniowania słonecznego na powierzchni obu modułów PV i porównano produkcję energii elektrycznej w wyniku konwersji fotowoltaicznej w obu rozwiązaniach.* ***(Porównanie efektywności modułów fotowoltaicznych pracujących w układzie nadążnym dwuosiowym i stacjonarnym)***

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

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Introduction

Electric energy produced by a photovoltaic system is strictly correlated with the structural and technical parameters of the PV module itself and it is a function of its spatial orientation [1][2].

The first of the factors discussed determines the efficiency of the conversion of solar energy into electric energy. According to the latest findings, there are new solutions which guarantee the efficiency at the level of more than 40 %; however, the information concerns prototype solutions tested in laboratory conditions. The PV modules that are commonly available do not provide such high efficiency levels and they require further research, and, what is connected to that, more financial investments. It is undoubtedly an important aspect of the matter and it can guarantee success in the near future, considering such rapid development of photovoltaics.

Adjustment of the spatial orientation of the module to the current external conditions makes it also possible to increase its power generation capabilities without any interference into its structure[3].

Optimization of the spatial orientation of a photovoltaic receiver

The energy obtained from the module as a results of photovoltaic conversion (disregarding the influence of the parameters of the module itself) is strictly connected with the geographical parameters (location expressed in the form of the latitude angle φ), temporal (solar declination angle δ, hour angle ω) and weather (atmospheric transparency factor) parameters [1][4].

Optimization of the spatial orientation of a photovoltaic receiver makes it possible to limit the influence of the factors mentioned above to a certain degree. The purpose of optimization is to assure that the receiver surface is situated at the right angle to the sun rays that fall on it. Full optimization requires adjustment to the positioning of the object in the online mode which is not possible in a fixed system. Thus, replacing fixed mount modules with tracking systems serves as an effective way to increase energy production in the photovoltaic system. The fact that this is not always possible due to the terrain conditions as well as the unavoidable increase of the cost of the installation and certain energy consumption for the internal operation of the system must, of course, be considered.

In a fixed system, the value of the elevation angle and of the azimuth angle at which the system should be operating in the annual cycle are usually determined on the basis of optimization calculations [1], with the use of more or less complex algorithms. Often, modifications with periodic adjustment of the receiver surface in order to increase the amount of the energy generated (increase of the inclination angle in winter months and its decrease in the summer season) are permitted.

In the case of tracking systems, adjustment of the spatial orientation of the module to the current direction of the solar radiation falling on the surface is performed by the control unit. In this way, it is possible to increase the availability of the photosensitive surface for the entire period [5].

Test stand and test objects

The tests were executed for two photovoltaic systems: a fixed mount system and a two –axis tracking system. The roof of the Faculty of Electrical Engineering building of the Poznań University of Technology (25 meters above ground level) was selected as the place of installation which made it possible to reduce unfavorable influence of external factors (shade, module surface pollution).

In the case of the fixed mount system, a primary element of its structure is an especially designed steel frame with casing containing the power inverter and the necessary wiring, including DC cables connecting the PV module with the device and AC cables leading to the junction box). A mini stand including an installed sensor for power density of solar radiation in the module plane was fitted in the upper part of the frame.

On the basis of optimization calculations, the module plane inclination angle was set at 37 °, and the azimuth deviation angle was assumed as 0°.

The tracking system working as a two-axis structure was located at the distance of 2 meters from the fixed mount structure. The system is controlled with the use of the lock algorithm. The positioning of the PV module plane results from mathematical dependencies which determine the current position of the Sun, as described by its annual and daily path in the sky.

The fixed mount system is presented on Figure 1.

Fig.1. A view of the fixed mount photovoltaic system installed on the roof of the Poznań University of Technology building

Control with the use of astronomical positioning was implemented on the basis of model tests executed beforehand with the use of an especially designed tracking system in which a sensor for measuring the intensity of solar radiation constructed by the author was used.

The tracking system is presented on Figure 2.

Fig.2. A view of the tracking photovoltaic system installed on the roof of the Poznań University of Technology building

In order to precisely determine the internal power demand of the system, its monitoring is conducted in parallel to the basic measurements with the use of a digital meter.

Both systems were equipped with the same photovoltaic modules of the Yohkon company manufactured in the polycrystalline technology with the unit capacity of 210 Wp.

Every photovoltaic module cooperates with a micro inverter of the Enecsys company with the MPPT (Maximum Power Point Tracking) function.

Central power inverters were eliminated in favor of individual power inverters thanks to which the selectiveness of the system was increased and the precision of monitoring electrical parameters was improved. The communication between the power inverter and the gateway is performed through the wireless Bluetooth network and measurement data is sent to the server by means of an Ethernet connection. This guarantees quick intervention in case of a failure.

Measurement results

Tests with the use of both PV systems were started on 13 June 2013. Analytics software provides the capabilities to run remote diagnostics of the operation of both systems, monitor the current operation status and control the operation of the actuators. Records made in the form of CSV or XLSV files reflect daily generation of electrical energy including the internal energy consumption of the tracking system, momentary DC/AC power generation and voltage values.

Figures 3, 4 and 5 present sample results of electric energy measurements performed for the fixed mount system and for the tracking system. The comparison covers selected days in June with varying weather conditions.

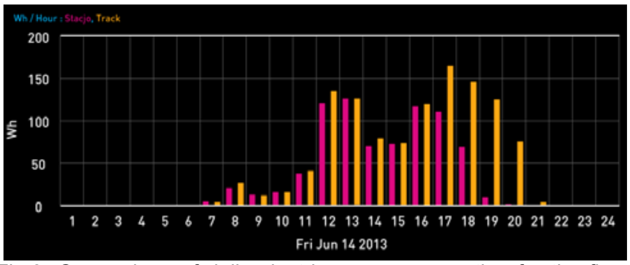

Fig.3. Comparison of daily electric energy generation for the fixed mount system (Stacjo) and for the tracking system (Track), day 14.06.2013, moderate cloud cover

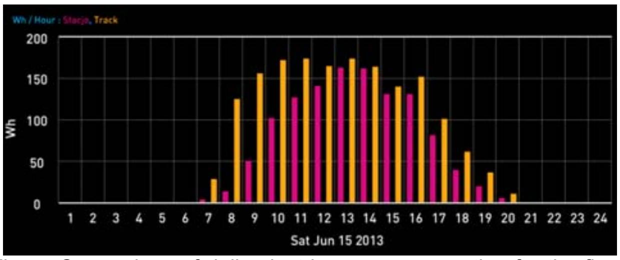

Fig. 4. Comparison of daily electric energy generation for the fixed mount system (Stacjo) and for the tracking system (Track), day 15.06.2013, cloudless sky

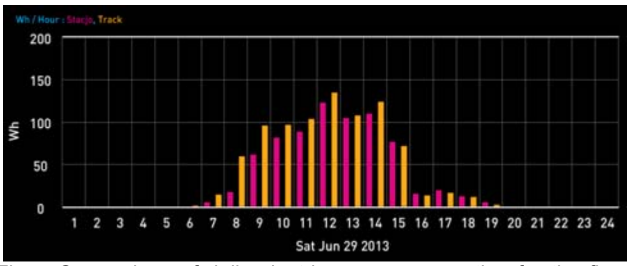

Fig.5. Comparison of daily electric energy generation for the fixed mount system (Stacjo) and for the tracking system (Track), day 29.06.2013, a cloudy day

Figure 6 presents a summary of electric energy generation in the period from 13.06.2013 till the end of June, with the exception of the following days: 22-23.06. and 25-28.06 when a failure in the system occurred and the works connected with its removal were conducted. The summary does not include energy loss for powering the tracking system.

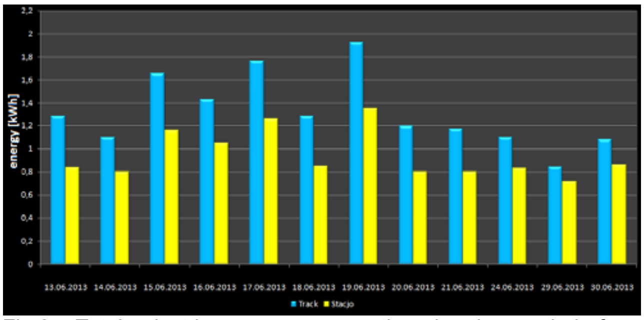

Fig.6. Total electric energy generation in the period from 13.06.2013 till the end of June with the exception of 22-23.06 and 25-28.06

Figure 7 presents a comparison of the value of electric energy generated for the month of July in the case of the fixed mount system and of the tracking system, where the latter includes the losses connected with powering the drive system.

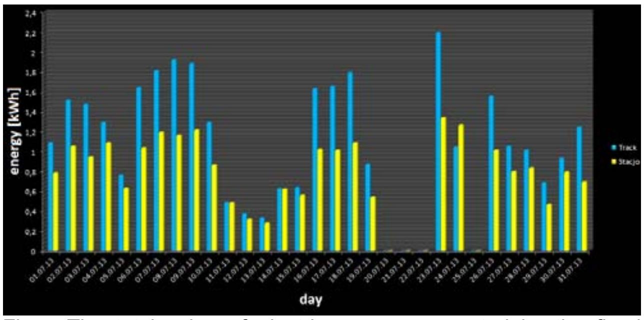

Fig.7. The total value of electric energy generated by the fixed mount system and in the tracking system on the month of July including the energy consumption for internal control

In parallel to the monitoring of electric energy generation, records of the density of solar radiation are collected with the use of LBX software.

An example of such a record is presented on Figure 8.

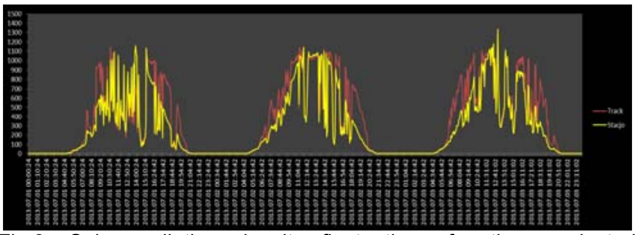
Fig.8. Solar radiation density fluctuations for three selected measurement days, 1-3.07.2013, in both systems

Conclusion

1. On the basis of the analysis of the results of solar radiation density measurements, it was concluded that the tracking system is more efficient than the fixed mount system. This applies, most of all, to the morning hours and to the evening hours which results from the adjustment of the receiver in the tracking system to the current direction of the Sun rays falling on the surface, with relatively imprecise positioning of the module in the fixed mount system (average annual optimization focused on the hours around noon in the summer period).

2. In the morning and evening hours, the solar radiation density values in the tracking system are almost two times higher than in the fixed mount system. This is confirmed with sample results of the measurements recorded on 06.07.2013, as follows: at 08:07:46, 707 W/m^2 in the tracking system, and, respectively, 349 W/m^2 in the fixed mount system. Similarly, for the evening hours on the selected day - 30.06.2013, at 19:50:25, the value was 191 W/m^2 in the tracking system and as low as 83 W/m^2 in the fixed mount system.

As it is clear from the measurement performed, when the sky is clear, the power density values of solar radiation registered by the silicon diodes of the sensor heads are almost equal in the hours around noon.

3. The total value of the net electric energy generated in both systems, that is – after the energy losses for the powering of the tracking system, in the period under analysis from 13.06. to 31.07.2013 also showed its advantage over the fixed mount system. The higher efficiency of the tracking system with regard to electric energy generation is a consequence of the possibility to obtain higher power density of solar radiation than in the case of the fixed mount structure as well as of the relatively low energy consumption for powering its drive.

Low energy consumption results from the use of a control system using an astronomical algorithm. This makes it possible to eliminate the “need to search” for the brightest point in the sky thanks to which the energy loss on constant adjustment of the system is reduced.

4. The total value of electric energy generation in the period from 13.06. to 30.06, with the exception of the days when the failure occurred, was 15,82 kWh in the tracking system and 11,31 kWh in the fixed mount system. Similarly, in July the values were, respectively, -30,13 kWh and 23,23 kWh. The “net” gain resulting from the use of the tracking system was 40% in the month of June and, respectively, 30% in July.

5. The most significant differences in the amount of energy generated by both systems were recorded on cloudless days, for example – on 9 July 2013, when the efficiency of the tracking system was higher by 55 % or on 7 July, where the efficiency was 52,5% higher. For full cloud cover, for example on 29.06., the gain from using the tracking system is 18 %, whereas for partial cloud cover on 14.06. – the gain was, respectively - 38 %.

REFERENCES

[1] Frydrychowicz-Jastrzębska G., Bugała A.: Sun tracking in PV Systems Aspects, *Monograph Computer Applications in Electrical Engineering*, Poznań University of Technology, 2012, 333-346

[2] Teneta J., Więckowski Ł.: Czasowa charakterystyka produkcji energii elektrycznej w nadążnych systemach PV, II krajowa konferencja fotowoltaiki, Upowszechnianie osiągnięć polskiej oraz światowej fotowoltaiki w procesie kształcenia na poziomie wyższym, Krynica Zdrój, 12-15 May 2011

[3] Serhan M., El-Chaar L.: Two axes sun tracking system: comparsion with a fixed system, International Conference on Renewable Energies and Power Quality, Granada, 23-25 March 2010

[4] Frydrychowicz-Jastrzębska G., Bugała A.: Energetic effectiveness of photovoltaic modules operating with the follow-up systems, *Przegląd Elektrotechniczny*, 6, 2013, 253-255

[5] Dhanabal R. et al. : Comparison of efficiencies of solar tracker systems with static panel single-axis tracking system and dual-axis tracking system with fixed mount, *International Journal of Engineering and Technology*, 5, 2013, 1925-1932

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