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RESULTS OF TWO YEARS' OPERATING-FUNCTIONAL RESEARCH OF THE PHOTOVOLTAIC COLLECTOR SYSTEM

Summary

The operating -functional research was conducted on a set of photovoltaic panels with power of 12.88 kW operating since June 2012. The economic and energetic analysis of the research stand and its practical suitability for a small family farm was performed in order to use the generated electricity to satisfy the farm's current demands. The research results have shown that the amount of electricity generated by photovoltaic panels would be sufficient to cooperate with other renewable energy sources (e.g. power supply of heat pumps) collecting and processing heat from livestock buildings or ground heat exchangers to heat up tap water and buildings. In the period from June 2012 to June 2013 10480 kWh of electricity with an average production of 815.2 kWh annually was produced, and in the period from June 2013 to June 2014 11519 kWh of electricity with an average production of 959.9 kWh monthly was generated. The panel was inclined at 20° to the Earth's axis and at 210° to the north (as per the compass rose: S-S-W direction).
***Key words**: energy, electricity, renewable energy sources, solar panel, photovoltaics*

WYNIKI EKSPLOATACYJNO-FUNKCJONALNYCH DWULETNICH BADAŃ INSTALACJI KOLEKTORÓW FOTOWOLTAICZNYCH

Streszczenie

Przeprowadzono badania eksploatacyjno-funkcjonalne zespołu paneli fotowoltaicznych o mocy 12,88kW pracującego od czerwca 2012r. Przeprowadzono analizę ekonomiczno-energetyczną stanowiska oraz jego praktyczną przydatność do zastosowania w małym rodzinnym gospodarstwie rolnym w celu wykorzystania pozyskiwanej energii elektrycznej na bieżące potrzeby gospodarstwa. Wyniki badań wykazały, że ilość pozyskiwanej energii elektrycznej przy pomocy paneli fotowoltaicznej pozwoliłaby na współpracę z innymi źródłami energii odnawialnej – (np. zasilanie pompy ciepła), pozyskującej i przetwarzającej ciepło z budynków inwentarskich lub z wymienników gruntowych do produkcji ciepłej wody użytkowej i na ogrzewanie budynków. W okresie od czerwca 2012r.do czerwca 2013r. wyprodukowano 10480 kWh energii elektrycznej, ze średnią produkcją 815,2 kWh/rok. Natomiast w okresie od czerwca 2013 do czerwca 2014 wygenerowano 11519 kWh energii elektrycznej ze średnią 959,9 kWh miesięcznie. Nachylenie kolektora wynosiło 20º względem powierzchni ziemi, oraz 210º względem azymutu N (wg „róży wiatrów" kierunek S-S-W).
***Słowa kluczowe**: energia, energia elektryczna, odnawialne źródła energii, kolektor słoneczny, fotowoltaika*

1. Introduction

In some Poland's rural areas the acting energy infrastructure and the absence of funds for new investments lead to the economic downturn. This results in the population impoverishment and unemployment growth. Study [8], in his study, states that that situation may significantly improve, if supplies of energy from agro-technical installations is ensured. The development of such installations may provide benefits such as the sustainability of the local entrepreneurship based on local environmental resources and renewable energy sources. The renewable energy sources may be essential for the sustainability of the Polish agriculture. According to special study [11], the sustainability of the livestock building construction, including production techniques and technology, should be based on non-conventional energy sources compatible with elements of conventional energy supply. In particular, this refers to economics, but it also positively affects the environment, animal well-being and society.

One of the possible solutions is to use the solar energy to produce electricity in photovoltaic installations of little power. These installations, contrary to passive solar and thermal systems, are not highly popular in Poland, yet mainly because of high costs of silicon cells that condition a long return on investment [5] and the absence of the real support from the regulators. The chance for such systems is a support of the European Economic Area Financial Mechanism. Investors may expect favourable preferential credits and grants under the Regional Operational Programmes. Moreover, it should be considered that the photovoltaic technology is noted to have the quickest decline in production prices – by 20% within 20 years [3].

Moreover, it is noteworthy that Poland is obliged to take actions to reduce the emission of greenhouse gases on the basis of the international agreements, among others, " EU Climate and Energy Package" [1]. On 16 January 2011 the Ministry of Economy approved the Objectives of the National Programme of Low-Emission Economy Development (NPLEED) [6] imposed by the need to reduce the emission of greenhouse gases and other substances emitted into air in all industries. The essence of the Programme is to ensure economic, social and environmental benefits (as per the sustainable development principle) resulting from actions that reduce the emission and achieved, among others, through the implementation of new technologies. The production of electricity in photovoltaic installations complies with any and all terms and conditions of the aforesaid documents.

The usage of the photovoltaic installations is primarily supported by the possibility to directly converse solar radiation into electricity. Of importance are also such factors as rich resources of cheap raw materials for the production of modules: silicon, aluminium and lead [4] and the pace of the development of technologies linked to photovoltaics (e.g. use of graphene).

The disadvantage of photovoltaic systems is the unequal generation of electricity per day and per annum [4]. Efficiency differences in individual months are highly considerable and may account for 90% (efficiency difference in May and December) [5]. Therefore, presently the most profitable solution is to sell the generated electric power to the provider. In addition, this solution prevents from costs of purchasing and handling batteries.

In order to assess the profitability of solar systems, up-to-date data from active systems and the experience of users of these systems are essential. This research is conducted, among others, by the Institute of Technology and Life Science in Falenty, Poznań Branch.

2. Research problem

On the basis of the analysis of the available reference books and the present knowledge gained under the previous research the following research problem is formulated:
1) To what extent is the volume of electricity produced by photovoltaic panels repeatable in comparison with the subsequent years of operation?

3. Research purpose

The aim of the research was to conduct the energetic analysis of solar photovoltaic panels in real conditions. The secondary aim was to review the correct operation of the system with respect to its technical efficiency, under which it was possible to prepare the technical and operating documentation to be practically implemented by farms.

4. Research object

The object of the research is a research stand comprising solar modules of photovoltaic panels of a total power of 12.88 kWp.

5. Research methodology

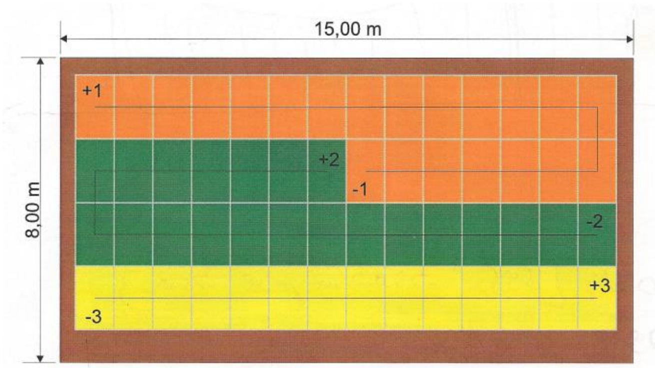
The research was conducted continuously from June 2012 to June 2014 considering all seasons of the year. The most significant ratios and parameters of the solar system operation (Fig. 1) were measured by one person every day at 7:00 a.m. before the panels began to operate effectively and the gathered data were provided in special tables comprising daily generation of electricity (kWh/day), average momentary power of the system (kW), total electricity generated from the first day of measures (kWh/day). Subsequently, the data were divided into months and years. The Flowchart on Fig 1.

The research stand comprised solar photovoltaic panels, inverter and data recorder. The solar system of a total power of 12.88 kW comprising 56 photovoltaic panels with a total area of 1.86 m^2 each and power of 230W was divided into three working groups (21 pieces, 21 pieces and 14 pieces – Fig. 2). Each solar panel was equipped with 3 emergency diodes used to shut part of the panel module down in case of a shadow, dirt or snow, thanks to which the module did not overheat and the operational efficiency of the entire system did not decline unnecessarily.

The panel was inclined at 20° to the Earth's axis and at 210° to the north (as per the compass rose: S-S-W direction). The solar system (Fig. 3) covered an area of 120 m^2 of the roof of the social and technical building (system size: 8m x 15m).

Source: Own study / Źródło: Opracowanie własne)

Fig. 1. Monitoring and control panel of the studied solar system
Rys. 1. Panel kontrolno-pomiarowy badanej instalacji solarnej



Source: SOLERA / Źródło: SOLERA

Fig. 2. Schematic layout of groups of solar photovoltaic panels
Rys. 2. Schemat rozmieszczenia grup paneli fotowoltaicznych

Source: Own study / Źródło: Opracowanie własne

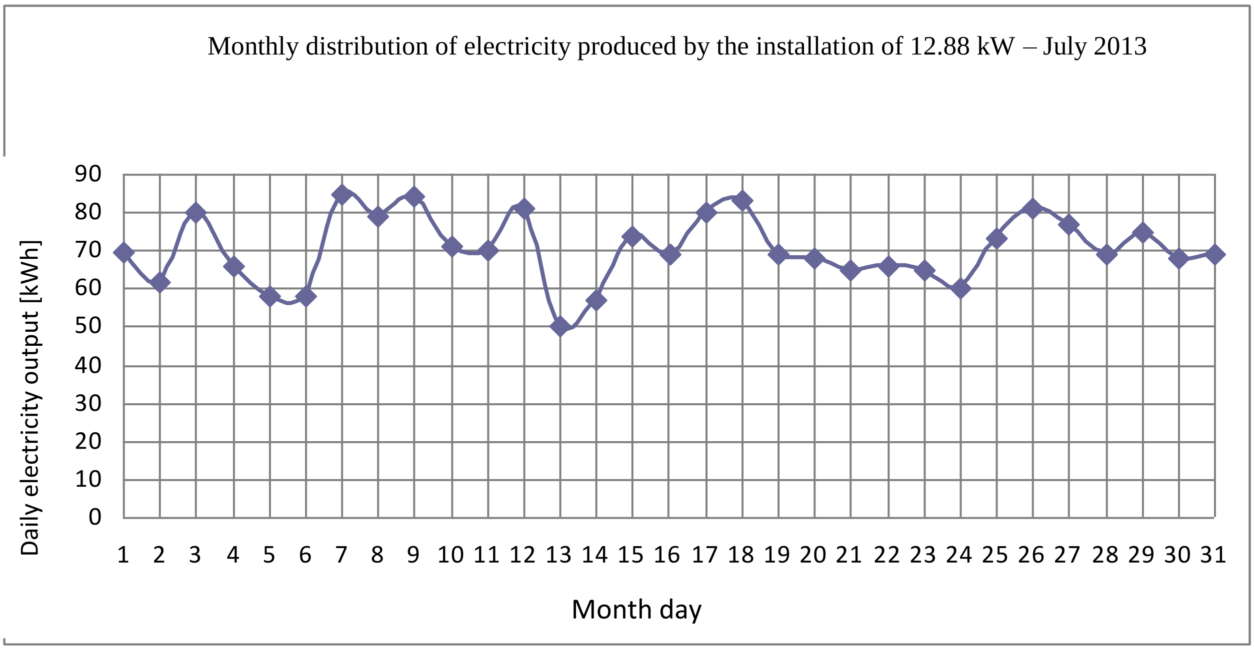
Fig. 3. View of the studied solar installation
Rys. 3. Widok badanej instalacji solarnej

6. Research results and their discussion

The entire system was divided into three chains comprising 14, 21, 21 modules, respectively. It is worthwhile emphasizing that the adjusted transformer-free inverter SMA Sunny Tripower 12000 with power of 12 kW is loaded at 107% in comparison with the installation power, hence the efficiency of the entire installation is greater.
The inverter readings were made in July 2013, every day as 04:00 p.m.

The highest power (85 kWh) was acquired on 7 July, and this means that from 04:00 p.m. of the previous day to 04:00 p.m. of the measurement day the installation of 12.88 kW produced 85 kWh.

The diagram of the monthly distribution of power production shows substantial deviations from the straight line and such deviations show that such factors as in sunlight, clouds, contamination of the surface of the photovoltaic panels have a significant effect (Fig. 4).



Source: Own study / Źródło: opracowanie własne

Fig. 4. Diagram of electricity production by the studied solar installation in July 2013
Rys. 4. Wykres produkcji energii elektrycznej przez badaną instalacje solarną w lipcu 2013r.

On 1 June 2014 values of electricity produced by the installation since the day of connecting the inverter, i.e. June 2012, were read. The obtained value of 21999 kWh may be compared to 10480 kWh.

Initial value: June 2012	Meter reading in June 2013	Meter reading in June 2014	Annual production in the second year
0 kWh	10480 kWh	21999 kWh	21999 – 10480 = 11519 kWh

Following the first year of the installation operation the annual power output was 10480 kWh. By dividing this figure by the installed power, it is possible to determine the amount of power to be produced by power of 1 kW installed in a specific location (in this case, this is Mściszewo, Wielkopolska Province, Poland).

$$\frac{10480\ kWh}{12{,}88\ kWp} = 813{,}66\frac{kWh}{kWp}$$

This dependence is analogous to the second year of the operation of the photovoltaic installation.

$$\frac{11519\ kWh}{12{,}88\ kWp} = 894{,}33\frac{kWh}{kWp}$$

By measuring values of the daily or monthly power output from the photovoltaic installation the efficiency of the modules are expected to decrease. Manufacturers of photovoltaic panels give warranties up to 20% of the loss of the nominal power after 25 years [12]. Meanwhile, in case of the studied installation the value of the annual power production in a year of the installation operation is 80 kWh greater compared to the first year due to better weather conditions – about 15% more insolation [W/m^2] in 2013/2014 season. That was confirmed by measurements done with Pyranometer.

On the basis of the conducted research and the energetic and economic analysis, the following conclusions are made:
1) The studied solar photovoltaic system of 12.88 kWp generated 10480 kWh of electricity annually, the maximum generation was in June 2012 (1612 kWh) and the minimum one was in December 2012 (264 kWh), whereas in 2014 the was generated 11519 kWh, and average 894,33kWh.
2) The system emerged to be around 5.5 times larger than the average household's demands, which was evaluated on the level of 1900-2100 kWh/a [13, 14].
3) It is necessary to conduct further research and to make a design and technology of the stand of the additional electricity source such as the wind turbine of little power

(around 1.2- 1.5 kW) that is able together with the existing solar system to balance the production of electric power in winter in order to balance a negative difference between electric power generated by panels in summer and in winter.

4) Apart from the fact that Poland does not have the effective mechanism that supports installations of renewable energy sources, including photovoltaic installations, it is noteworthy that based on measures taken after 2 years of the photovoltaic system operation, it can be said that Polish climatic conditions also favour the production of electricity from the Sun, similarly to our Western neighbours.

5) The results of the measurements taken in the period from June 2013 to June 2014 proved the results obtained in the period from June 2012 to June 2013 at the amount of the produced electricity and its distribution in comparison with the subsequent months of the year.

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