Improving energy efficiency of solar panels

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Abstract. This article is about a photovoltaic power plant built at the Korean side's expense, equipped with Korean-made solar panels, and where the author conducted scientific and practical research. The study used a scientific-practical, observational, comparative measuring method. All solar panel trackers were set at 30^0 degrees and not equipped with a sun tracking system, except for only one solar panel. The tracker of the TOP SUN module has a manual tracking system for the Sun, in which a person has to manually changes position from 15^0 to 45^0 degrees depending on the seasons. Thanks to the authors, a solar tracker has been developed to improve the efficiency of solar panels, which has a sun tracking system and low energy consumption, which is a key aspect. During the day, the solar panel parameters with and without a tracking system for the Sun were obtained; also, their power was calculated, and for comparison, a graph of the power difference was plotted. On average, a solar panel with a solar tracking system generates 30 % more energy than a solar panel without a tracking system.

1 Introduction

It is known that the energy industry of Uzbekistan is mainly thermal power plants, which significantly harm the environment and ecology. In order not to exacerbate the problem, diversification of the energy system is required, where renewable energy sources will play a main role because, according to various estimates, by 2030, the share of such types of energy will be about 30-35% of the world's energy production, and it's realistic, because the exploitation of solar energy is very convenient. For example, with the help of solar panels, solar ovens, and solar collectors, we can get electricity and heat energy; using solar energy, it is possible to produce hydrogen, which is also necessary for decarbonization; from solar ovens for various purposes, it is possible to obtain high temperatures and also using solar air collectors it is possible to develop a conveyor device for drying various types of fruits and cocoons, which are used in the agro-textile industry and using solar radiation in polymeric materials we can determine their resistance, as well as test them for light fastness [1-6].

Solar energy can play a dominant role in our country's energy supply because the solar potential is estimated at 9000 billion kWh/year. However, despite this huge potential, the current state of the country's renewable energy industry is not in excellent conditions; there were some problems with the development of this industry, so considering this fact, legislative acts are adopted, for example, the Decree of the President of the Republic of

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Uzbekistan dated 22.08.2019 No. PP-4422 “On aacelerated measures to improve energy efficiency of economic sectors and the social sphere, the introduction of energy-saving technologies and the development of renewable energy sources”. According to this decree, by 2030, the share of renewable energy sources in total energy generation energy will be 25%, and this will be done through the construction of new plants, including hydroelectric power plants with a capacity of 1.9 GW and solar photovoltaic power plants with an installed capacity of 5 GW [7-8]. Already in our country, solar stations are being rapidly built, and solar panels are being installed on residential buildings; a vivid example on the roofs of educational buildings of the Tashkent State Technical University networked interactive solar panels were installed. Although hydropower is also resource-saving and environmentally friendly, more focus on solar energy despite the significant disadvantages of solar energy, such as the dependence of efficiency of the solar battery on the geometry of its surface and also all modules without exception regardless of the material manufacture mono or polycrystalline are subject to degradation. Because it is known that about 35% of households are located far from the centralized network and supplying them with energy is a rather complicated work, which is technological, so here solar energy may play a key role in supplying these consumers [9-18].

But, do not forget that, during the operation of solar photovoltaic stations and solar panels, various technical difficulties arise, such as the negative impact on the environment and reduced energy efficiency. Solving these problems requires a thorough study and analysis of their work. To improve the energy efficiency of photovoltaic solar stations and solar panels, scientists are conducting extensive work, for example, the dissertation work of Yarmukhametov U.R. “Solar power plants with a solar tracking system for the power supply of agricultural consumers”, where the subject of the study was the degree orientation of the receiving surface to the Sun on which the performance of these station depends. A scientific article Kitayeva V.M., Yurchenko A.V., Skorokhodov A.V., Okhorozina A.V. “Sun tracking systems” shows an example of the application of a single-axis and two-axis sun tracking system and the cost-effectiveness of their use is also proven. Also, in the article Mirzayev S.M., Parpiyev O.R. “Many years of operating experience of the Parkent 1000 kW Large Solar Furnace” states that the efficiency of this solar furnace depends on the solar tracking system [20-21].

So, our study aims to improve the energy efficiency of a solar panel by developing a solar tracker equipped with a solar tracking system with low energy consumption. The objectives of the study are to analyze the current state of the station and solar modules, monitor the station, observation of the course of the Sun on the territory of the station, measure the current electrophysical parameters, and compare them with the catalog data of solar panels and devise solar tracker, which equipped with a sun tracking system and a low energy consumption.

2 Methods

The author used a scientific-practical, observational, comparative, and measuring method in the research process. Developing a solar tracker with systems for tracking the Sun along the azimuth angle is a practical and main part of the study. The photovoltaic plant in which scientific research was carried out is located in the Namangan Republic of Uzbekistan. This test station is equipped with Korean-made solar panels, as it was built with grant funds from the Korean side. The station, the scheme of which is shown in Figure 1, consists of 8 rows, where 492 pieces of various solar panels are installed, and the parameters of these panels are shown in Table 1. Panels that have a power of 250 W are placed on stationary solar trackers, which are set to 30^0 degrees, and the largest power panel TOP SUN is installed on the tracker, which has a manual tracking system for the Sun. From Figure 1, it is not difficult to understand that the Sun falls on the surface of various panels depending on the row and place, from morning until about the beginning of noon (depending on the time of year), and when the Sun moves along the azimuthal angle its rays will partially fall, but some panels will not fall at all as a result of which it becomes impossible to get more energy.

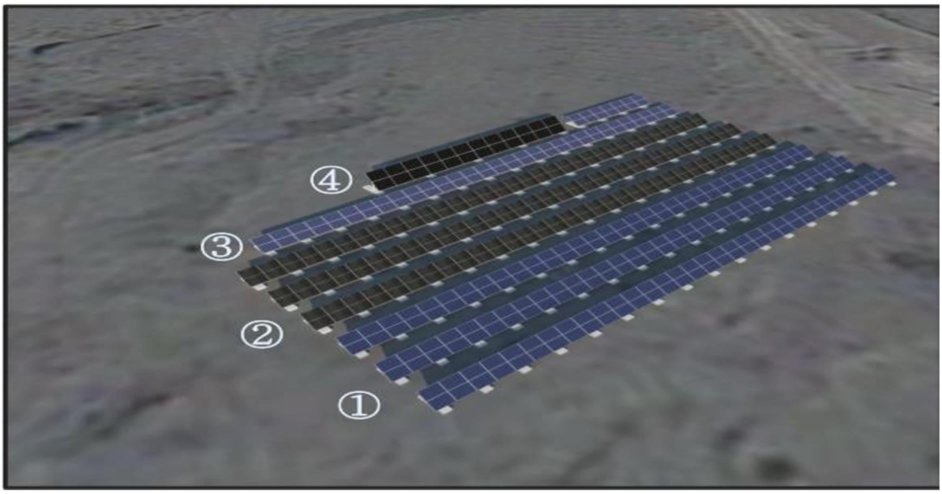

Fig. 1. General layout of photovoltaic plant.

Table 1. Main parameters of solar panels of under study photovoltaic power plant.

Model of solar panels	**Hanwha Hsl**	**Jspv Jsmm**	**S-Energy Sm**	**Top Sun Tp**
Rated power P, W	250	250	250	400
Voltage at Vpmax, V	30.4	30.9	30.8	49.39
Current at Ipmax, A	8.23	8.25	8.14	8.1
Short-circuit current Isc, A	8.79	8.8	8.67	8.7
Open-circuit voltage Uoc, V	37.7	38	37.5	60.55
Module efficiency n, %	15.5	15.5	15.03	15.6

The table was compiled by the author himself, where the data were taken in the photovoltaic plant itself during its study. The table shows that the TOP SUN solar panel has the highest efficiency, primarily due to its rated power and the efficiency of the other modules in the same, except for the S-ENERGY panel. It has an efficiency of almost 0.1 % less than the others, but this difference can be neglected. TOP SUN panels tracker is not automatic, single-axis, and has 4 positions. For example, the tilt angle of the first position is set to $15^{0,}$ and the tracker axis will move to this angle in the May, June, and July months, the angle of inclination of the second position is $25^{0,}$ and the axis of the tracker is attached to this point in April and August. The tilt angle of the third position is oriented at 35^{0}, to which the axis of the tracker moves in March and September, and finally, to the fourth position, the angle o which is 45^0, the axis of the tracker is adjusted in January, February, October, November, and December. Due to the lack of an automatic solar tracking system for all modules of the station, this process takes time, eventually generating less energy from solar panels and consequently decreasing the energy efficiency of the photovoltaic station. It is known that the short circuit current of the solar panel is directly proportional to the solar radiation power, and the ordinate of the maximum power point is almost directly proportional to the magnitude of the solar radiation power [21]. There is no energy storage system at the above photovoltaic power plant under study; that is, there are no batteries that can help cover peak loads; although they are expensive because this station is not autonomous, it is integrated with the general grid of the power system. So, it would be advisable to use a solar tracker with a tracking system for the Sun, which to a large extent, will generate more energy and reduce the payback period [22]. Therefore it is necessary to devise an automatic tracker equipped with a system for tracking the sun on two axes. After that, we authors decided to use a solar tracker for this photovoltaic power plant, which we devised ourselves. The general view of the proposed tracker is shown in the following figure.

Fig. 2. General view of proposed solar tracker.

As can be seen from the above figures, the solar tracker is not stationary but moveable, uniaxial, and has a sun tracking system. The frame of the tracker is made from a metal profile, which has several advantages. For example, it is not subject to corrosion, has a long service life, is resistant to moisture, is resistant to temperature extremes and other negative factors, is an affordable price, does not emit toxic substances into the environment, has a high bearing capacity, can maintain strength and rigidity for decades, due to ready-made holes for fasteners, flexibility, and low thickness, it is easy and quick to assemble a frame of various sizes from it and thanks to a wide range of sizes profile elements of any purpose and shape can be purchased. The solar panels were attached to the metal profile through a pivot joint, where pivot bearings were used, similar to the one shown below.

Fig. 3. General view of pivot bearings.

The pivot bearings were selected for our solar tracker because they have many advantages. For example, they can be used at high temperatures, have compact radial dimensions, they quiet operation, can be used in dusty environments, are vibration-resistant, shock-resistant, highly wear-resistant, and do not require regular maintenance and lubrication.

Fig. 4 a. General view of linear actuator.

The main mechanism of this device is a linear drive (or actuator) that will rotate the solar panel along the axis. The above figures show the general view of this linear drive and its parameters. The linear actuator model is BHTG-600-12-30, powered by a direct current (DC) source; it is low energy consumption, which is very acceptable for our solar tracker; its power consumption is quite low, that consumption voltage and current is 12 Volts and 5 Amps per hour respectively. The stroke of the actuator is 600 mm, which is quite sufficient to move the solar panel along the axis. The stroke speed is 30 mm per second, which is also normal for movement. In addition, the load capacity is 500 N, which proves to hold large-sized solar modules. It is impossible to get energy directly from the general network to power it, so a power supply unit (fig. 5) is used, which converts alternating current to direct current.

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Fig. 5. Power supply for actuator

Figure 4 shows the power supply that is used for a linear actuator, the model of which is ZH-J39-125; input parameters are alternating voltage 100-240 Volts and current 1.6 Amps, output parameters are voltage 12 Volts and direct current 5 Amps. These output parameters are acceptable for our actuator. The advantage of this power supply is its price; it is cheap, which contributes to not increasing the cost of the tracker; simplicity, comfort, and ease to use; and it can operate at a frequency of 50 Hz and 60 Hz.

3 Results and Discussion

The tables below show some parameters obtained by measurement, where T is time, E is solar flux density, I_{sc} is short circuit current, U_{oc} is open circuit voltage. In Table 2, these are the parameters of a solar panel that does not have a sun-tracking system; in Table 3 these are the parameters of a solar panel that is equipped with a sun-tracking system.

Table 2. Parameters solar panel without tracking system.

T, h	E, W/m^2	I_{sc}, A	U_{oc}, V
10:15	593	5.36	33.91
11:15	652	6.04	33.66
12:15	656	5.92	33.28
13:15	574	4.62	33.24
14:15	478	3.33	33.09
15:15	243	1.74	33.48
16:15	157	0.89	33.15

Table 3. Parameters solar panel with tracking system.

T, h	E, W/m^2	Isc, A	Uoc, V
10:15	629	5.24	53.5
11:15	657	5.48	53
12:15	653	5.46	53
13:15	464	4.03	52.57
14:15	372	2.66	53
15:15	280	1.93	53.5
16:15	82	0.7	52.03

For comparison, according to these parameters, the power generated by the solar panels for several hours was calculated, and a graph of the power difference was compiled, which is given below.

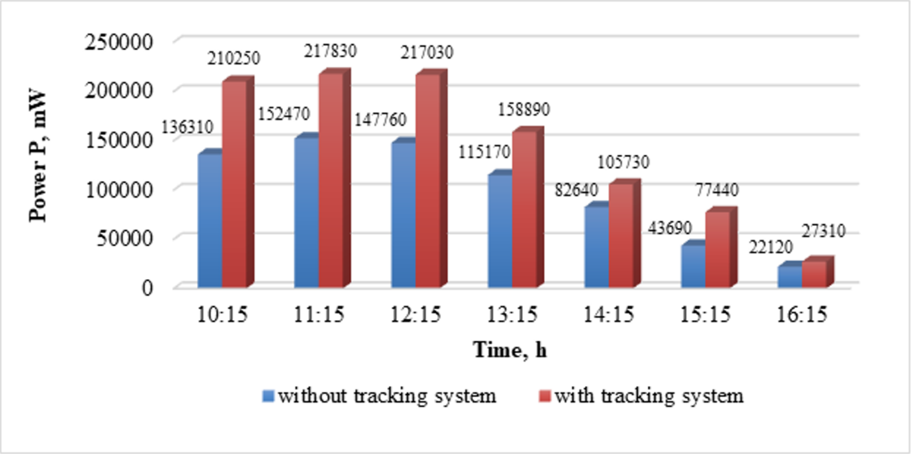

Fig. 6. Power difference graph

It is not difficult to understand from the graph that the solar panel, in which the tracker has a tracking system, generates much more energy. This suggests that to increase the efficiency of solar panels, it is necessary to equip their trackers with a sun tracking system since the tracker will direct the solar panel to the side where solar radiation is greatest, and the power, in turn, will increase since it directly depends on the value solar energy radiation power. For example, at 12:15, the generated power of the solar panel with a tracking system is 217.036 Watts, and the power of the solar panel without a tracking system is 147.760 Watts; if compared, it is almost 32 % less. At 10:15, the generated power of the module with the tracking system was 210.250 Watts; without the tracking system was 136.310 Watts, which is 35.1 % less. In general, for each hour, the generated power of a solar panel with a tracking system is always greater by 30 % than that generated by a solar panel without a tracking system.

4 Conclusions

And so, from the above, we can conclude the following conclusions:

1. Solar energy shortly will develop significantly in our country, as it is the most acceptable and has a huge potential. The Decree of the President of the Republic of Uzbekistan on renewable energy sources serves as an impetus for further introduction into our country.
2. The solar tracker developed by the authors, which has a sun tracking system, is quite applicable and suitable for the studied photovoltaic power plant since it has a simple structure, it is convenient, and, most importantly, low energy consumption, which is a key aspect.
3. At different hours of the day, the power of solar panels, which the tracker has a tracking system, is, on average, 30 % more than the power generated by the module in the tracker, which does not have a tracking system.
4. Therefore, to improve the energy efficiency of solar panels in the trackers on which they are installed, it is necessary to install a tracking system for the Sun, depending on their location.

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