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ENERGY PRODUCTIVITY OF PHOTOVOLTAIC CELLS IN NITRA

Vladimír Cviklovič*[1], Zuzana Palková[1], Martin Olejár[1], Ana Petrović[1]

[1]Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Electrical Engineering, Automation and Informatics, Nitra, Slovakia

Abstract: This contribution is oriented to measurement and evaluation of the obtained energy from photovoltaic cells efficiency in practice conditions. Photovoltaic cells were monitored during one year in Nitra, Slovakia. Cells are monocrystalline with surface 1.95 m^2 and in full measurement time are directed perpendicular to the sun rays. Tracking and stationary systems were used for results evaluation. Six cells per system are used in the combined serial-parallel connection. Output energy from both systems is 496.257 kWh. Price of obtained energy is 69.48 EUR for actual price of electric energy, which is 0.14 EUR per kWh. The output power of the photovoltaic tracking system was higher by 20.39% opposite to stationary system.

Key words*: solar cell, solar tracker, tracking systems, polycrystalline cell*

INTRODUCTION

Converting of solar energy to electrical energy by photovoltaic cells is popular in this time. There are two basic types of photovoltaic cells – monocrystalline and polycrystalline. Theoretical efficiency of monocrystalline cell varies from 11.5 to 16 %. Polycrystalline cell has efficiency up to 14 %. Assuming that efficiency of the quality of collectors based on crystalline silicone is about 18 ÷ 20 % [1]. Cell is working on the base of the photovoltaic effect, firstly observed by physicist A. E. Becquerel in 1839. The photovoltaic effect is the creation of voltage in a material upon exposure to light [2]. The mostly used material for convert of solar energy to electrical is semiconductor P-N junction.

Our measurement system is placed on the roof of Renewable energy sources laboratory of Department electrical engineering, automation and informatics in Nitra. Latitude of GPS location of laboratory is 48°18'9.484'' north and longitude is 18°5'43.96'' east. Altitude is 137 m. Obtained energy is used for heating and lighting of

* Corresponding author. E-mail: vladimir.cviklovic@uniag.sk

laboratory. System is monitored 24 hours a day. Various tracking algorithms were tested on tracker.

MATERIAL AND METHODS

Used cells STP040S – 12/Rb are developed by SUNTECH. Total efficiency 12.6 % with a 25 years warranty is specified in the manufacturer's datasheet. Optimal operating voltage is 17.6 V and optimal current is 2.56 A. Maximum power is 45 Wp (1000 W·m^{-2}) and operating temperature is from -40 to +85 °C. The cells are produced from monocrystalline silicon. Six cells are used in the combined serial-parallel connection as shown in Fig. 2. Active surface of cells is 1.95 m^2. The temperature coefficients declared by manufacturer are shown in Tab. 1.

Table 1. Declared temperature coefficients of PV module STP040S – 12/Rb

Nominal operating cell temperature	*45 °C*
Short-circuit current temperature coefficient	*(0.055 ± 0.01) % / K*
Open-circuit voltage temperature coefficient	*-(78 ± 10) mV / K*
Peak power temperature coefficient	*-(0.48 ± 0.05) % / K*
Power tolerance	*± 5 %*

The pyranometer SG002 was used for the measurement of global solar radiation intensity. The measurement is based on the principle of temperature difference, which is created on black and white surface. Thermocouplers are used for temperature measuring of these surfaces. Pyranometer is situated on the tracker. Therefore, value of the global radiation intensity is not distorted by azimuthal error. The pyranometer is thermally isolated from the metal construction and it is placed in the sufficient distance to minimize the thermal impact. Technical parameters of used pyranometer are in Tab. 2 and its design is shown in Fig. 1.

Table 2. Technical parameters of the pyranometer SG002

Measuring range, W· m^{-2}	*0 – 1200*
Spectral range, µm	*0.3 – 3*
Output voltage, V	*0 – 2*
Power supply, V	*18 – 30*
Response time, s	*50*
Operating temperature, °C	*-30 – +60*
Minimal load impedance, Ω	*500*
Error, %	*± 3*

The temperatures are measured by calibrated digital temperature sensors DS18B20. Communication between control microprocessor and sensors is realized by 1-wire protocol. Standard accuracy is ± 0.5 °C in temperature range from -10 to + 85 °C. Accuracy is better than 0.25 °C in temperature range from – 10 to + 100 °C. The temperature sensors were additionally calibrated for this range.

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Figure 1. Pyranometer SG002

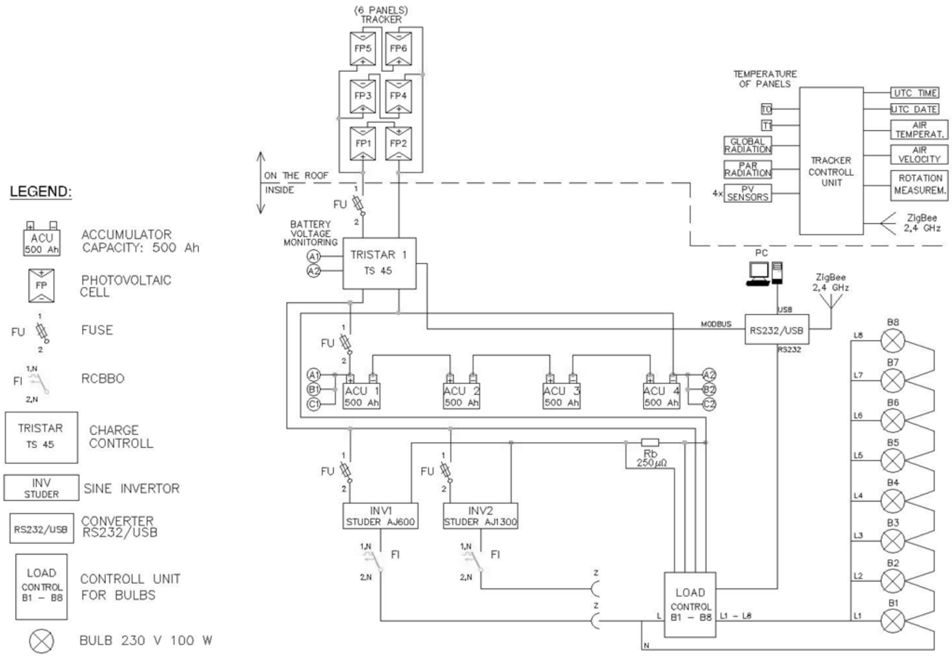

Figure 2. Block diagram of connection

TriStarTM controller TS-45 is used for battery charging. The controller operates in one mode at the time. Rated solar current of the controller is up to 45 A and system voltage is set to 24 V in our case. Accuracy of the voltage measurement is lower than 0.1 % ± 50 mV. Modbus communication protocol was used. Communication is realized on the RS-232C physical layer.

System is loaded by bulbs, which are switched by the module Load Control (Fig. 2). Output current of system and battery voltage is measured by this module. Converter resolution is 12-bit. The sine wave inverter AJ1300 was used. Its manufacturer is STUDER company. Maximum output apparent power is 1300 VA and efficiency is up to 95 %. Input voltage is optimally 24 V. Inverter output voltage is sine waveform with effective value 230 V / 50 Hz, it is generated by the *PWM* principle with passive filtration.

The measurement system is controlled by the single-chip microcontroller modules. Data are recorded by the program in Labview via *USB* port as shown in Fig. 2. Measurements are saved to data files in Matlab structure (*.dat) for suitable results evaluation.

RESULTS AND DISCUSSION

Collected energy from system was approximately equal to supplied energy during the measurement. Therefore, battery voltage was regulated to 26 V. Constant battery voltage is controlled by the program in Labview. The basic role of load control module is regulation of output power. System is based on the industrial single-chip microcontroller C8051F340, which was manufactured by Silicon Laboratories. All important parameters were monitored and saved to the file, namely: cells output voltage, cells output current, battery voltage and load current. These data are necessary for energy relationship calculation. The amount of electric energy was calculated based on data from whole year of systematic measurement. Acquired energy for individual months is presented in Tab. 3.

Table 3. Calculated data of electric energy amount, global radiation and efficiency

Month	*Tracking system output energy [kWh]*	*Stationary system output energy [kWh]*	*Global radiation [$kWh \cdot m^{-2}$]*	*Efficiency of tracking system [%]*	*Efficiency of stationary system [%]*
May	*33,12*	*28,10*	*266,50*	*12,43*	*10,54*
June	*53,61*	*37,88*	*379,43*	*14,13*	*9,98*
July	*59,26*	*44,35*	*429,22*	*13,81*	*10,33*
August	*52,14*	*38,49*	*369,53*	*14,11*	*10,41*
September	*29,59*	*25,76*	*237,90*	*12,44*	*10,83*
Oktober	*27,43*	*25,40*	*223,53*	*12,27*	*11,36*
November	*21,15*	*19,99*	*168,11*	*12,58*	*11,89*
Average	*39.47*	*31.42*	*296.32*	*13.11*	*10.76*

Fig. 3 shows the comparison of the produced electric energy amount between static solar panels and tracker solar panels, which are placed in the above mentioned photovoltaic power plant. For the data processing were used records collected during time period from May to November in 2013.

The produced electric energy amount during this period is calculated in kWh per month. In total, during this monitoring period the amount of produced electric energy was 276.29 kWh for tracker solar panels and 219.967 kWh for static solar panels, respectively. As it can be seen, the energy produced by tracker solar panels is greater than power produced by static solar panels. But that difference depends on period of the year. The difference was the highest during the summer sunny days in July; the maximum value of electric energy was 59.290 kWh per month for tracking system and 44.349 kWh per month for stationary system. Insignificant difference was found in May, September, October and November. However, visible and significant difference was found in June, July and August. This probably corresponds to length of sunlight, which falls directly to tracker in summer period. On the contrary, the curves are approximate in wintertime, which means that diffuse radiation is used equally. This can be confirmed with values in November, where almost no difference was found. It is depending on the diffuse radiation quantity. The tracking system produces 21.148 kWh per month, which is very close to 19.986 kWh per month produced by stationary system.

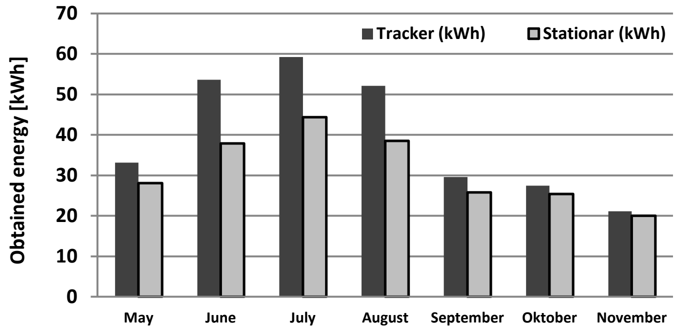

Figure 3. Comparison of the obtained amount of electric energy between static solar panels and tracker solar panels

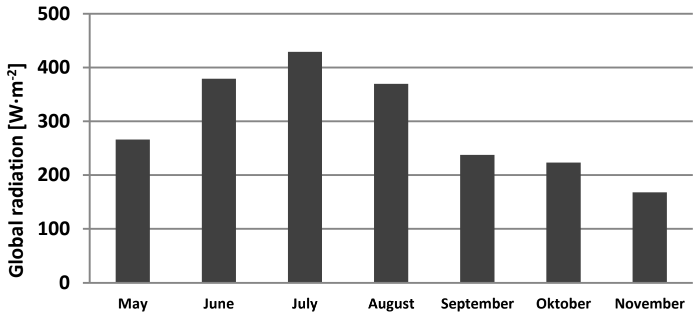

Figure 4. Global radiation from May to November

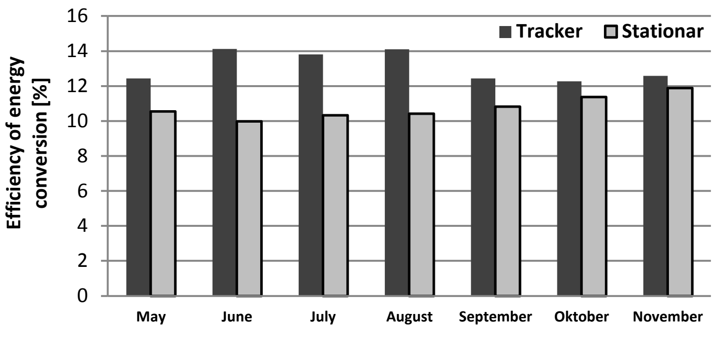

Figure 5. Efficiency of energy conversion in %

Fig. 4 shows global radiation and efficiency for every month individually, during the period from May to November 2013. There is big difference between individual months, for example in August was the global radiation 369.529 kWh·m^{-2} compare to September where it was only 237.895 kWh·m^{-2}. There were more rainy days in Central Europe during the September 2013 and that is the reason, that the global sun radiation is lower.

Efficiency of tracker and six static solar panels is presented in Fig. 5. Efficiency of photovoltaic solar system can be significantly increased with using of tracking position system from May to September. Higher efficiency is caused by minimal evidence of solar diffuse radiation.

CONCLUSIONS

The output power of the photovoltaic tracking system was higher by 20.39 % opposite to stationary system according to described conditions in time from May to November at year 2014. Maximum efficiency of tracking system was 14.13 % in June. Produced energy by tracking systems was 276.29 kWh at mentioned period. Output energy from stationary system was 219.967 kWh. Same type of photovoltaic cells is used in both systems. Output energy from both systems is 496.257 kWh. Price of obtained energy is 69.48 EUR for actual price of electric energy, which is 0.14 EUR per kWh.

BIBLIOGRAPHY

[1] Libra, M., Poulek, V. 2012. Photovoltaic Solar Systems in the Czech Republic. *Applications of Physical Research in Engineering*. Scientific Monograph. SUA in Nitra, 2012. ISBN 978-80-552-0839-8.

[2] Williams, R. 1960. Becquerel Photovoltaic Effect in Binary Compounds. *Journal of Chemical Physics*. Volume 32, Issue 5. American Institute of Physics. ISSN 1089-7690.

ENERGETSKA PRODUKTIVNOST FOTONAPONSKIH ĆELIJA U NITRI

Vladimír Cviklovič, Zuzana Palková, Martin Olejár, Ana Petrović

Slovački poljoprivredni univerzitet u Nitri, Tehnički fakultet, Institut za elektrotehniku, automatiku i informatiku, Nitra, Slovačka

Sažetak: Ovaj rad se bavi merenjem i ocenom efikasnosti dobijene energije iz fotonaponskih ćelija u praktičnim uslovima. Fotonaponske ćelije su bile praćene tokom jedne godine u Nitri, Slovačka. Ćelije su monokristalne, površine 1.95 m^2 i tokom punog merenja usmerene upravno na sunčeve zrake. Za ocenu rezultata su korišćeni praćenje i stacionarni sistemi. Šest ćelija po sistemu su upotrebljene u kombinovanoj serijsko-paralelnoj vezi. Izlazna energija iz oba sistema je 496.257 kWh. Cena dobijene energije iznosi 69.48 EUR po trenutnoj ceni električne energije, što je 0.14 EUR za 1kWh. Izlazna snaga fotonaponskog sistema praćenja bio je viši za 20.39% u poređenju sa stacionarnim sistemom.

Ključne reči*: solarna ćelija, solarni tragač, sistemi za navođenje, polikristalna ćelija*

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