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RESEARCH ON THE FEASIBILITY OF UTILIZING SOLAR PHOTOVOLTAIC STATIONS IN PUMPING STATIONS

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ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ИСПОЛЬЗОВАНИЯ СОЛНЕЧНЫХ ФОТОВОЛЬТАИЧЕСКИХ СТАНЦИЙ В НАСОСНЫХ СТАНЦИЯХ

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ABSTRACT

The possibility of using solar photovoltaic stations in pumping stations was investigated in the article. Scientific principles of designing a photovoltaic station, which can satisfy the energy demand of the consumer based on the example of a pumping station consuming 50 kW of energy per day, were presented. A consumer using 50 kW of energy per day consumes an average of 18,396,000 W of electrical energy per year. The presented photovoltaic station produces an average of 18,679,000 W of electrical energy per year. 283 kW of unused energy is supplied to the grid. Meeting the energy demand has a positive impact on the Republic's energy system. The demand for non-renewable energy resources decreases. Environmental damage is mitigated.

АННОТАЦИЯ

В статье исследуется возможность использования солнечных фотоэлектрических станций в насосных станциях. На примере насосной станции, потребляющей ежедневно 50 кВт энергии, представлены научные основы проектирования фотоэлектрической станции, способной удовлетворить потребности в энергии. Потребитель, использующий 50 кВт энергии в день, расходует в год в среднем 18 396 000 Вт электрической энергии. Предлагаемая фотоэлектрическая станция производит в год в среднем 18 679 000 Вт электрической энергии. 283 кВт избыточной энергии поступает в сеть. Удовлетворение потребностей в энергии само по себе оказывает положительное воздействие на энергетическую систему Республики. Снижается потребность в нерегулируемых источниках энергии. Вред окружающей среды сокращается.

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Keywords: pump, renewable energy sources, solar energy, photovoltaic station, design, PVsyst.
Ключевые слова: насос, возобновляемые источники энергии, солнечная энергия, фотоэлектрическая станция, проектирование, PVsyst.

Introduction

Since the beginning of the 19th century up to the present day, the primary sources of energy have been non-renewable resources such as oil, gas, uranium, and hydrocarbons. Until now, these resources have accounted for about 90% of the energy sector. Various gases and harmful substances emitted by conventional power plants have significantly impacted the surrounding environment. This impact has led to the acceleration of phenomena such as Arctic and Antarctic melting, and global warming. Initially, one of the main energy sources, oil and gas, has become a significant issue at both national and global political levels, resulting in sharp fluctuations in oil and gas prices. The new era demands new sources of clean and affordable electricity. Renewable energy sources, particularly solar energy, are now in demand. According to the predictions of world scientists, by the year 2100, solar energy will become the dominant source of energy for humanity. For Uzbekistan, solar energy also holds significant potential as an alternative energy source. Our country experiences nearly 300 sunny days per year. The total solar potential in our country is estimated at 51 billion tons of oil equivalent. Solar energy can be utilized for various purposes, including electricity generation, hot water supply, and heating. In order to improve the energy system of the Republic of Uzbekistan, a transition to purposeful use of "Green Energy" with a total capacity of 4,300 MW is envisaged. This includes 2,100 MW - large solar and wind power plants, 1,200 MW - public facilities, industrial facilities with solar panels installed on buildings and structures, and 550 MW - small solar power plants operated by entrepreneurs. Additionally, a 100 MW solar photovoltaic station was built in the Karmana district of Navoi province, which has contributed to an increase in the country's energy security. According to the Ministry of Energy, by 2026, the installed capacity of solar and wind power plants in Uzbekistan is expected to reach 8,000 MW, and hydroelectric power plants - 2,920 MW (a total of 10,920 MW). The issue of resource sustainability in the context of energy and water scarcity is becoming increasingly relevant in the Republic. The issue of energy efficiency is also becoming central to energy production.

In our country, social infrastructure facilities, factories, and manufacturing plants are closely related to the primary electricity consumption of water supply systems. All pump stations in the Republic operate in parallel with the local grid. The increasing load on the natural grid and the extensive use of electrical energy by highly-demanding consumers naturally lead to an increase in the load on the network. Integrating solar energy into the electricity consumed by pump station buildings can reduce the local grid load, decrease the consumption of non-renewable resources in thermal power plants, and reduce CO_2 emissions into the atmosphere. Particularly, the gradual transition to electricity consumption in water supply systems has been planned year by year. For the period from January to September of the past year, a total of 5,879.9 million kWh of electricity was allocated, of which 5,732.07 million kWh was actually consumed, showing an increase of 206.8 million kWh compared to the same period in 2021. The use of photovoltaic stations to meet the electricity demand of pump installations is expected to significantly contribute to the aforementioned changes [2,3,7].

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Theoretical Part And Methods

The theoretical foundations for designing a photovoltaic station to meet the demand for required electrical energy have been developed. The stages of the design process are outlined in Figure 1 below. Based on the demand analysis, a 10 kW photovoltaic station design has been proposed.

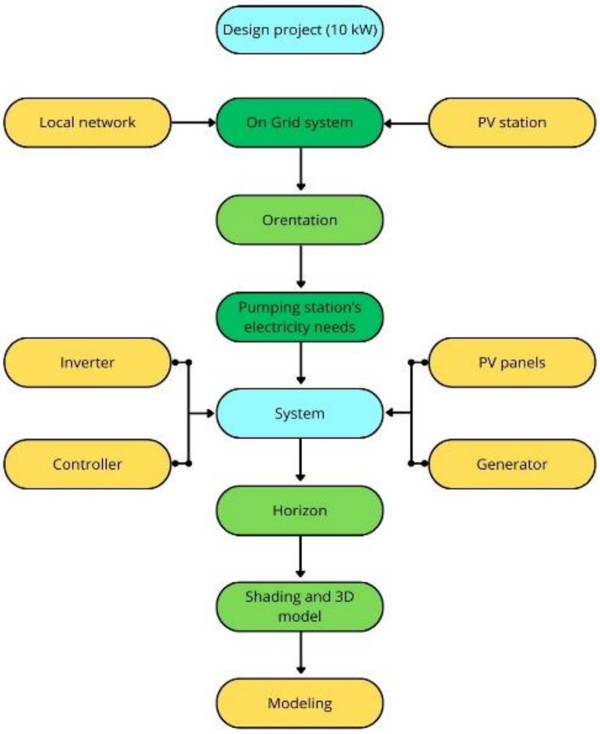

Figure 1. Algorithm for PV Station Design

On-grid photovoltaic (PV) systems are known to operate in parallel connection with the local grid. Proper orientation of the reception area is of significant importance in the design of a photovoltaic station. The amount of energy produced by photovoltaic panels is directly proportional to the angle of inclination relative to the installed surface. The angle of incidence of solar rays varies with the season. The orientation of the photovoltaic panel surface is determined once per year according to the angle of inclination, and it is defined by the following formula:

$$\beta_0 = \varphi - \delta_0 \ (1)$$

Here, φ represents the geographic latitude of the area, and δ_o is the solar declination angle for the given month. Solar irradiation is determined according to the Couper formula by the following expression:

$$\delta = 23.45 \sin\left(360 \ \frac{284+n}{365}\right) \ (2)$$

(2) According to the formula, for the winter season in Tashkent city (with a geographic latitude of 41°15'5"52), the optimal tilt angle would be as follows:

$$\beta_0 = 41° - (-20.7°) = 61.7°$$

In this order, the optimal tilt angle for the summer season would be calculated as follows:

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$$\cos\delta = \frac{\cos(23.5°) + \cos(18.5°)}{2} = 21.1°$$
$$\beta_0 = 41° - 21.1° = 19.9°$$

According to the seasons, the optimal tilt angle for installing photovoltaic panels relative to horizontal varies as follows: 62° in winter, 41° in spring and autumn, and 20° in summer. For Tashkent city, it is recommended to install fixed structures within the range of 38° to 44°. The efficiency of solar panels depends on radiation. At standard test conditions (W_o= 1000 W/m^2, T = 25°C, AM = 1.5), panels produce maximum electrical energy. Radiation intensity or temperature rise affects the electrical energy produced by photovoltaic panels. An increase in temperature leads to a decrease in the efficiency of photovoltaic cells, thus affecting the production of electrical energy [1,4].

To calculate the required energy for meeting demands according to working hours, it is determined as follows:

$$Q_c = (Q_t \cdot n) \cdot h \quad (3)$$

here h is the working time of the consumer, n is the number of consumers

Since the project envisages the design of a photoelectric plant producing 10 kW/h of electricity, the working time of consumers is not taken into account. Taking into account the non-normality of radiation and temperature, which are considered necessary factors for the operation of a photoelectric plant, the required photovoltaic stations power is calculated as follows:

$$Q_{PVS} = Q_c \cdot k \quad (4)$$

here k = 1.2

The required power is calculated by the following formula according to the active time interval [5,6].

$$Q_{a,h} = \frac{Qc \cdot k}{t} \quad (5)$$

According to (3):

$$Q_c = (7000 \cdot 2) \cdot 3 = 42\ 000 \text{ W}$$

According to (4), the required power of the photovoltaic plant is:

$$Q_{PVS} = 42\ 000 \cdot 1.2 = 50\ 400 \text{ W}$$

According to (5) for the required active power interval:

$$Q_{a,h} = \frac{42000 * 1.2}{5} = 10\ 080 \text{ W·h}$$

$$10\ 080 \text{ W} \approx 10 \text{ kW}$$

A 10 kW capacity photovoltaic system was designed using the PVsyst software.

THE RESULTS OBTAINED AND THE TASKS PERFORMED ARE AS FOLLOWS

The schematic diagram of the photovoltaic system is presented in Figure 2. To set up the photovoltaic system, 24 photovoltaic panels with a power output of 440 W each were utilized.

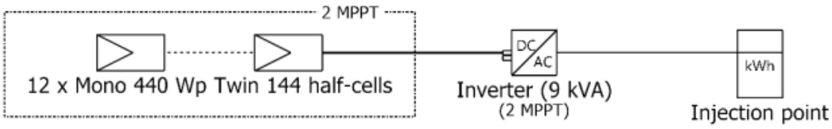

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Figure 2 shows the electrical schematic of the 10 kW station.
According to Figure 2, the 12 panels are connected in series and parallel to each other.

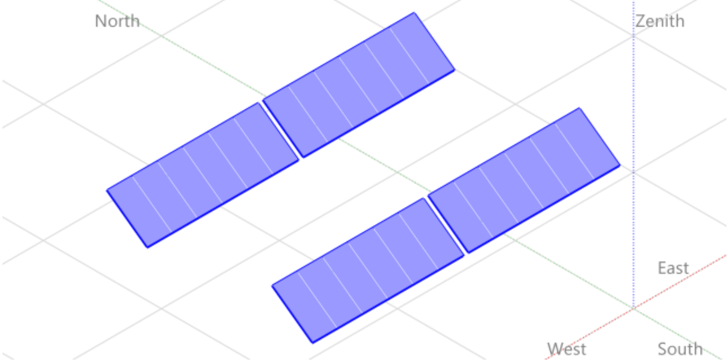

Figure 3 shows the 3D model of the 10 kW station.

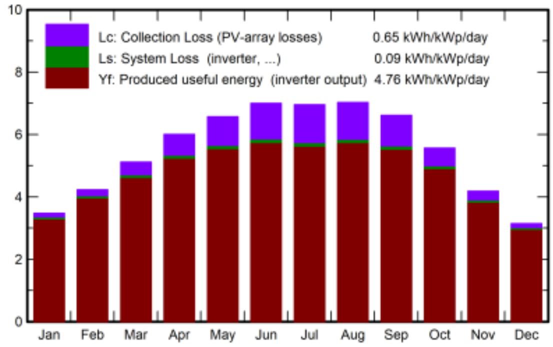

Figure 4 Normalized productions (per installed kWp)

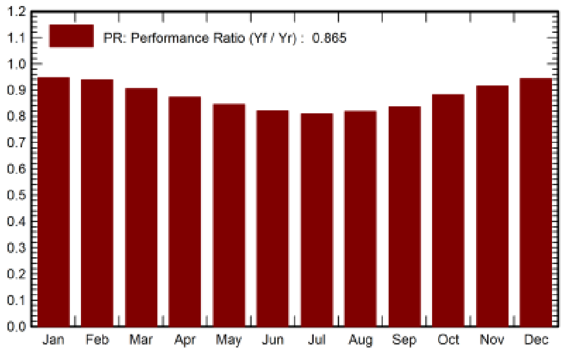

Figure 5 Performance Ratio PR

	GlobHor kWh/m^2	DiffHor kWh/m^2	T_Amb °C	GlobInc kWh/m^2	GlobEff kWh/m^2	EArray kWh	E_Grid kWh	PR ratio
January	58.0	22.63	-2.43	107.9	105.2	1099	1079	0.947
February	75.6	28.56	-1.09	118.5	116.1	1196	1174	0.938
March	121.8	44.02	4.19	158.6	154.6	1543	1515	0.905
April	161.1	53.40	11.61	180.3	175.4	1693	1661	0.873
May	206.2	62.00	17.45	203.6	197.5	1851	1816	0.845
June	226.2	58.50	23.43	210.2	203.5	1856	1820	0.820
July	226.9	57.97	25.45	215.8	208.9	1880	1843	0.809
August	204.9	48.67	24.15	217.9	211.9	1915	1880	0.817
September	158.7	37.80	18.38	198.6	193.5	1785	1752	0.836
October	114.1	30.38	10.70	172.5	168.8	1636	1607	0.882
November	69.6	22.80	4.77	125.5	122.7	1236	1214	0.916
December	50.5	20.15	-0.30	97.4	95.3	988	969	0.942
Year	1673.6	486.88	11.43	2006.7	1953.4	18679	18330	0.865

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

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Figure 6 Balances and main results

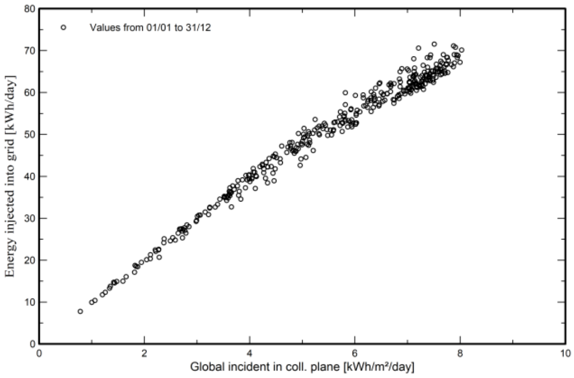

Figure 7 Daily Input/Output diagram

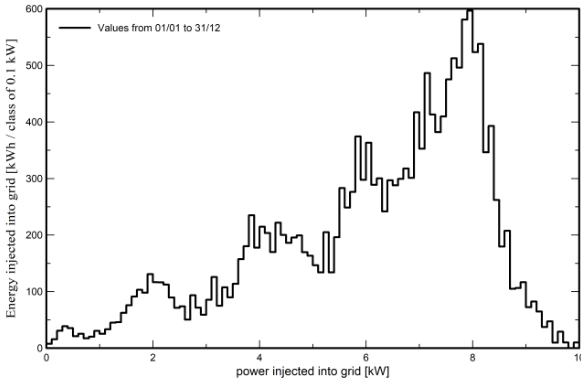

Figure 8 System Output Power Distribution

Conculusion

The majority of water supply and irrigation facilities operate connected to the local electrical grid. Peak operating hours influence the demand for electricity by consumers during specific times. Generating electricity puts high pressure on stations and centers. Utilizing solar panels as a renewable energy source to meet the energy demand of pump stations affects the system for meeting energy needs. The photovoltaic system transmits the same amount of energy as used by consumers. A consumer who uses 50 kW of energy consumes an average of 18,396,000 W of electrical energy annually. The provided photovoltaic system generates an average of 18,679,000 W of electrical energy annually. The excess 283 kW of unused energy is transmitted to the grid. Changes in consumer operating hours, differences in energy consumption, and variations in radiation affect these results. Initial findings indicate that a 10 kW photovoltaic system adequately meets consumer needs.

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