PERFORMANCE ANALYSIS OF SOLAR SYSTEMS - SINGLE AXIS VS FIXED SYSTEM

*Nedyalko Todorov Katrandzhiev *, Nikolay Nenkov Karnobatev*

Department of Computer Systems and Technologies
University of Food Technologies, 26 Maritza Blvd., 4000 Plovdiv
Bulgaria

***** Corresponding Author, e-mail: ned.katrandzhiev@gmail.com

Abstract:A performed experimental comparative analysis of output power and energy production between a fixed solar panel and single axis (east-west) solar tracking solar panel is presented in this paper. Fixed mounting of solar panels was preferred due to the lower cost, nevertheless the solar tracking panel increased energy production.

Key words: photovoltaic system, solar system, solar tracker, green energy, solar energy.

1. INTRODUCTION

Solar energy is becoming more popular with each passing day. It can be converted into electricity with photovoltaic panels (PV) or in heat with solar collectors. The amount of solar energy generated by PV during the day is proportional to the collected radiant energy. Therefore, the solar panels were oriented in a direction that contributed to the collection of the maximal amount of radiation energy on annual basis [5]. A mechanism that continuously positions the solar panel so it was always facing to the sun was used in order to increase the collected energy.

The purpose of this article is to present experimental comparison of energy production between a fixed solar panel and single axis solar tracking solar panel in Rhodope Mountains, Bulgaria, Smilyan. Such analysis has not been made for this region till the moment.

2. MATERIALS AND METHODS

Two solar systems were developed for the purpose of the experiment - fixed and single axis solar tracking. The solar tracker worked according to the algorithm developed in [1]. Solar systems were equipped with identical solar panels Wotech Solar Poly WT100P [2]. These panels were connected to identical PWM (pulse width modulation) solar controllers LDSOLAR SD2420C [3], with the same load resistors

2 Ω 150W. The output power as well as the generated electric energy were recorded with a DC power data logger, specially designed for this purpose using the method described in [4]. The data logger was based on an AV power measuring circuit. The designed data logger is presented on fig. 1. The parameters of the data logger were presented in table. 1. The values taken by the data logger (voltage and current) were used to calculate the instantaneous power and energy production. Data was logged and calculated every 255 ms, after which the results was sent to a server, where they were averaged at an interval of 60 s and recorded in a database. The data could be viewed graphically through a mobile application there was also a possibility to generate CSV reports.

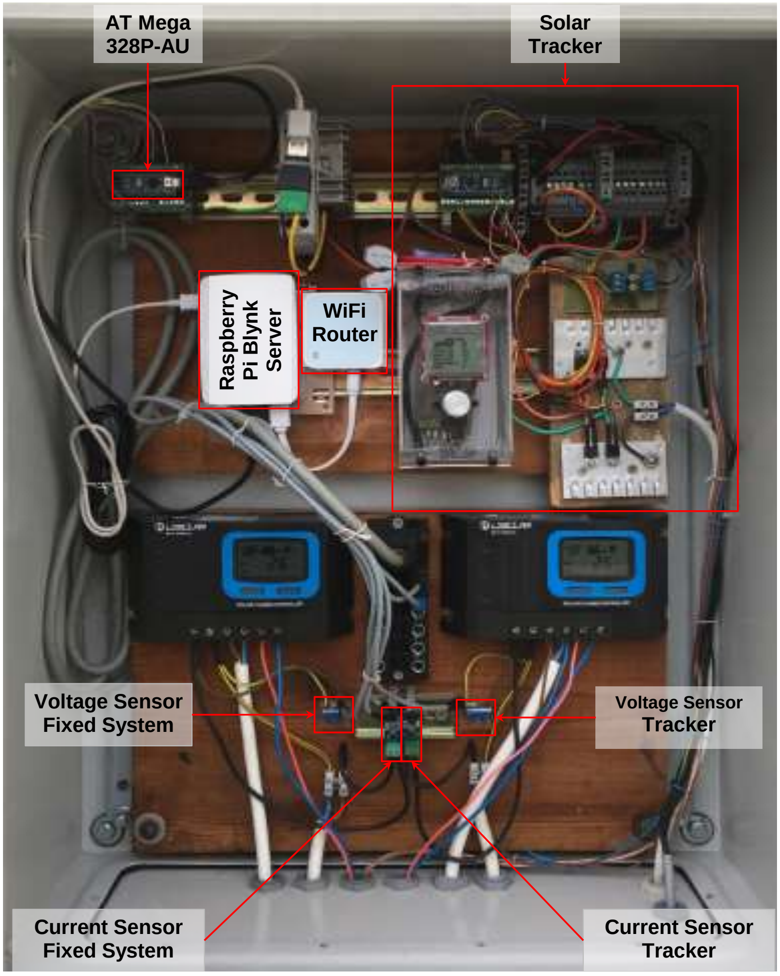

Figure 1. Hardware modules of the data logger and solar tracker

Table 1. Characteristics of Data Logger

Parameter	***Value***
Measuring range, Voltmeter	0 ÷ 37.35 V
Input resistance, Voltmeter R_{IN}	38.1 kΩ
Max consumption of Voltmeter	12.8 mW
Voltmeter resolution	36.47 mV
Measuring range, Ammeter	-20 ÷ 20 A
Input resistance, Ammeter	1.2 mΩ
Average sensitivity, Ammeter	100 mV/A
Error, Ammeter	±1.5 %
Methodological error AV	0.018%

The basis of the data logger was the microcontroller unit device (MCU) Atmel Mega 328. MCU read the current and the voltage and computed the power and the energy every ¼ second. The microcontroller measured the current through current sensor ACS712-20A and the voltage was measured on a resistive voltage divider. The current sensor was with an input resistance 1.2 mΩ and was using an analogue hall sensor with an operational amplifier to transform the current to voltage. The read and computed data was transferred to a data server.

3. RESULTS AND DISCUSSION

Performance analysis of two types of photovoltaic systems (with and without solar tracking) with identical solar panels is made in this caption.

3.1. Data logger accuracy test

A measurement of the output power of the two solar systems was made under equal conditions aiming to test the accuracy of the data logger presented in [4], i.e. both solar systems (the single axis and the fixed one) operated as fixed with identical loads.

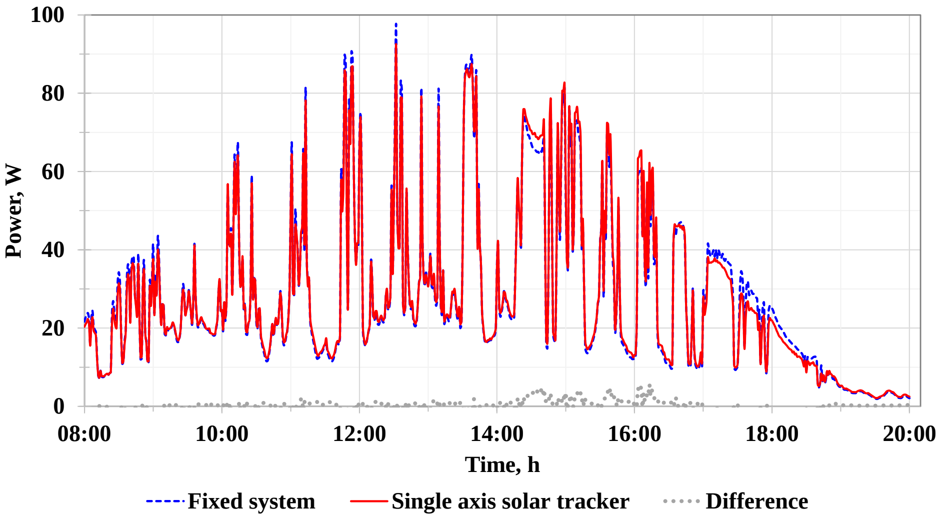

Figure 2. Output power and energy production of fixed and single axis solar tracking photovoltaic systems both of them working as fixed systems by power DC data logger

This measurement showed negligibly small differences in the output power between the two systems, which could be seen in the graph presented in fig.2 and fig.3. The difference in energy produced between the two systems was 0.5% in favor of the fixed system. This difference was due to the production tolerances of: solar panels, resistors acting as a load, voltage and current sensors, the current power of solar controllers. Also there was a measurement error from the ammeter and the voltmeter, namely a methodological error.

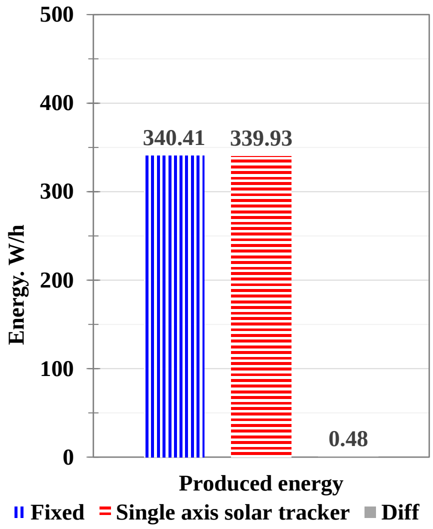

Fig. 3. Energy production of fixed and single axis solar tracking photovoltaic systems both of them working as fixed systems by power DC data logger

3.2. Difference in generated energy on a clear day

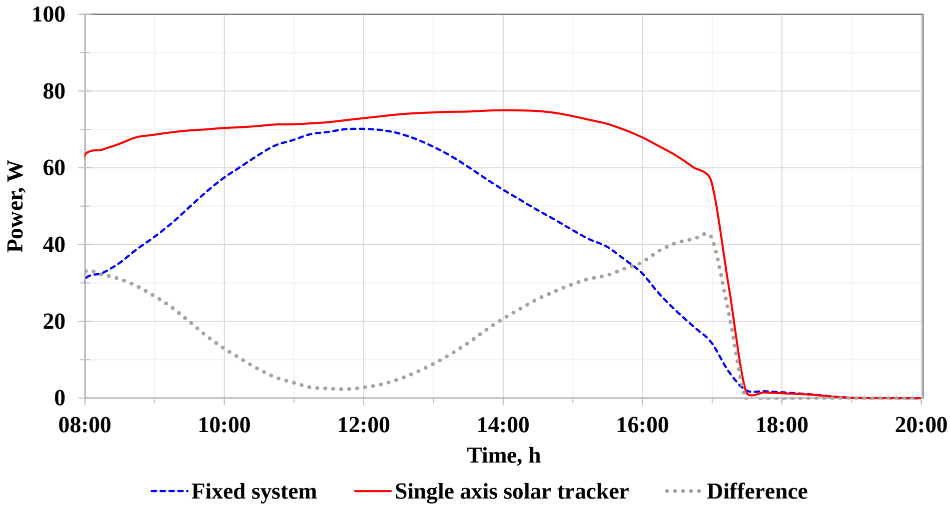

Figure 4. Output power of fixed and single axis solar tracking photovoltaic systems for 16.04.2020, a sunny day

The energy generated by the fixed panel for the reporting period 08:00 - 20:00 on a clear day (16.04.2020) was **466.59 Wh**, and from the solar tracker was **659.66 Wh** fig.5. The biggest difference in power output was before and after noon. At noon, the two systems emitted approximately the same amount of power because the incident rays from the sun at that time were perpendicular and / or with small deviations from the perpendicularity with the fixed solar panel in the east-west direction fig.4. In this time range, the two systems received the same amount of solar radiation. It was found in [5] that with small deviations from the perpendicularity the losses were insignificant. Clear day power graphs for different days had a similar shape.

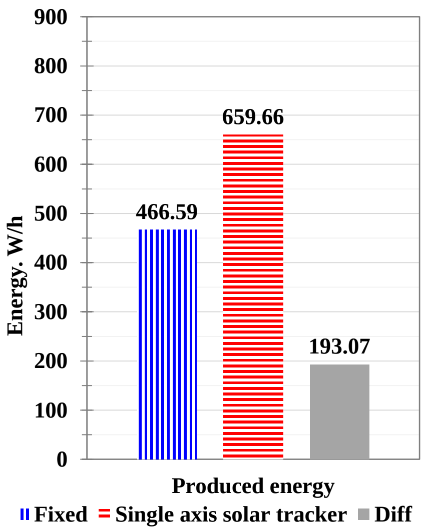

Figure 5. Output energy production of fixed and single axis solar tracking photovoltaic systems for 16.04.2020, a sunny day

3.3. Difference in generated energy on a day with scattered clouds

To make the comparison with scattered clouds, as it was difficult to report uniformity in the clouds, measurements were made for three days – 18th and 19th of April 2020 and 1st of May 2020. The obtained results for Output power and Energy production in the fixed and the single axis solar tracking photovoltaic systems are presented in fig. 6-9.

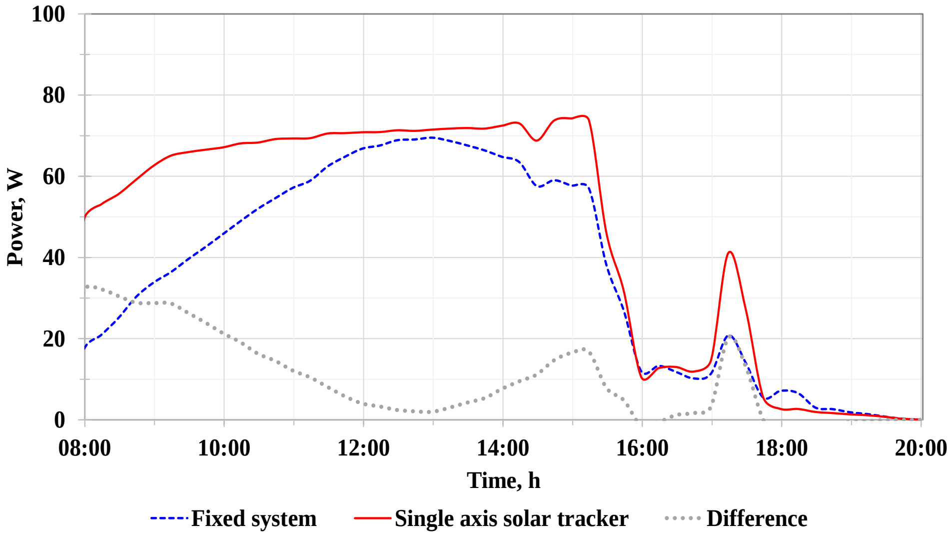

Figure 6. Output power of fixed and single axis solar tracking photovoltaic systems for 18.04.2020, scattered clouds

The generated energy was different, on a day with scattered clouds, due to the random nature of the clouds, respectively the percentage increase in the tracking panel varies depending on when and how much the clouds were in the range of **26.9% to 35.9%.** For example, with light clouds before and after noon and heavy clouds at noon, there was a big difference in the energy production of the two systems. In the other case - strong clouds before and after noon and weak or absent at noon there was a small difference in the energy produced by the two systems. The power graphs differ significantly and have a strong number of peaks and dips.

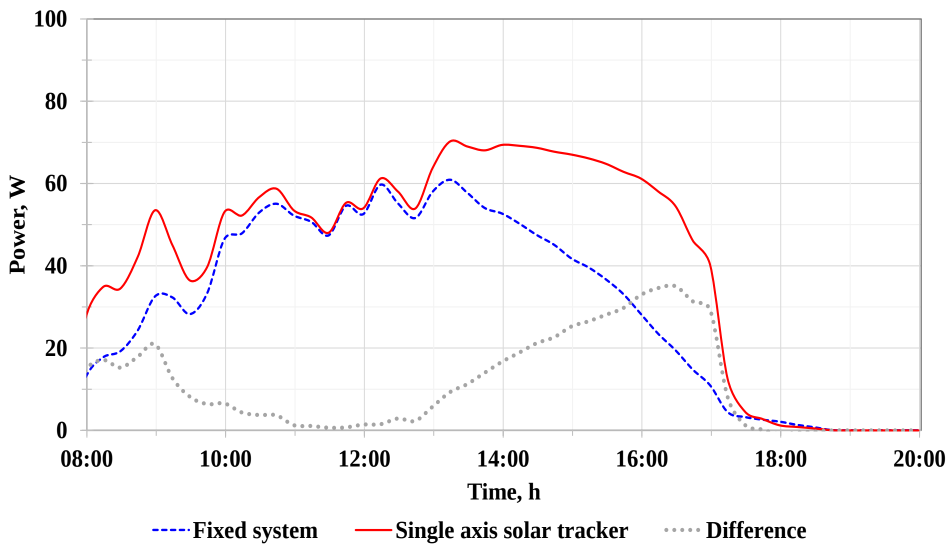

Figure 7. Output power and energy production of fixed and single axis solar tracking photovoltaic systems for 19.04.2020, scattered clouds

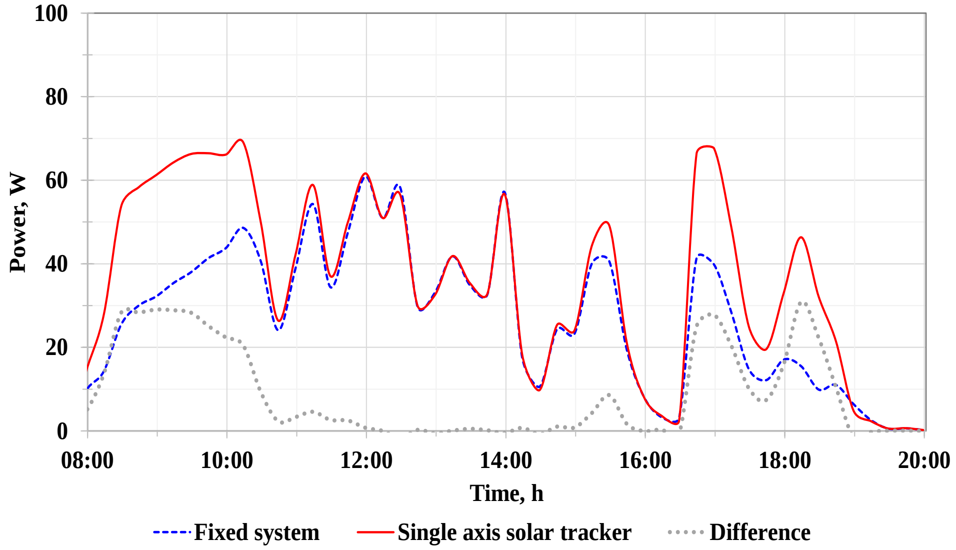

Figure 8. Output power and energy production of fixed and single axis solar tracking photovoltaic systems for 01.05.2020, scattered clouds

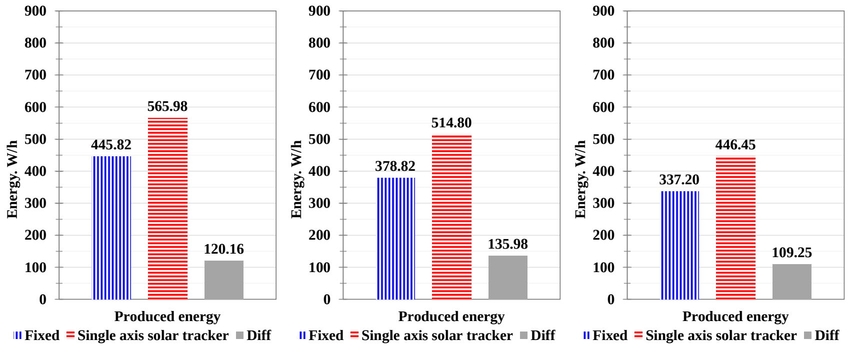

Figure 9. Energy production of fixed and single axis solar tracking photovoltaic systems for 18.04.2020, 19.04.2020 and 01.05.2020, scattered clouds

3.4. Difference in generated energy on a day with dense clouds

The two solar systems comparing, in terms of efficiency in the presence of dense clouds, was made in three days, corresponding to the required atmospheric conditions. The difference between the two systems was minimal due to the lack of direct sunlight, to which the solar tracker optimization was directed. Both systems energy production was greatly reduced because the sun rays density reaching the panel was low. The percentage difference between tracking and fixed solar systems on days with dense clouds varied between **4.1 % and 10.2 %.** The power graphs varied due to the different cloud densities on different days (fig. 10-13).

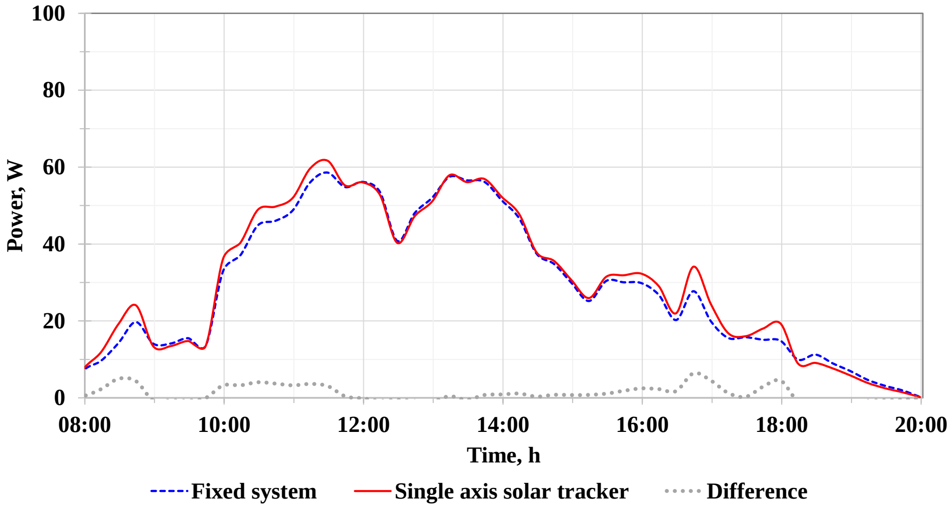

Figure 10. Output power of fixed and single axis solar tracking photovoltaic systems for 15.05.2020, dense clouds

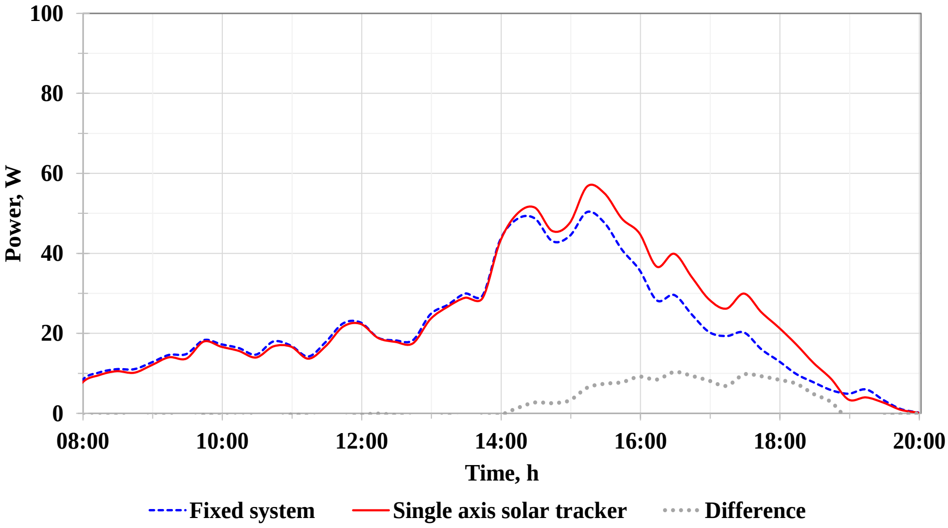

Figure 11. Output power of fixed and single axis solar tracking photovoltaic systems for 16.05.2020, dense clouds

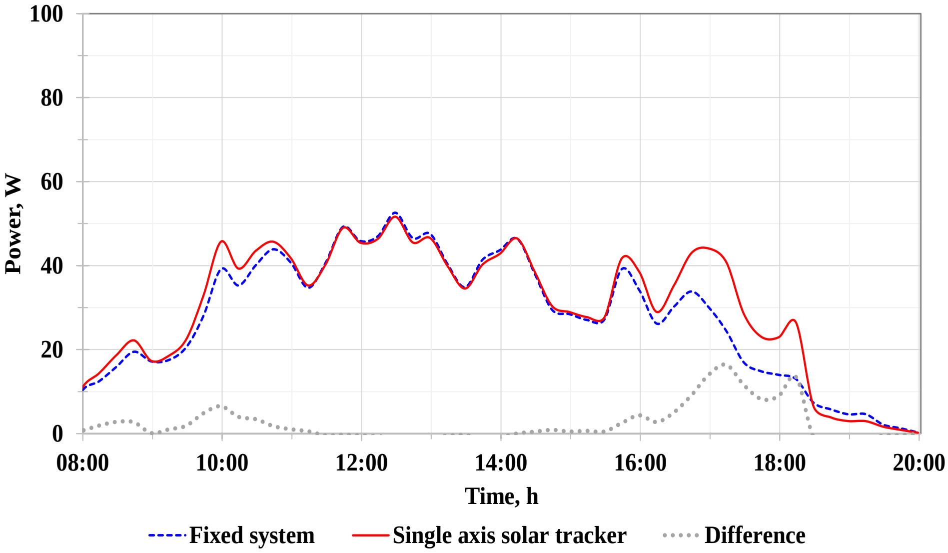

Figure 12. Output power of fixed and single axis solar tracking photovoltaic systems for 17.05.2020, dense clouds

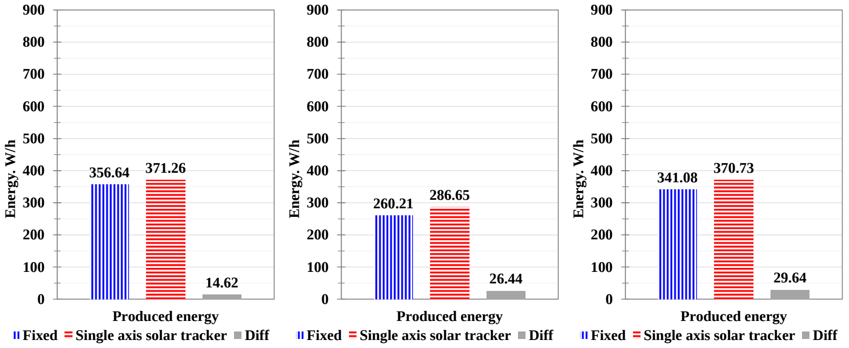

Figure 13. Energy production of fixed and single axis solar tracking photovoltaic systems for 15.05.2020, 16.05.2020, 17.05.2020, dense clouds

3.5. Difference in generated energy on a day with dense clouds and snow

The difference in energy production in the two systems on days with snowfall, similar to days with dense clouds, was minimal due to the lack of direct sunlight, to which the optimization of the solar tracker was directed. In addition, the energy production of both systems was greatly reduced because the density of the sun's rays reaching the panel was low. The percentage difference in energy production between tracking and fixed solar systems on days with snowfall was between **5.7 % and 9.35 %.** The power graphs varied (fig. 14-16).

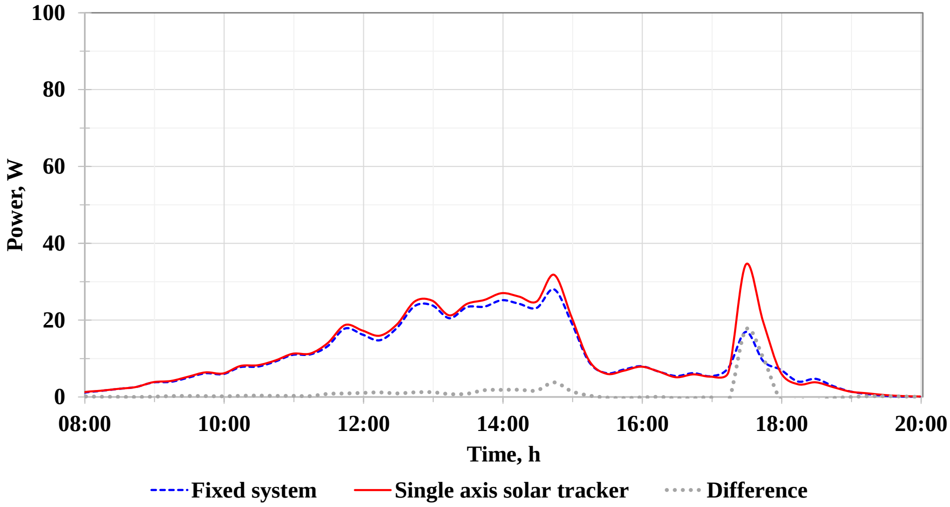

Figure 14. Output power of fixed and single axis solar tracking photovoltaic systems for 15.04.2020, dense clouds and snow

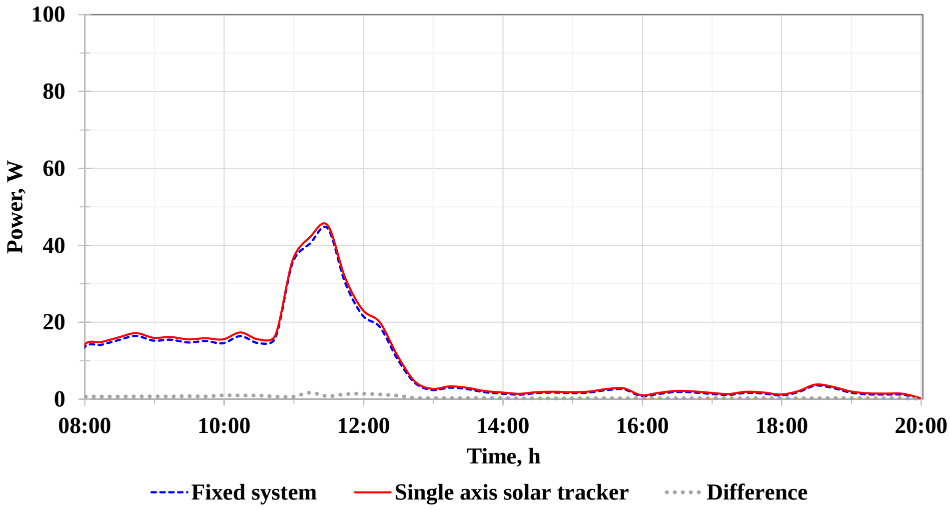

Figure 15. Output power of fixed and single axis solar tracking photovoltaic systems for 21.05.2020, dense clouds and snow

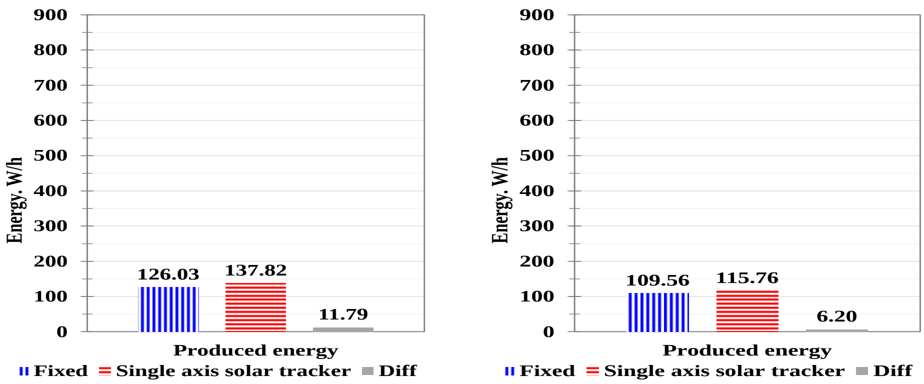

Figure 16. Energy production of fixed and single axis solar tracking photovoltaic systems for 15.04.2020 and 21.05.2020, dense clouds and snow

4. CONCLUSION

The solar tracker is more efficient than the fixed panel and the energy yield is significantly increased on a **clear day** and on a day with **scattered clouds.**

The solar tracker is more effective than the fixed one in dense clouds and snowfall. In the mentioned conditions the production of energy from the tracking and fixed solar systems was greatly reduced. The difference in energy production between the two systems was in favor of the solar tracking system, but was negligible. Therefore, it is pointless to invest in solar trackers in regions with year-round predominant dense clouds and/or snowfall. It is more reasonable to use a fixed solar system, but with a larger number of solar panels, instead a solar tracking mechanism.

REFERENCES

[1] Nedyalko Katrandzhiev, Nikolay Karnobatev, Energy Costs Reduce in Energy-Efficient Buildings by Applying Single Axis Solar Tracker, *2019 Second Balkan Junior Conference on Lighting (Balkan Light Junior)*, Plovdiv, Bulgaria, 2019, pp. 1-5, doi: 10.1109/BLJ.2019.8883440.

[2] Wotech Solar, www.wotechsolar.com

[3] *Solar Controller*-Wuhan Welead S&T Co., Ltd, www.ldsolarpv.com

[4] Nikolay Karnobatev, Develop Test and Implementation of Low Cost DC Power Data Logger, *2020 XXIX International Scientific Conference Electronics (ET)*, Sozopol, Bulgaria, 2020, pp. 1-4, doi: 10.1109/ET50336.2020.9238184.

[5] Nedyalko Katrandzhiev, Nikolay Karnobatev, Influence of the angle of fall of light on the photovoltaic panel and its optimization - literature review, *2019 Second Balkan Junior Conference on Lighting (Balkan Light Junior)*, Plovdiv, Bulgaria, 2019, pp. 1-5, doi: 10.1109/BLJ.2019.8883613.

Information about the authors:

Nedyalko Todorov Katrandzhiev – Professor, Department of Computer Systems and Technologies, University of Food Technologies

Nikolay Nenkov Karnobatev – PhD Student, Department of Computer Systems and Technologies, University of Food Technologies

Manuscript received on 07 December 2020