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Evaluating the effectiveness of photovoltaic panels with a rotation mechanism for region of Republic Bashkortostan

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Abstract-This paper deals with evaluation of the effectiveness of using the solar panels in the Republic of Bashkortostan and with the issue of the efficient use of solar energy potential gained from photovoltaic panels via tracking the Sun’s trajectory. The study based on long-term measurements of the selected parameters, the efficiency of the installed system was evaluated in the static regime. We study two types of photovoltaic panels: micromorph and crystal. This article discusses the feasibility of a method for increasing the efficiency of photovoltaic panels on the rotary mechanisms. The authors gives a comparison of photovoltaic panels with rotary mechanism and without them.

Keywords—Solar panels, photovoltaic, micromorph, crystalline.

1. Introduction

The use of renewable energy sources (hereinafter RES) is one of the priority direction of development of electric-power industry of Russian Federation. The share of solar power(hereinafter SP), biogas and wind power plants is increasing, and there are created the legal framework for use of objects of Renewable energy sources in Russian Federation[1, 2]. In addition to the quantitative increase in the share of RES in electric-power industry of Russian Federation, there are also important to make researches and design new technical solutions to increase effectiveness of RES. In this paper, authors will consider methods of increasing the effectiveness of the using photovoltaic panels in the Republic of Bashkortostan.

One of the method of increasing the effectiveness of photovoltaic panels is the use of rotary mechanisms for photovoltaic panels. In researches in this area are engaged a number of foreign companies such as Transtecno, Smart Solar, who suppose that through the use of rotary mechanism and system of tracking the Sun’s trajectory of electric power and effectiveness of photovoltaic panels may increase by 10-40% [3-5]. Also, studies devoted to the assessment of the effectiveness of the rotary mechanisms for the solar panels have been widely presented in paper of Miroslav Rimar, Marcel Fedak, Michal Hatala, and Peter Smeringai [6]. In this study authors concluded that using rotary mechanisms in PV for the Europe gives a significant increase in energy gain by about 23% in the period of the year with a relatively low number of hours of sunshine when compared to the summer maxima. Based on the evaluation, along with the increasing duration of a daily sunshine, there was the increase in the rotary system efficiency. Theoretically, in the summer time, there is an energy gain up to 40% compared to the static system without rotation. In winter, the gain is lower and varies in the interval between 5% and 10%. This study shows us that rotary mechanism increase the efficiency of PV for Europe, so in this paper we will estimate the efficiency of using rotary mechanism for PV in the Republic of Bashkortostan.

According to the long-term plan of the Republic of Bashkortostan by 2018, it is planned to build two solar power plants with a total capacity of 15 MW. And for the successful operation and effective use of this type of energy source in the Republic of Bashkortostan it is required to estimate the efficiency of rotary mechanisms at SP in this region.

The main task in this paper is to estimate the effectiveness of rotary mechanisms for photovoltaic panels in region of Republic of Bashkortostan and to find optimal design of using photovoltaic panels for convenient operation.

2. Characteristics Considered Climate Zone

Considered climate zone (Republic of Bashkortostan) is located between 51 ° and 56 ° north latitude and 22 ° and 30 ° east longitude (from Pulkovo), the average annual temperature of 2,7 °, average rainfall 589 mm per year. This area is characterized by long cold winters and moderately warm summers. [7]

In the area under rainfall observed in the form of snow, rain, hail, frost and dew. Depending on the phase state of the precipitation can be solid, liquid or mixed. Within the city of Ufa solid precipitation as snow falls from October to April. The liquid phase deposits include all types of rainy. To the mixed phase is wet snow and rain, rain and hail, and others. Precipitation mixed type observed in spring and autumn. According to long term average data per year in Ufa 75 days with solid precipitation 71 days - with liquid, 17 days - with mixed, steady snow cover formed in the middle of November and lasts until the end of March, and sometimes the first ten days of April. The average year is about 164 days with snow cover, it is more than five months. The first snow is observed in late October. So it is also important to take into account rainfall, because the energy gain depends on it.

3. The object of Research

The object of research is the solar panels installed at the Department of Electromechanics "Ufa State Aviation Technical University", Fig. 1, and representing two photovoltaic panels manufactured by Hevel (micromorph module area of 1.43 m2, the nominal power of 125 W and a crystal module with area of 1.286 m2, the nominal power crystal module 223 W) installation angle of PV modules 39 degrees.

Fig. 1 – Solar panels installed in Ufa State Aviation Technical University

4. Assessment of efficiency of PV.

To evaluate the effectiveness of using rotary mechanisms at PV by authors were made comparison between yearly energy production of PV panels with and without rotary mechanism. Yearly production of PV without rotary mechanism shown in Figure 2-4 and Table1..

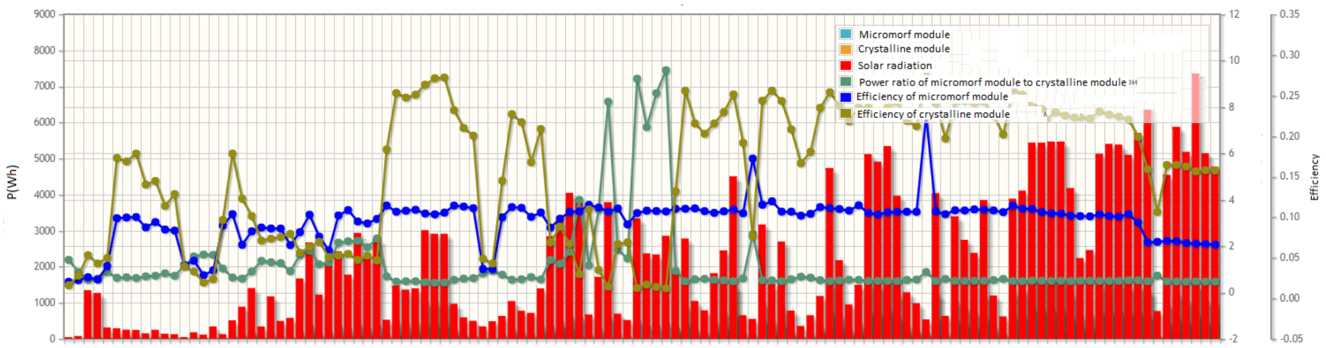

Fig 2. Graphic of energy production for 01.01.2014-30.04.2014

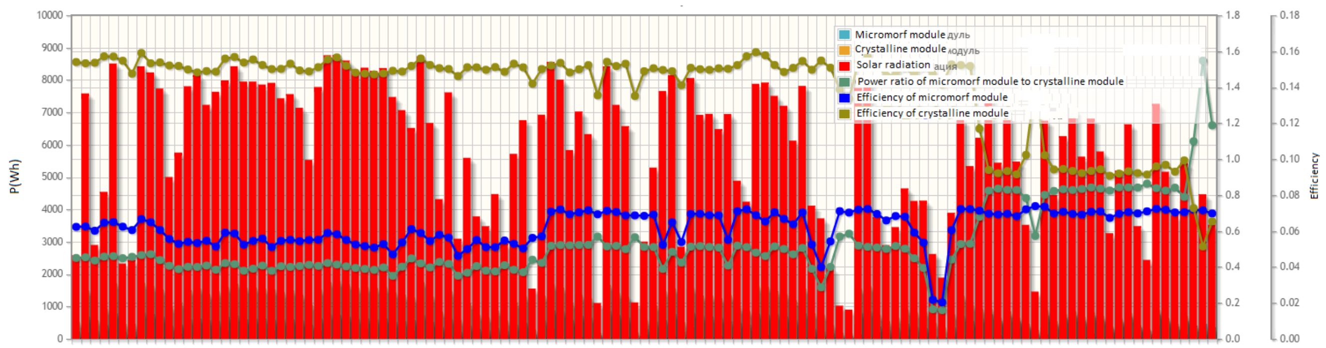

Fig 3. Graphic of energy production for 01.05.2014-31.08.2014

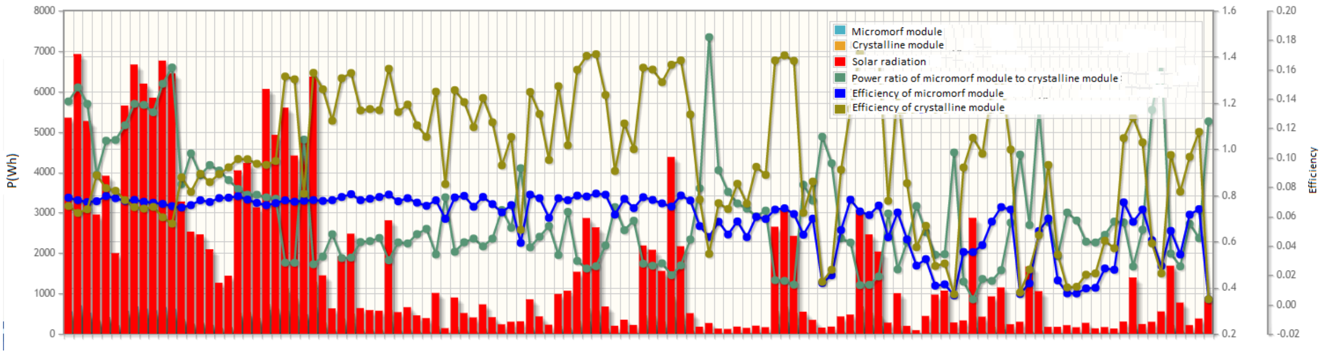

Fig 4. Graphic of energy production for 01.09.2014-31.12.2014

Table 1. Results of observation of PV panel without rotary mechanism for 2014. Efficiency

Weather data	
Number of days of monitoring during the reporting period	365
The environment average daily temperature (°C)	5.23
The environment average daytime temperature (°C)	6.42
Minimum ambient temperature (° C) during the reporting period	-34.38
Maximum ambient temperature (° C) during the reporting period	36.95
Average daily temperature of the rear surface of the PV Pramac (° C)	10.98
Average daily temperature of the rear surface of the PV TCM-210SB (° C)	10.7
The maximum wind speed for the period (m / s)	12.68

Electricity generation in the reporting period (unit value)	
Average daily solar radiation during the reporting period, kWh / m2	3.248
Average daily solar radiation during the reporting period on silicon (temp. Corr.) KWh / m2	3.247
Average daily solar radiation during the reporting period on silicon kWh / m2	2.996
Average daily energy output PEM Pramac during the reporting period, kWh	0.329
Average daily energy output PV TCM-210SB during the reporting period, kWh	0.598
Pramac Luce kWh/kWp, h	961.031
TCM-210SB kWh/kWp, h	978.002
The ratio of the average daily energy production FEM and FEM Pramac TCM-210SB	0.551
Solar energy conversion efficiency	
Rated power PV Pramac Luce, W	125
Rated solar energy conversion efficiency of the PV Pramac Luce,%	8.74
The average solar energy conversion efficiency of the PV Pramac Luce during the reporting period,%	7.09
Rated power PV TCM-210SB, W	223
Rated solar energy conversion efficiency of the PV TCM-210SB,%	17.34
The average solar energy conversion efficiency of the PV TCM-210SB for the period,%	14.31

From the data analysis of daily production for the year can be seen that the annual efficiency for micromorph module - 7.09% and for crystalline module - 14.31%. The average solar radiation was 3,248 kWh / m2, the average annual output for micromorph module - 0.329 kWh, for crystalline module - 0.598 kWh. The nominal efficiency for micromorph module- 8.74%, for crystalline module - 17.34%.

While the maximum effective use of rotary mechanisms maximum possible efficiency of PV will be nominal, whereas hourly output power at nominal efficiency study of SP will be:

$$\Delta W_{av(m)} = I \cdot S_m \cdot n_m = 3{,}248 \cdot 1{,}43 \cdot 0{,}0874 = 0{,}406 \text{ kWh} \quad (1)$$

$$\Delta W_{av(c)} = I \cdot S_c \cdot n_c = 3{,}248 \cdot 1{,}286 \cdot 0{,}1734 = 0{,}724 \text{ kWh} \quad (2)$$

where I –average daily solar radiation in kWh/m^2; S_m, S_c area of mircromorf and crystalline module respectively; n_m, n_c - efficiency of mircromorf and crystalline module 2gisrespectively

The yearly energy production of panels with rotary mechanism will be:

$$\Delta W_{y1(m)} = W_{av(m)} \cdot T = 0{,}406 \cdot 365 = 148{,}19 \text{ kWh} \quad (3)$$

$$\Delta W_{y1(c)} = W_{av(c)} \cdot T = 0{,}724 \cdot 365 = 264{,}26 \text{ kWh} \quad (4)$$

where T is number of days in year equal to 365.

The yearly energy production of panels without rotary mechanism will be:

$$\Delta W_{y2(m)} = W_{(m)} \cdot T = 0{,}329 \cdot 365 = 120{,}09 \; kWh \quad (5)$$

$$\Delta W_{y2(c)} = W_{(c)} \cdot T = 0{,}598 \cdot 365 = 45{,}99 \; kWh \quad (6)$$

where W_m, W_c- average daily production of energy of micromorf and crystalline module without rotary mechanism respectively.

Further, we estimate the difference of yearly energy production between PV with the use of rotary mechanisms and without them:

$$\Delta W_{y(m)} = W_{y1(m)} - W_{y2(m)} = 148,19 - 120,09 = 28,11\ kWh \quad (7)$$

$$\Delta W_{y(c)} = W_{y1(c)} - W_{y2(c)} = 264,26 - 218,27 = 45,99\ kWh \quad (8)$$

Then the annual effect of installing rotary mechanism will be:

$$\Delta_m = \frac{\Delta W_{m(c)}}{W_{m2(c)}} 100\% = \frac{45,99}{218,27} 100\% = 17,4\% \quad (9)$$

$$\Delta_c = \frac{\Delta W_{y(c)}}{W_{y2(c)}} 100\% = \frac{45,99}{218,27} 100\% = 17,4\% \quad (10)$$

With the use of rotary mechanisms, the production of electrical energy for micromorph modules is increasing by 23.4% and 17.4% for crystalline module.

Micromorph module with power 125 W can be purchased for $ 111.6 and the crystalline module with power of 225W for $ 235.94, average lifetime of photovoltaic panels about 25 years [8].

Let determine the cost of energy produced, depending on the payback period. Let take payback in 25 years.

Then, generated electricity for 25 years for panels without rotating mechanism is:

$$W_{\Sigma(C)} = W_{y(C)} \cdot t_p = 218,27 \cdot 25 = 5456,75 kWh \quad (11)$$

$$W_{\Sigma(m)} = W_{y(m)} \cdot t_p = 148,19 \cdot 25 = 3002,25 kWh \quad (12)$$

where $W_{y(m)}$, $W_{y(c)}$- average annual output micromorph and crystal panels respectively, t_p - payback period in years.

Then the cost of energy generated by the PV is founded as:

$$C_{(C)} = \frac{S_C}{W_{\Sigma(Crystalline)}} = \frac{235,97}{5456,75} = 0.043\$ / kWh \quad (13)$$

$$C_{(M)} = \frac{S_M}{W_{\Sigma(Micromorf)}} = \frac{111.6}{3002,25} = 0.037\$ / kWh \quad (14)$$

where S_m, S_c- cost of micromorph panel and crystal panel respectively.

Thus the cost of energy at a payback period of 25 years is $ 0.037 / kWh for crystalline module and $ 0.043 / kWh for micromorph module.

With rotary mechanism micromorph module with power 125 W can be purchased for $ 207.27 and crystalline with power 225 W for $ 331.63 [9]

Then the cost of produced energy is:

$$C_{(CR)} = \frac{S_\kappa}{W_{\Sigma(C)}} = \frac{331.63}{264,26 \cdot 25} = 0.05\$ / kWh \quad (15)$$

$$C_{(MR)} = \frac{S_M}{W_{\Sigma(m)}} = \frac{207.27}{148,19 \cdot 25} = 0.056\$ / kWh \quad (16)$$

From these considerations it can be concluded that the cost of electricity produced by PV with the use of rotary mechanisms is $ 0.056 / kWh for micromorph module and $ 0.05 / kWh for crystalline, and cost of electricity gained by PV without rotary mechanism cost of electricity is $ 0.043 / kWh for micromorph module and $ 0.037 / kWh for the crystalline.

5. Conclusion

In this study authors studied the efficiency of PV panels installed in Republic of Bashkortostan. For this study authors used the solar panels installed at the Department of Electromechanics of "Ufa State Aviation Technical University". The results based on monitoring the PV panels through the year. From an economic point of view results showed, that the use of rotary mechanisms not effective for PV installed in the Republic of Bashkortostan, because of high relative cost to unit of energy produced for PV with rotary mechanism and because it require more maintain service comparing to PV without rotary mechanism. However, from technical point of view the using of rotary mechanisms for PV increasing the efficiency for micromorph modules is by 23.4% and 17.4% for crystalline. Comparing to other studies made on this field and for other regions it much lower. For example, in [10 - 14] they have received theoretical result that rotary mechanisms can increase efficiency up to 40% in Europe, but we estimated the increasing of efficiency only up to 24%-25 %. From this results that adaptive mechanisms such as rotary mechanism in the Region of Bashkortostan can be used only to increase maximum output power of solar plant without increasing the area occupied by them.

The results obtained can be used in practice in the design and justification of the economic viability of PV in the Republic of Bashkortostan.

References

[1] Ismagilov F., Rianov L, Khairullin I, Vavilov V., A mathematical model of a three-axis electromechanical converter of oscillatory energy // Russian Electrical Engineering Volume 84, Issue 9, September 2013, Pages 528-532

[2] Baranov NN, Unconventional sources and methods of energy conversion. M. Publishing House "MEI", 2012.- 384 with.

[3] Vissarionov VI, Deriugina GV Kuznetsov VA, Malinin NK, Solar Energy. M. Publishing House "MEI", 2011.- 276 with.

[4] In Bashkortostan build solar power plants // Electronic resource URL: http://www.bashinform.ru/news/548726/ (date accessed 11/22/2014)

[5] Bezrukikh PP Wind power. (Reference and handbook). Moscow, ID "Energy", 2010.

[6] Miroslav Rimar, Marcel Fedak, Michal Hatala, and Peter Smeringai. “The Synergistic Effect of Thermal

Collectors Rotation in relation to Their Energy Efficiency and Stagnation Compared with the Static Thermal System in the Conditions of Central Europe". International Journal of Photoenergy.

[7] Ufa // Electronic resource URL: http://ru.wikipedia.org/wiki/%D0%A3%D1%84%D0%B0 (date accessed 11/22/2014)

[8] Ufa // Electronic resource URL: http://alt.rkraft.ru/solnechnye-batarei.html (date accessed 11/01/2015)

[9] Ufa // Electronic resource URL: http://energy-ds.ru/development/solnechnye-trekeri.html (date accessed 11/01/2015)

[10] Marchenko O.V., Solomin S.V. "Economic efficiency of renewable energy sources in autonomous energy systems in russia". International Journal of Renewable Energy Research 2014: 548-554.

[11] RETScreen International, Analyse de Projets d'Installation Photovoltaïque, Centre de Technologie et d'Énergie de CANMET Varennes (CTEC), Canada 2004.

[12] Camelia Stanciu, Dorin Stanciu. "Optimum tilt angle for flat plate collectors all over the World – A declination dependence formula and comparisons of three solar radiation models". Energy Conversion and Management Volume 81, May 2014, Pages 133–143.

[13] Camelia Stanciu, Dorin Stanciu. "Optimum tilt angle for flat plate collectors all over the World – A declination dependence formula and comparisons of three solar radiation models". Energy Conversion and Management, Volume 81, May 2014, Pages 133–143.

[14] M Sameti, Electrical energy efficient building through distributed generation, International Journal of Renewable Energy Research (IJRER), 2014, 4(3), 777-783.