EFFICIENCY OF FIXED AND TRACKING PHOTOVOLTAIC PANEL

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Abstract. The paper presents the results of four year experimental investigation on the efficiency of photovoltaic panel PVM10/PF working in Latvia meteorological conditions during March-October, 2009-2013. Regardless of relatively small intensity of solar radiation and the number of sunny hours in the Baltic region, there are areas where it is economically reasonable to use photo-electric converters or photovoltaic panels for production of electricity and heat energy. The conversion efficiency of a panel depends on the materials and technology used at its production, on the intensity of solar radiation, as well as the panel inside and outside air temperature. The intensity of solar radiation during summer months has been measured and the ratio of solar energy transfer into electric energy, when the panel was working at stationary fixed and tracking the sun mode has been stated. It was established that working in tracking the sun mode the yearly output of the solar panel is 1.41 times higher than working at a fixed position, but considering only clear sunny days 1.59 times higher.

Keywords: solar panels, photovoltaic, fixed, tracking the sun, solar radiation.

Introduction

The objective of the research is to ascertain the increase of mono-crystalline silicon photovoltaic (PV) panel PVM10/12PF electric power in case when it is working fixed stationary in the south direction (Fig. 1), and when working in tracking the sun stand (Fig. 2) in the meteorological conditions of Latvia.

Photovoltaic conversion of the sun's electromagnetic radiation to electric energy takes place in PV cells. Individual cells are combined to create photovoltaic panels using series-parallel connections, providing the required direct current voltage. The efficiency of PV panels depends on their construction and production technology. Today PV panels based on silicon are most widely used. They can be mono-crystalline, poly-crystalline and amorphous based thin layers in shape of flexible PV panels. PV systems can be considered for autonomous or off-grid, not connected to mains electricity. They are producing power for a single user or for a small region of consumers. On-grid PV systems are connected to mains electricity. PV panels have insignificant exploitation expenditures, as they do not have moving parts. They are not electrically dangerous, produce direct currant possible to charge in accumulator batteries. They can work in a system with wind, combustion–electric engine or other generators. The conversion efficiency of the PV panels depends on several factors. In large scale it is determined by the material and its structure, as well as technology used in the production. For instance, silicon mono-crystalline PV panels have the conversation efficiency 25 %, silicon-polycrystalline panels – 20 %, and amorphous silicon panels only 10 %. The efficiency of PV cells based on mono-crystalline silicon is approximately 20 % for mass produced panels [1].

Fig. 1. **Photovoltaic panel PVM10/12PF in fixed position with power measuring device**

Fig. 2. **Photovoltaic panel PVM10/12PF on the sun tracking stand EPR–203**

The output power of the PV panels essentially depends on the working temperature. As the account point temperature of 25 ºC is accepted. The lowered power can be calculated considering the so-called temperature coefficient. For each degree of the surrounding air temperature above 25 ºC the value of the panel power falls. The conversion efficiency of the PV panels depends also on the intensity of solar radiation and its spectrum of wavelengths. Maximum of electric energy can be obtained when solar radiation strikes the panel surface perpendicularly.

Materials and methods

During summer time in Latvia days are long. The longest day lasts for 17.9 hours. Working in the stationary position solar panels can use the solar radiation energy only partly. In order to register the produced amount of electric energy by the PV panel, a special device has been developed and patented, the volt-ampere characteristic of which is similar to the volt-ampere characteristic of an electric accumulator [2]. Therefore, the device, in fact, measures the amount of electricity charged in the accumulator. As the register of the device power, the cmodule HOBO H08–007 has been used. The investigation of the photovoltaic panel in 2009 was commenced. For experimental investigation a mono-crystalline silicon PV panel PVM10/12PF (Table 1) with the working area 0.1 m^2 has been used, and the investigation was carried out in two intervals. In 2009 and 2010 the panel was working in a fixed position oriented in the south direction with the angle of inclination to the horizon 53º (Fig. 2), at which the panel power is at its maximum.

Table 1

Technical data of photovoltaic panel PVM10/12PF

Parameter	Symbol	Dimension	Value
Peak power	W_p	W	10
Nominal voltage	U	V	12
Wp point voltage	U_{Wp}	V	17
Wp point current	I_{Wp}	A	0.6
Short-circuit current	I_{sc}	A	0.8
Surface area	L	m^2	0.1
Transformation factor	K_p	%	12-15
Size	Length x height x depth	mm	280 x 365 x 6
Mass	M	kg	0.4

The amount of electric energy produced by the panel was measured and registered in every 12 minutes during these two years using the module HOBO H08–007. The obtained results were processed and analyzed. The power of electric energy developed by the panel was calculated.

At the end of 2012 the solar panel PVM10/12PF has been mounted on the sun tracking stand EPR–203, activated by a solar tracker EPS–103 and during the summer of 2013 the panel was working in tracking the sun regime (Fig. 2). Every 5 minutes the output of electric energy has been registered and the obtained data collected and analyzed. In order to state the difference between the produced amount of electric energy in fixed and tracking the sun mode on clear sunny days, the amount of the produced electric energy on four sunny days of 2009 and 2010 was compared with the output of the energy in 2013 during the four sunny days by the date nearest to the four days in the previous years, when the intensity of solar radiation was the same. There the same place, weather conditions, PV panel and measuring equipment has been used, heightening the precession of the results.

Results and discussion

During the 8 summer months of 2009 and 2010 while working at a fixed stand, the amount of electric energy produced by the panel PVM10/12PF on the average per month was 91.6 kWh·m^{-2}, but in 2013 during the 8 summer months working in tracking the sun regime the average monthly electric energy output was 129.2 kWh·m^{-2} or by 1.41 times more (Table 2). The output of electric energy by the stationary working solar panel PVM10/12PF during a year has changed insignificantly – from 0.61 to 0.69 kWh·m^{-2}, but when working in tracking the sun mode, it has changed from 0.84 to 1.2 kWh·m^{-2} depending on the length of a day. In Table 2 the average electric energy output of the panel PVM10/12PF during two years working in the fixed regime is compared with the electric energy output by the panel working in tracking the sun mode during 2013. As it is seen from Table 2, during all the months the ratio of the produced electric energy is 1.41 times higher when working in tracking the sun mode.

Table 2

Output of electric energy by panel PVM10/12PF working at fixed and tracking the sun mode

Mode	Electric energy output Q, kWh·m^{-2} per month								
	III	IX	V	VI	VII	VIII	IX	X	Total
Fixed	8.38	13.66	13.58	12.16	14.65	12.90	10.10	6.13	91.6
Tacking the sun	19.68	15.15.	24.58	23.15	19.90	20.49	12.85	6.50	129.2
Q_{tr}/Q_{fix}	2.35	1.11	1.81	1.90	1.36	1.59	1.27	1.06	1.41

Fig. 3-7 present the power characteristic curves of the electric energy output and computed amount of the produced electric energy during sunny days of 2009 and 2010, when the panel PVM10/12PF was working in a fixed stand, but in 2013 in tracking the sun mode. It follows that the panel PVM10/12PF working in tracking the sun mode during a day has produced significantly more electric energy than working in a fixed stand. The increase in electric energy output during clear summer days: on March 10, 2010 and March 11, 2013 (Fig. 3), on April 21, 2009 and April 21, 3013 (Fig. 4), on June 24, 2009 and June 8, 2013 (Fig. 5) and on September 2, 2009 and September 5, 2013 (Fig. 6) is 1.38, 1.65, 1.71 and 1.62 times accordingly, or 1.59 times on the average.

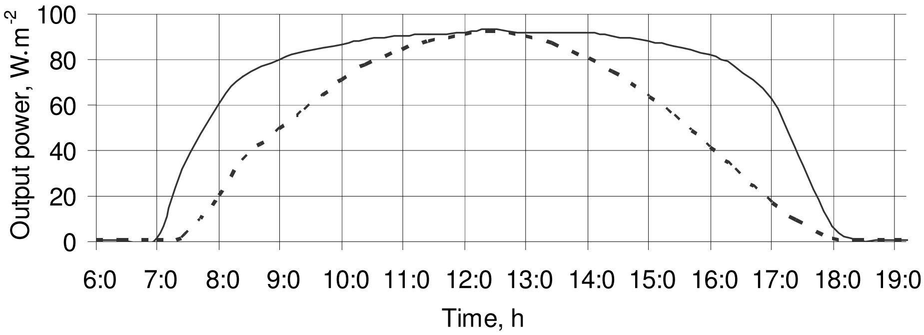

Fig. 3. **Power of PV panel PVM10/12PF:** working in fixed regime on March 10, 2010 (--- Q_{fix} = 0.61 kWh·m^{-2} per day) and tracking the sun regime on March 11, 2013; (— Q_{tr} = 0.84 kWh m^{-2} per day); $Q_{tr} = 1.38Q_{fix}$

It means that during sunny days the difference between the produced by the panel amount of electric energy in tracking the sun mode is considerably higher than working in a fixed position.

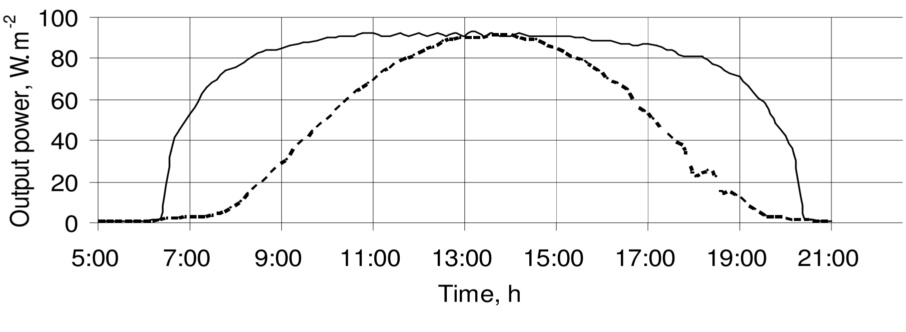

Fig. 4. **Power of PV panel PVM10/12PF:** working in fixed regime on April 21, 2009 (--- Q_{fix} = 0.68 kWh m^{-2} per day) and tracking regime on April 21, 2013; (— Q_{fix} = 1.12 kWh m^{-2} per day), $Q_{tr} = 1.65Q_{fix}$

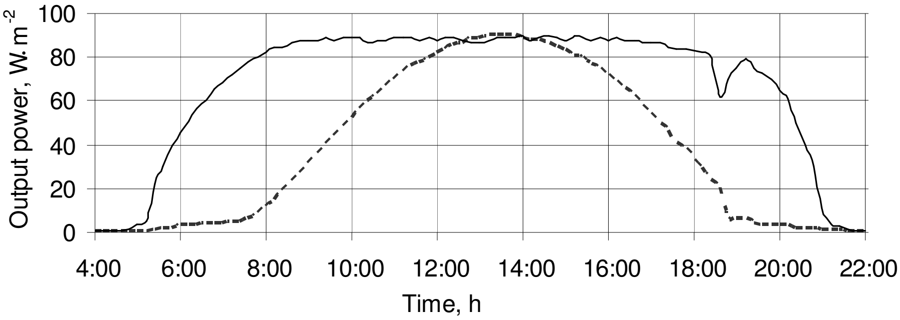

Fig. 5. **Power of PV panel PVM10/12PF:** working in fixed regime on June 24, 2009 (--- Q_{fix} = 0.69 kWh·m^{-2} per day) and tracking regime on June 08, 2013; (— Q_{tr} = 1.18 kWh·m^{-2} per day); $Q_{tr} = 1.71 Q_{fix}$

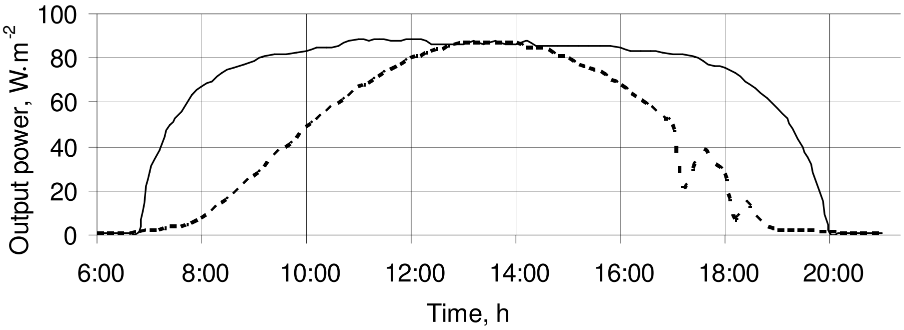

Fig. 6. **Power of PV panel PVM10/12PF:** working in fixed regime on September 2, 2009 (--- Q_{fix} = 0.62 kWh·m^{-2} per day) and in tracking regime on September 7, 2013 (— Q_{tr} = 1.0 kWh m^{-2} per day), Q_{tr} = 1.62 Q_{fix}

From Fig.6 it is seen that after an hour from sunrise the panel output power was more than 50 % of its maximum value. In opposite to this, when working in a fixed regime the panel PVM10/12PF output power in the middle of the summer reached 50 % of the maximum power only a little more then in 7 hours.

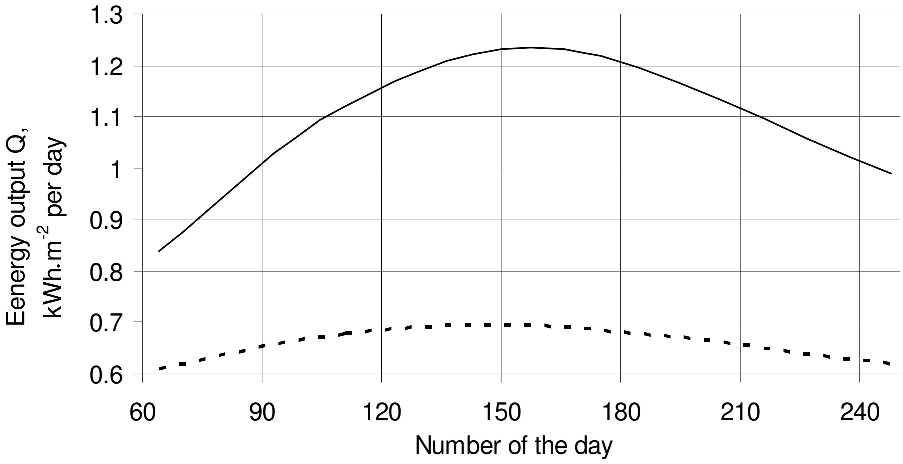

Fig. 7. **Energy produced by the panel PVM10/12PF:** placed on a fixed stand (--- Q_{fix}) and tracking the sun mode (— Q_{tr}) depending on the length of a clear sunny day

From Fig. 7 it follows that in the fixed regime the panel PVM10/2PF has not used all the length of a day and the amount of the electric energy output only insignificantly increases from March till June.

Conclusions

1. Working in tracking the sun mode the solar panel PVM10/2PF yearly produces 1.41 times more electric energy than in a fixed position.
2. Considering only clear sunny days the panel in tracking the sun mode produces 1.59 times more electric energy than working in a fixed position.

References

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