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 300 degrees and not equipped with a sun tracking system, except for only one solar panel. The tracker of the TOPSUN module has a manual tracking system for the Sun, in which a person has to manually change position from 150 to 450 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

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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The photovoltaic plant is located in the Namangan region of Uzbekistan. The station, whose test station is equipped with Korean solar trackers, was built along the Parkent social sphere. The station, whose construction was made solar panels, as it was built and this will be done by 2030. The largest power panel TOP SUN is installed on the biggest domestic power plant 1000 kW Large Solar Furnace. The sharing of renewable energy sources in total energy generation energy is about 35%. Although hydropower is also resource technologies and the development of renewable energy sources. According to this decree, the share of renewable energy sources will be already 25% by 2030. From these data of the course of the research process are analyzed, the current state of the station, and compare the dependence of efficiency on which the performance of the solar tracking system depends. It has already been stated that the efficiency of this solar furnace depends on the dependence of the solar battery on the geometry of the receiving surface to the Sun. “Sun tracking systems” shows an example of the application of solar energy in supplying these consumers with grant funds and its surface. Although technological solutions of solar energy are subject to degradation, the efficiency of this solar furnace depends on the dependence of the solar battery on the geometry of the receiving surface to the Sun. “Sun tracking systems” shows an example of the application of solar energy in supplying these consumers with grant funds and its surface.

2 Methods

The author used a scientific article Kitayeva V.M., Yurchenko A.V., Skorokhodov A.V., Okhorozina A.V. “Many years of operating experience” Sun tracking systems” shows an example of the application of solar energy in supplying these consumers with grant funds and its surface.

The scheme of which is shown in the image 1, consists of 8 solar trackers equipped with a solar tracking system with a manual tracking azimuth angle is a practical and main part of the study. The off-station test station is equipped with Korean solar trackers which are being installed on stationary solar panels. The efficiency of various solar panels is compared during the operation of the station, where 492 pieces of various solar panels are installed, and the parameters of the different panels are shown in rows, where 492 pieces of various solar panels are installed, and the parameters of the different panels are shown in rows.
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.

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

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

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 panel's tracker is not automatic, single-axis, and has 4 positions. For example, the tilt angle of the first position is set to 15°, 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°, and the axis of the tracker is at this point in April and August. The tilt angle of the third position is oriented at 35°, to which the axis of the tracker moves in March and September, and finally, to the fourth...
position, the angle of which is 45°, 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...
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. 4a. 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 figure shows 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 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.
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, while 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, and $U_{OC}$ 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

<table>
<thead>
<tr>
<th>$T$, h</th>
<th>$E$, W/m²</th>
<th>$I_{SC}$, A</th>
<th>$U_{OC}$, V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15</td>
<td>593</td>
<td>5.36</td>
<td>33.91</td>
</tr>
<tr>
<td>11:15</td>
<td>652</td>
<td>6.04</td>
<td>33.66</td>
</tr>
<tr>
<td>12:15</td>
<td>656</td>
<td>5.92</td>
<td>33.28</td>
</tr>
<tr>
<td>13:15</td>
<td>574</td>
<td>4.62</td>
<td>33.24</td>
</tr>
<tr>
<td>14:15</td>
<td>478</td>
<td>3.33</td>
<td>33.09</td>
</tr>
<tr>
<td>15:15</td>
<td>243</td>
<td>1.74</td>
<td>33.48</td>
</tr>
<tr>
<td>16:15</td>
<td>157</td>
<td>0.89</td>
<td>33.15</td>
</tr>
</tbody>
</table>

### Table 3. Parameters solar panel with tracking system

<table>
<thead>
<tr>
<th>$T$, h</th>
<th>$E$, W/m²</th>
<th>$I_{SC}$, A</th>
<th>$U_{OC}$, V</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15</td>
<td>629</td>
<td>5.24</td>
<td>53.5</td>
</tr>
<tr>
<td>11:15</td>
<td>657</td>
<td>5.48</td>
<td>53.0</td>
</tr>
<tr>
<td>12:15</td>
<td>653</td>
<td>5.46</td>
<td>53.0</td>
</tr>
<tr>
<td>13:15</td>
<td>464</td>
<td>4.03</td>
<td>52.57</td>
</tr>
<tr>
<td>14:15</td>
<td>372</td>
<td>2.66</td>
<td>53.0</td>
</tr>
<tr>
<td>15:15</td>
<td>280</td>
<td>1.93</td>
<td>53.0</td>
</tr>
<tr>
<td>16:15</td>
<td>82</td>
<td>0.70</td>
<td>52.03</td>
</tr>
</tbody>
</table>
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.

4 Conclusions
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