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Review article

EXPERIMENTAL RESEARCH OF DOUBLE-SIDED SOLAR MODULES EFFICIENCY IN THE CLIMATIC CONDITIONS OF CENTRAL KAZAKHSTAN

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Abstract

The article presents studies of double-sided solar modules in Kazakhstan. To conduct an experimental research of double-sided solar modules efficiency in the climatic conditions of Central Kazakhstan we have created an experimental solar power plant (SPP) located on the territory of Karaganda State Technical University. The solar power plant consists of four photovoltaic modules of KZ PV 270 M72 type and four photovoltaic modules of FSM-185D type. The rotary system was not used; solar panels are southward (directed to the south). The comparison was made with the solar power plant without orientation system which uses four photovoltaic modules of KZ PV 270 M72 type produced by Astana Solar LLP.
The statistical analysis of information with an assessment of parameters of distribution and criteria for processing of results of scientific experiment is carried out. The correlation and regression analysis is performed. The least square method (coefficient calculation) is used in data processing. We have developed the computational model simulating the SPP by means of which the theoretical averaged values of energy amount generated in kWh/day have been obtained, and the actual values have been received by in-use measurements of SPP parameters within a year. The results of this work showed that the use of double-sided solar modules in Kazakhstan is very promising and can be a decisive factor for their widespread use with the tendency to lower prices.

Keywords: energy saving technologies, double-sided modules, solar power plant, Kazakhstan, solar modules, electric power.

1. Introduction

An important feature of the double-sided solar modules is the ability to generate the eclectic energy not only by the front side in contact with sunlight, but also the back side through absorbing residual, scattered and reflected sunlight that falls on the rear working surface of the panel. For almost 50 years the scientists

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energy of orbital space stations. Their efficiency was 20–30 % higher compared to single-sided modules, but the high cost did not make it possible to use them in terrestrial conditions [1–4]. Today the manufacturers from the USA, Canada, the European Union, Russia and Southeast Asia reduced their price to near the cost of single-sided panels. Now the difference is less than 50 % and some Chinese and Russian manufacturers almost equal the price with single-sided panels [5]. Yingli Solar YGE YL320PD-35b cell solar panel with capacity of 325 Watts is $240 USD produced by the Chinese manufacturer. There are similar solar modules in design produced in Russia but the pricing proposals for the same capacity are higher by 60 %, and the single-sided modules produced in this country are also more expensive than those produced in China.

The good example of the double-sided modules use for the electric energy generation is the project in the Japanese city of Asahikawa [6–9]. It is the coldest city in the country, it has the lowest temperature in the country — minus 41°C, while the thickness of the snow cover is about 70 cm, it is even more than the average value in Kazakhstan, and the snow melts longer than in other regions of the country. In general, the weather conditions are similar which allows us to take into account this experience in the present work. There is a similar problem associated with snow falling on the surface of the solar module; when it operates even in severe frost the temperature rises by 20–30 °C, thus providing for snow melting, but if the snow covers more than half of the area of the module, its surface cools down and it stops operating. In this case, the surface must be cleaned of snow. The cell solar panels are located at the height of 1.8–2 meters above the ground with an angle of inclination equal to 40° relative to the ground. The accumulated snow is removed with special equipment. In summer to heighten the effect of the panels the soil under them is covered with white material which increases the percentage of reflected sunlight. We have taken into account all these facts in our research [10–11].

2. Experimental procedure

Double-sided modules have one important advantage; they can be placed not at an angle of inclination to the sun with respect to geographical latitude, but vertically in relation to the earth at an angle of 90^0, in this case the dust and snow pollution of solar panels is considerably reduced [12–17]. After our research in winter conditions of Northern and Central Kazakhstan with a significant level of snowfall, these panels stay almost clean if they are located vertically and raised to a height of 0.7–1 meter. The average thickness of snow cover is 30 cm in Kazakhstan, but it can reach a height of more than a meter in places of snow accumulation and drifts in different years. The same effect is achieved with regard to the dust deposition on their surfaces. The presence of snow cover under the solar module can increase its efficiency by 1–2 % depending on its purity in the months of the year. In summer, the surface of the ground has been painted white from back side to improve the efficiency of sunlight reflection to the back side of the panel. If inclined double-sided panels work less efficiently on average up to 30 % according to the location of the surfaces of the sunlight reflection.

To conduct an experimental research of double-sided solar modules efficiency in the climatic conditions of Central Kazakhstan we have created an experimental solar power plant (SPP) located on the territory of the Karaganda State Technical University (KarSTU). The master students of educational program "Non-traditional and renewable energy sources" have been invited to carry out the research. The SPP is structurally divided into two independent parts and designed so that any solar modules can be tested by installing them to a metal frame. The observations have been carried out during 2017 without interruptions. Karaganda is located in Central Kazakhstan with strongly continental temperate climate with geographical location 49°48'N 73°07'E. For the experiments we have bought four monocrystalline solar modules with two-way sensitivity of FSM-185D type (produced by Russia). The main technical specifications are according to the manufacturer. The manufacturer guarantees the maintenance of 90 % of the nominal capacity – for 10 years, maintenance of 80 % of the nominal capacity – for 25 years. The efficiency of solar radiation conversion on the front side of such a photocell is several percent higher than on the back side and reaches a value of 19 %. The photocell efficiency from the back side is 14–15 %. The ground on the SPP back side is painted with light-reflecting white colour.

Table 1. Technical specifications of FSM-185D

Parameters	Front side of the module	Back side of the module
Capacity Pmax , W	186	102
Voltage in Max Power, V	34,0±2,5	
Max Power point current, A	5,47	2,48
Short-circuit current, A	5,6	2,65
Open-circuit voltage, V	43,8	
Switching voltage, V	24	
Overall dimensions, mm	1568×808×43	
Mass, kg	17,0	

Fig. 1. External view of SPP with FSM-185D double-sided modules

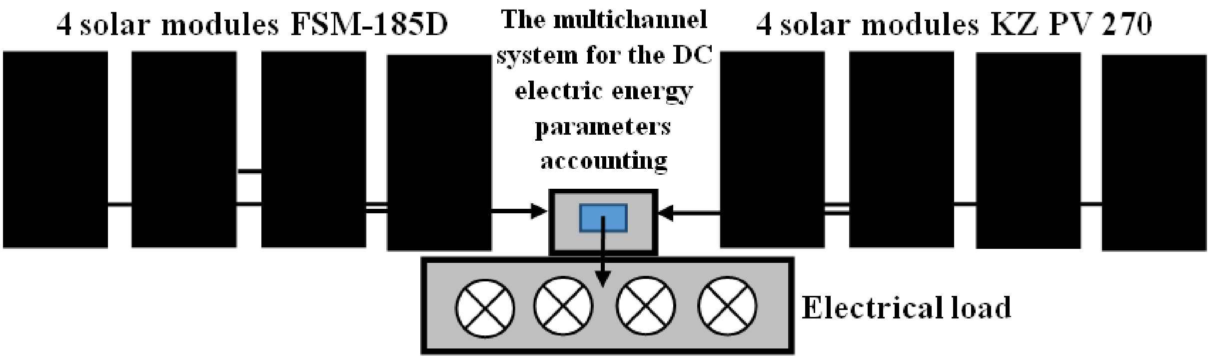


Fig. 2. Schematic diagram of the electrical connections of solar modules

The SPP consists of four photovoltaic modules of KZ PV 270 M72 type and four photovoltaic modules of FSM-185D type. The inclination angle is 50° with respect to ground and equal to the angle of the geographical latitude. The rotary system was not used; the solar panels are directed to the south. The fixed installation will allow evaluating the panel efficiency without a sun movement tracking system. FSM-185D modules are less in capacity than KZ PV 270 M72 ones by 1.45 times in comparison with the front side but double-sided panel is able to generate the electric energy using the back side.

The comparison is made with the solar power plant without orientation system which uses four photovoltaic modules of KZ PV 270 M72 type produced by Astana Solar LLP. The basic technical characteristics are as follows: installed capacity – 270 W; nominal voltage – 24V; ampere rating – 7.5 A; silicon wafer type – polycrystalline 6’ (156×156 mm), number – 6 columns of 12 cells; dimensions – 1.967×992×40 mm, acceptable deviation – 0/+5W; efficiency of 16 %.

The 24 V DC standard wire is used for the solar modules connection. To simulate the electrical load at the SPP the electric bulbs are used. The multichannel system for the DC electric energy parameters accounting is used. The SPP scheme has been simplified; it has no inverter, charge controller and batteries. The main purpose of the research is to assess the efficiency of two different types of modules.

3. The results and analysis

The obtained results are presented in Fig. 3–5. The statistical analysis of information with an assessment of parameters of distribution and criteria for processing of results of scientific experiment is carried out. The correlation and regression analysis is performed. The least square method (coefficient calculation) is used in data processing. The descriptive statistics and mathematical methods are performed with MS Excel spreadsheet. We have developed the computational model simulating the SPP by means of which the theoretical averaged values of energy amount generated in kWh/day have been obtained and the actual values have been received by the SPP practical parameter measurements within a year. It can be said that analyzing received values there is a difference in the data what is explained by imperfections in the mathematical model created by us in which it is difficult to consider a number of external factors influencing the production of electric energy [18–20]. These are such factors as, for example, the solar activity, pollution of cell solar panel, atmospheric transmittance, reflection of sunlight from the snow cover, the number of sunny days per year, etc. Too many factors influence the theoretical calculation, so we have performed calculations using the simplified model without taking into account these factors. According to the results of the 2017 year the block with four KZ PV 270 M72 solar modules has the amount of generated energy of SPP by 12 % more than FSM-185D ones, but it proves that double-sided solar panels can be effective in Kazakhstan environment (Fig. 5).

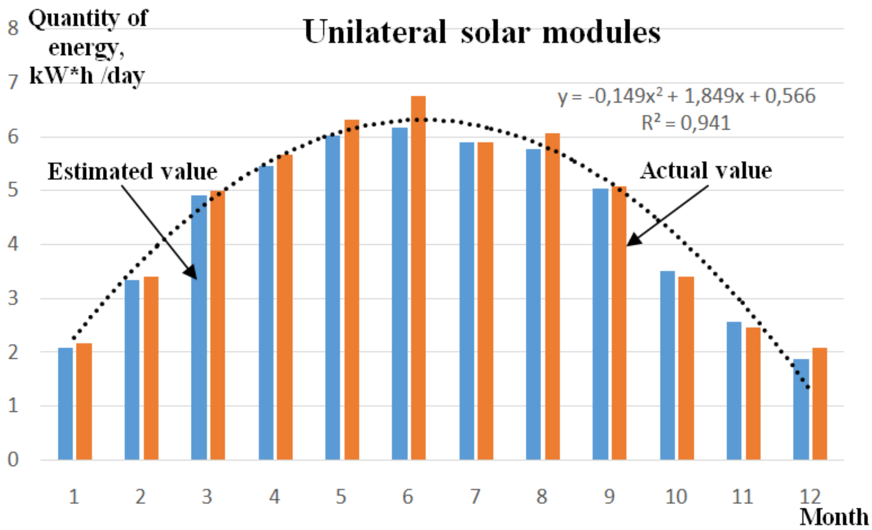


Fig. 3. Average value of kWh*h/day by month for four KZ PV 270 M72 solar modules

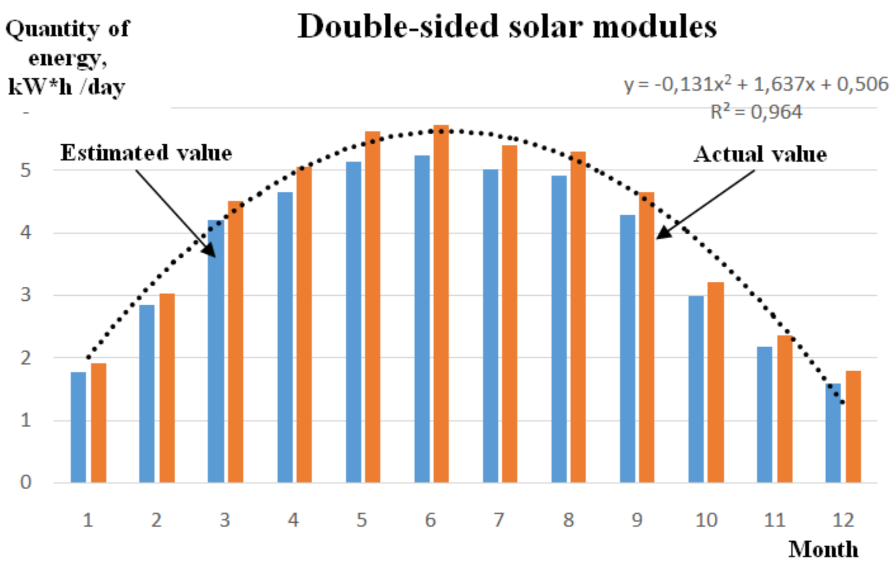
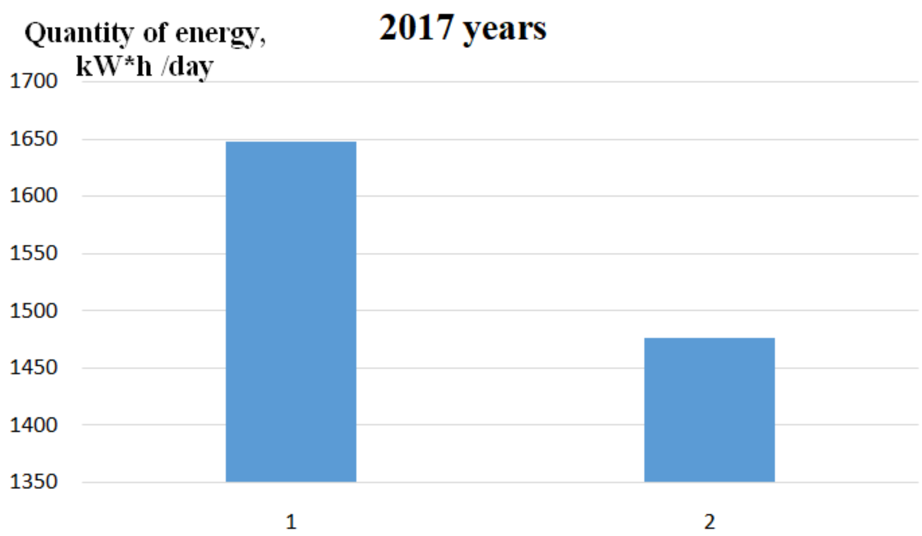


Fig. 4. Average value of kWh*h/day by month for FSM-185D four solar modules

FSM-185D solar modules have produced about 30 % more energy than single-sided panels with the capacity of 185W and they are able to compete with panels which exceed by 1.45 times their front side capacity. Our installation angle of 50° has provided an increase in capacity of about 30 % but on the basis of the preliminary research we can say that if the installation angle of 90° will be used, it may lead to the capacity increase of 50–60 %.



1 – KZ PV 270 M72; 2 – FSM-185D

Fig. 5. Amount of SPP energy produced in 2017 taking into account the segmentation into single- and double-sided parts

According to the results of research during 2017 it can be concluded that the used double-sided modules are better adapted to the conditions of Central Kazakhstan. There were more than 200 sunny days that year and it played a positive role in the total amount of energy produced. The temperature 25 °C is recommended by the manufacturer while their operation, so we have made the measurements of the surface temperature at the appropriate temperature surrounding the stands on a sunny day in April 2017, while the surface of the solar double-sided modules has been heated to 45 °C, and single-sided to 56 °C. According to the results of observations for 2017 the difference in surface heating temperature reached from 8 to 13 °C depending on the month of the year. The double-sided solar modules are less heated and better cooled which will allow them to maintain their performance within the range of 5–6 % as opposed to single-sided ones, and this is an additional percentage of the generated energy. Perhaps there is an error in the measurements made by Aktakom ATT-2533 touch-free temperature gauge, but the temperature difference is still obvious. We have established a dependency that an increase in temperature by 1 ºC from 25 ºC leads to a decrease in the capacity of the solar panel by about 0.5 %.

4. Conclusion

Thus, we may conclude that the use of double-sided solar modules in Kazakhstan is very promising and can be a decisive factor for their widespread application with the tendency to lower prices. The use of double-sided solar modules allows us to stop using the position control systems and reduce the cost for the metal structure of the base stand where the modules are placed. The double-sided modules are recommended for use at installation angles from 30-90º with the most favorable installation angle of 90º. It solves a number of problems with precipitation and accumulation of dust and snow on the module surface. The double-sided modules have been tested in the conditions of Central Kazakhstan and have shown the best performance of capacity from 1 m^2 of the module area and less heat which is also a positive factor.

Conflict of interest

The authors declare no conflict of interest.

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