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Optimizing solar energy utilization as an alternative power source for the Khorezm region

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Abstract. In this work, the power efficiency of solar photovoltaic cells, which are used as an alternative energy source, was studied using the "PVGis" program. It shows the possibilities of achieving the specified maximum power of the solar cell by determining the areas for the establishment of high-efficiency solar power plants and complying with the requirements for the installation of solar photovoltaic cells. Research through the application was conducted for 10 days in Khiva and Shavat districts of Khorezm region of the Republic of Uzbekistan. With the help of the program, every new day's information in these districts was calculated with high accuracy. The 10-day average power in Khiva district was 3.5 kW, and in Shavat district it was 3.2 kW. From our results, it can be seen that Khiva district showed higher energy efficiency of solar panels for building solar power plants than Shavat district.

INTRODUCTION

In recent times, the global demand for electricity has been steadily increasing. However, the depletion of non-renewable energy resources has created challenges in meeting this rising demand. The effective utilization of alternative energy sources has emerged as a critical solution to address these challenges. Solar energy, in particular, offers a highly promising alternative due to its environmental sustainability, safety, and efficiency. Semiconductor photoelectric converters, commonly known as photovoltaic cells or PV cells, represent one of the most efficient means of harnessing solar energy and converting it into electricity. To fully maximize the rated power output of photovoltaic cells, it is essential to adhere to precise installation guidelines [1–3].

Before the installation of PV cells, it is imperative to consider the geographical location of the installation area [4,5]. Daylight tracking mechanisms have also been developed to align the PV cells with the sun's movement throughout the day, allowing for optimal energy capture [6–8].

In recent years, the adoption of solar photovoltaic technology has gained significant traction in our Republic, serving as an effective means to fulfill the growing energy demands. However, challenges persist, particularly in the context of illuminating residential streets and sidewalks. Regrettably, established guidelines for the installation of solar panels are not consistently followed in these scenarios.

This oversight results in suboptimal charging of solar-powered lighting systems during daylight hours, leading to insufficient illumination during nighttime. As a consequence, the objective of providing well-lit neighborhoods remains unmet. Failing to account for the geographic location when installing solar panels further inhibits the full utilization of photovoltaic cells.

EXPERIMENTAL RESEARCH

In this work, the main parameters of solar photovoltaic cells used as an alternative energy source were researched through the "Photovoltaic Geographical Information System (PVGIS) Solar Forecast" program, and in order to

establish high-efficiency solar power plants, Khorezm Region determined the areas and followed the requirements for installing solar photovoltaic cells. the possibilities of increasing efficiency are shown.

The monthly or seasonal values of the optimal angle of azimuth in the installation, which affects the power efficiency of the solar panel, were calculated using the equation analytically calculated by Nizhegorodov. It is known that in the construction of independent power supply systems, if solar light energy is used, the first step is to select a solar panel. The main technical characteristics of the selected solar panel are the following: power, current, type of solar cells, temperature coefficient and dimensions. In addition, it is necessary to pay attention to the performance parameters in different conditions. The power of the solar panel, for example 1650x992mm, can vary from 250 to 370 watts. In our country, silicon mono- and polycrystalline solar panels (Fig. 1) enjoy extensive utilization. The efficiency of these solar panels is subject to variations contingent on their manufacturer and the type of photovoltaic cells employed. Presently, solar panel efficiency typically ranges from 15% to 22%.

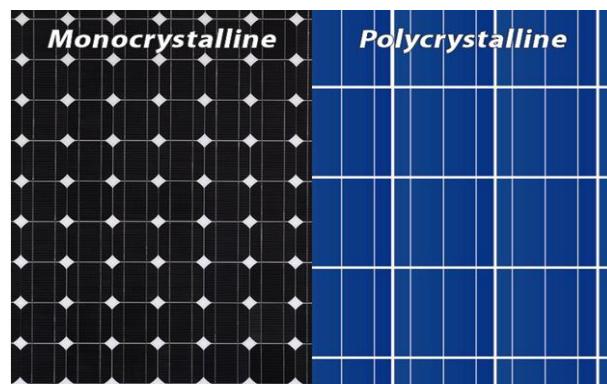


FIGURE 1. Monocrystalline and polycrystalline silicon solar panels

The dimensions of the panel depend on its power(W). For example, the Risen solar cell with a power of 280 W has the following dimensions: 1650x992x35 mm, weight 18 kg. Altek portable battery with a power of 10 W weighs only 1.4 kg, the size is 290x350x25 mm. In addition, open circuit voltage and short circuit current must be taken into account. This information will help you make the optimal selection of all components of a stand-alone solar power plant for safe connection and use. The power of the solar panel can be different, it depends primarily on the quality of the photocells, light and ambient temperature. For example, in cloudy weather, in fog, in strong dust, the voltage decreases. The efficiency of solar panels is highly dependent on the angle at which the panel is positioned relative to the horizon (Figure 2).

The solar cell should be directed towards the sun, so that the maximum flow of sunlight falls on the solar panel. We know that the sun moves along the equator, so if we are in the northern hemisphere, we need to point the front of the battery towards the south. If we are in the southern hemisphere - it is necessary to direct to the north.

In accordance with the optimal solar panel placement angle, latitude of the year and season, battery performance is guaranteed to be maintained for 10 years up to 90% of the initial parameters. The influence of the orientation of the solar panel on its efficiency was calculated by the specialists of "Thermo technology" company. The results are presented in Table 1 below. From the results, we can see that if the solar panel is installed at an angle of 35^0 to the horizon to the south, the efficiency reaches 100%. In the table, directions with high efficiency are marked with a green area.

Many studies have been conducted by scientists on the optimal tilt angle in width [9-26]. In particular, the monthly or seasonal values of the azimuth optimal angle for solar panel installation were analytically calculated by Nizhegorodov. Equations developed by Nizhegorodov are presented in Table 2.



FIGURE 2. Angles of placement of solar panels a) in space b) in the plane.

From this we can see that the change in the culmination angle of the sun in each lunar season causes the distribution of the light energy falling on the earth's surface to change.

TABLE 1. The influence of the orientation of the solar panel on its efficiency

The direction	Efficiency of a solar photovoltaic cell of 1 kW												
	East	South-eastern					South	South-west				West	
Horizon angle	90°	105°	120°	135°	150°	165°	180°	195°	210°	225°	240°	255°	270°
15°	86,2	88,8	91,1	93,1	94,5	95,4	95,6	95,3	94,3	92,9	91,0	88,6	86,0
20°	85,5	88,9	91,8	94,3	96,1	97,3	97,6	97,2	96,0	94,1	91,6	88,7	85,3
25°	84,7	88,7	92,2	95,2	97,3	98,5	98,9	98,5	97,2	94,9	92,0	88,4	84,4
30°	83,7	88,4	92,2	95,6	97,9	99,4	99,8	99,3	97,7	95,3	92,0	88,0	83,4
35°	82,6	87,5	91,9	95,5	98,1	99,5	100,0	99,4	97,8	95,2	91,7	87,2	82,3
40°	81,1	86,6	91,2	94,9	97,6	99,2	99,7	99,1	97,4	94,7	90,9	86,3	80,8
45°	79,6	85,2	90,1	93,9	96,7	98,2	98,7	98,1	96,4	93,6	89,7	84,8	79,2
50°	77,6	83,6	88,6	92,5	95,2	96,8	97,2	96,6	95,0	92,2	88,2	83,2	77,4
55°	75,6	81,6	86,7	90,5	93,2	94,7	95,2	94,6	93,0	90,2	86,3	81,2	75,2
60°	73,3	79,3	84,3	88,2	90,8	92,2	92,5	92,0	90,5	87,9	83,9	78,9	72,9

TABLE 2. Equations developed by Nizhegorodov

Month	Culmination angle
January	$\beta_{opt.}(m) = 0.9901F + 24.631$
February	$\beta_{opt.}(m) = 0.6613F + 26.283$
March	$\beta_{opt.}(m) = 1.2657F - 8.6368$
April	$\beta_{opt.}(m) = 0.89F - 11.878$
May	$\beta_{opt.}(m) = 0.381F - 9.3689$
June	$\beta_{opt.}(m) = 0.0235F - 2.9196$
July	$\beta_{opt.}(m) = 0.138F - 4.2233$
August	$\beta_{opt.}(m) = 0.3931F - 0.4064$
September	$\beta_{opt.}(m) = 0.1767F + 23.08$
October	$\beta_{opt.}(m) = 0.6592F + 23.08$
November	$\beta_{opt.}(m) = 0.9975F + 23.192$
December	$\beta_{opt.}(m) = 0.9236F + 29.184$

RESEARCH RESULTS

Numerous modeling programs currently exist to predict the characteristics of solar photovoltaic cells in advance. Among these, the widely recognized qualitative modeling program is "PVgis". This program has been developed as an Android application called "PV Solar Forecast" for smartphones, operating directly over the Internet. When specifying the state, city, or district, it provides information about the angle, azimuth, latitude, air temperature, pressure, wind speed, humidity, and several other parameters relevant to the installation of solar photovoltaic cells. Furthermore, it offers air temperature predictions for up to a week. The program facilitates the calculation of daily

data with a high degree of accuracy, enabling the monitoring of operational processes, efficiency, and economic benefits of photovoltaic cells.

We installed the "PV Solar Forecast" application on a smartphone and conducted our observations in the Khorezm region, encompassing Shavat and Khiva districts Fig.3. We closely monitored the power output of the solar photovoltaic cell, with a maximum power rating of $P=8.5$ kW, from October 1st to October 10th. In this scenario, key constant parameters for Shavat district included a latitude of 41.65° , an azimuth facing south at 180° , a horizon angle of 350° , and a selected panel power of 8.5 kW. Likewise, constant parameters for Khiva district were a latitude of 41.38° , an azimuth oriented south at 180° , a horizon angle of 350° , and a panel power of 8.5 kW.

The 10-day average values of variable key parameters for Shavat district were 768 mm.Hg for pressure, 10°C for temperature, and 3.9 m/s for wind speed. Conversely, in Khiva district, the 10-day average values were 767 mm.Hg for pressure, 12°C for temperature, and 3.7 m/s for wind speed. Over this period, the sunrise time on the first day was 7:28 am, and on the last day, it was 7:39 am. The sunset times were 5:59 pm on the first day and 5:48 pm on the last day.

When analyzing the graph illustrating the change in electric current power produced over time, it becomes evident that the photovoltaic cell reaches its maximum power output when the sun reaches its zenith at midday. On October 4th and October 10th, the power output of the solar panel was notably lower due to cloudy weather and lower temperatures. Notably, on October 3rd, the solar panel operated at full capacity, generating 8.52 kW of electricity in the middle of the day in Khiva district, benefitting from clear, cloudless, and dust-free conditions.

Comparing our observations, the 10-day average power output in Khiva district measured 3.5 kW, while in Shavat district, it amounted to 3.2 kW. These results indicate that Khiva district demonstrated higher energy efficiency for solar panels, making it a more favorable location for constructing solar power plants in comparison to Shavat district.

Equations Nizhegorodov developed the seasonal values of the optimal angle of azimuth for installation of solar panels in Khiva and Shavat districts during 10 days of October:

$$\beta_{\text{opt.}}(m) = 0.6592F + 23.08$$

calculated using the equation. (Table 3)

TABLE 3. Seasonal values of the optimal angle of azimuth for installation of solar panels in Khiva and Shavat districts during 10 days of October

Days	Shavat district		Khiva district	
	F	$\beta_{\text{opt.}}(m)$	F	$\beta_{\text{opt.}}(m)$
1 October	22	37,5824	31	43,5152
2 October	21	36,9232	29	42,1968
3 October	22	37,5824	28	41,5376
4 October	25	39,56	30	42,856
5 October	23	38,2416	31	43,5152
6 October	20	36,264	28	41,5376
7 October	22	37,5824	26	40,2192
8 October	22	37,5824	27	40,8784
9 October	24	38,9008	27	40,8784
10 October	22	37,5824	23	38,2416

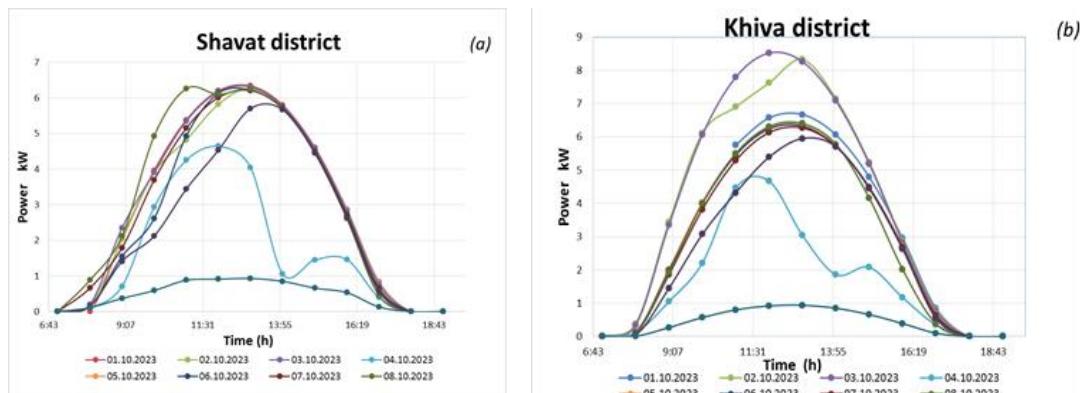


FIGURE 3. Variation of the power of a solar photovoltaic cell with a maximum power of $P=8.5$ kW over time.

CONCLUSIONS

In conclusion, the Pvgis program, tailored for the prediction of key parameters in solar photovoltaic cells when utilizing solar energy as an alternative electricity source, offers valuable capabilities. By utilizing the program to pre-calculate the parameters of solar photovoltaic cells that are best suited for each region within our country, we can effectively identify ideal locations for constructing highly efficient solar power plants equipped with solar panels. Our study focused on assessing the impact of geographical locations within the Khiva and Shavat districts of the Khorezm region on the efficiency of solar panel systems. Our findings confirm that Khiva district boasts a favorable positioning for the development of a solar power station incorporating solar panels.

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