Analysis of the efficiency of a 300kw solar photovoltaic system in the climate of uzbekistan

[1]Raxmatov Ilhom Ismatovich, [2]Samiev Kamoliddin A'zamovich, [3]Juraev Khusniddin Oltinboyevich, [4]Mirzaev Mirfayz Salimovich

[1]*Associate Professor of the Department of Heliophysics, Renewable Energy Sources, Candidate of Technical Sciences, Bukhara State University., Uzbekistan*
[2]*Professor of Physics Department, Doctor of Technical Sciences, Bukhara State University., Uzbekistan*
[3]Doctor of Pedagogical Sciences, Professor, Dean of Physics and Mathematics faculty *Bukhara State University., Uzbekistan*
[4]*Associate Professor of the Department of Heliophysics, Renewable Energy Sources, Doctor of Philosophy in Technical Sciences, Bukhara State University., Uzbekistan*

Abstract. In this research work, the efficiency of a 300 kW grid-connected solar photovoltaic system was analyzed over a year under the climatic conditions of different regions of Uzbekistan. It has been established that the maximum power value that a 300 kW solar photovoltaic installation can produce per year is 0.477 MW, and the minimum is 0.452 MW. Taking into account regional climatic conditions, it was determined that the shortest payback period for photovoltaic systems from generated electricity is 8.6 years, and the shortest is 9 years. It is estimated that between 90.4 and 95.5 tons of CO2 gases could be prevented in the region by 300 kW solar photovoltaic systems.

Key words: solar radiation, temperature, energy, solar panels, inverter, climate indicators, levelized cost of energy.

1.Introduction.

When analyzing the number of articles devoted to the study of photovoltaic systems from 2010 to 2023 in the scientific electronic database (sciencedirect.com), it can be seen that 315 articles were published in 2010, and 4134 articles were published until November 2023. . This shows the increase in demand for energy over the years and the need to use renewable energy devices, as well as the relevance of research in this field [1].show the fig 1.

[1] i.i.raxmatov@buxdu.uz
[2] ksamiev@buxdu.uz
[3] h.o.juraev@buxdu.uz
[4] m.s.mirzayev@buxdu.uz

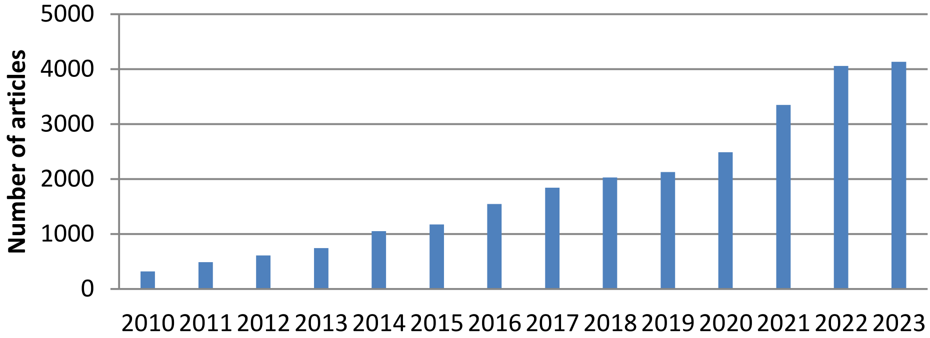

Fig.1. Number of articles devoted to the research of photovoltaic systems in sciencedirect.com scientific electronic database.

In Table №1 presents the results of studies on photoelectric systems with similar and different climatic conditions, and the parameters describing the characteristics of the considered system are compared. In research, the efficiency of CIS, p-si, JKM250PP-60, ND-235E1H type solar panels was studied, in which it can be seen that the efficiency of the CIS panel was 19.6% [2;3]. In the study by Abdulhameed Babatunde Owolabi et al. 2022, the efficiency of the inverter given in the studied articles was 96.4%, and the efficiency of the system was 14.5% [4].

Table №1

General characteristics of studied photovoltaic systems

№	The location of the study	Time of research	Types of PV	Panel efficiency (%)	Inverter efficiency (%)	System efficiency (%)	Literature
1.	Thailand	2012	p-si	11.2	93	10.41	Chimtavee and Ketjoy (2012)
2.	Turkey	2013	p-si	9.54	-	-	Eke and Demircan (2013)
3.	India	2014	p-si	11.07	-	10.52	Tripathi et al. (2014)
			a-si	6.56	-	6.06	
4.	Lesotho	2015	p-si	10.93	87.75	9.58	Mpholo et al. (2015)
5.	India	2016	p-si	13.71	-	-	Shravanth Vasisht et al. (2016)
6.	Ghana	2017	HIT	-	-	-	Quansah et al. (Akhter et al., 2020)
			m-si	-	-	-	
			p-si	-	-	-	
			a-si	-	-	-	
			CIS	-	-	-	
7.	Japan	2018	p-si 1	10.8	89.1	-	Tahir et al. (Quansah et al., 2017)
			p-si 2	9.5	89.2	-	
			CIS	10.1	85.1	-	
			CIS	9.3	85.3	-	

8.	Malaysia	2019	a-si	9.34	94.14	8.8	Akhter et al. (Akhter et al., 2020)
			p-si	12.7	93	11.33	
			m-si	7.3	93.1	6.8	
9.	South Korea	2022	m-si	15.04	96.4	14.51	Abdulhameed Babatunde Owolabi et al. (2022)
			p-si	13.32	96.16	13.26	
10.	Tamil Nadu, Southern India	2019	p-si	17.99	-	-	P. Ramanan et al. (2022)
			CIS	19.57	-	-	
11.	Jazoir	2020	ND-235E1H	12.1	96	9.7	S. Bouacha et al. (2020)
12.	Bamako	2023	JAM60S09-320/PR	-	-	-	Bakamba dite Djénéba Sacko et al. (2023)
13.	Kenya	2023	JKM250PP-60	15.27	-	-	Emmanuel Ayora et al. (2023)

Description of solar photovoltaic system. A 300 kW solar photovoltaic system is connected to one transformer. The photovoltaic system consists of 546 solar panels, each of which has a power of 550 W and covers an area of 3554.1 m^2. In addition, 6 solar inverters with a total capacity of 300 kW are used. Solar inverters coordinate the voltage, current and power of the panels using solar optimizers connected to the modules.

Technical characteristics. The investigated solar photovoltaic cells consist of 550 W Ipvisola monocrystalline cells. Its technical characteristics are presented in [5].

Data collection and monitoring. The ambient temperature and solar radiation required for this study were obtained from the NASA-SSE database. The location coordinates of the regional centers of Uzbekistan served as boundary conditions for obtaining accurate NASA data on ambient temperature and solar radiation. The solar inverters are considered to be connected to a local network that transmits data to a gateway that transmits data to the servers of the solar energy monitoring system. This information is provided remotely through the Ipvisola online portal in real time. Electricity efficiency data is stored in the solar monitoring portal on an hourly, daily, monthly or yearly basis. The monitoring unit provides real-time financial and technical data on the operation of the solar power plant.

Performance analysis. The properties of a grid-connected solar photovoltaic system were analyzed using the 1998 IEC 61724 standard (International Electrotechnical Commission, 1998) [6,7]. The performance indicators presented in this standard are very important to evaluate the performance of photovoltaic systems and to determine the losses shown by the systems [8]. The evaluated parameters are the performance factor, power output, system collection losses, final power and power utilization factor.

Energy output model of photovoltaic device. The annual energy production of a solar photovoltaic power plant is calculated as follows

$$E_{PV} = P_{r,pv} D_f P_{sh} N_d \qquad (1)$$

where E_{PV}- the output power of the photovoltaic device is kW·h, $P_{r,pv}$- nominal power of the photovoltaic device kW, D_f - overall reduction factor, P_{sh}- average daily maximum solar hour, N_d- the number of days in a period, such as a year.

The coefficient of reduction of the nominal characteristics is calculated by modeling the actual temperature of the element as follows [7-9]:

$$T_C = T_a + \left(\frac{T_{NOCT} - 20°C}{S_{NOCT}}\right) \cdot S_s \quad (2)$$

where T_C- the actual operating temperature of the cell, °C, T_a- ambient temperature, °C, T_{NOCT}- normal operating temperature of the cell, °C, S_s- intensity of solar radiation, kW/m^2 da, S_{NOCT}- intensity of solar radiation under standard test conditions (STC) kW/m^2.

The amount of reduction in maximum power due to the effect of temperature is calculated as a percentage,

$$P_{red} = \alpha(T_C - 25°C) \quad (3)$$

where P_{red}- percentage reduction in maximum output power; α- represents the decrease in maximum output power due to each °C %/°C change in cell temperature.

Therefore, the coefficient of reduction of the nominal characteristics due to the temperature change of the module is calculated as follows

$$D_{temp} = 1 - P_{red} \quad (4)$$

Taking into account the derating factor of the nominal characteristic due to the aforementioned system components, D_{sys}, the total derating factor of the nominal characteristic can be described as

$$D_f = D_{temp} D_{sys} \quad (5)$$

The power factor of the photovoltaic device is determined using equation (6).

$$Capacity\ factor = \frac{E_{PV}}{P_{r,pv} \cdot 8760} \quad (6)$$

Economic analysis. The cost of a 300 kW solar photovoltaic device is $293,396.14. In November 2023, the exchange rate is 1 US dollar = 12270.1 Uzbek som [9]. Thus, the total cost of this project was about 3 600 000 000 Uzbek soms. Payback period and LCOE were used to calculate and analyze economic indicators during the study. The comparative price of energy is determined as follows:

$$LCOE = \frac{CRF * C_1 + C_{O\ \&M}}{E_A} \quad \frac{cost}{kWh} \quad (7)$$

where C_1- investment capital; $C_{O\ \&M}$ - annual operating and maintenance costs; E_A- annual electricity production; CRF - a permanent annuity at the present value of receiving that annuity over a period of time.

$$CRF(i,n) = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (8)$$

The payback period is defined as the time required for the cash flows of the project to cover the investment capital costs [11; 12]. The reimbursement period is determined as follows:

$$SPP = \frac{IC_0}{CF_1} \quad (9)$$

where IC_0 is the value of invested capital; CF_1 is the project's annual cash flow.

The advantage of solar photovoltaic systems is that they do not emit greenhouse gases (GHG) during their entire operation [13]. In 2019-2020, the average emission coefficient for solar PV systems in Uzbekistan was 0.4087 tons of CO_2/kW·h [14]. The grid emission factor usually calculates the amount of carbon dioxide that can be avoided by generating electricity using solar photovoltaic systems. Using this network emission coefficient, the reduction of greenhouse gas emissions into the atmosphere is calculated according to the following formula

$$(CO_2)_a = 0.4087 \cdot E_A \quad (10)$$

where E_A - energy produced during the specified period.

2.Results and comments.

Ambient temperature and solar radiation data were obtained from NASA-ESS.

Fig. 2 shows the indicators of the power that a 300 kW solar power plant can produce for a year in a cross-section of regions. These indicators were calculated using formula 1. Looking at regions, the highest production of electricity during the year was observed in Termiz, and the lowest in Tashkent and Gulistan.[11-15] A solar power plant with a capacity of 300 kW for a year is 0.477 MW in Termiz, and 0.452 MW in Tashkent and Gulistan.

.

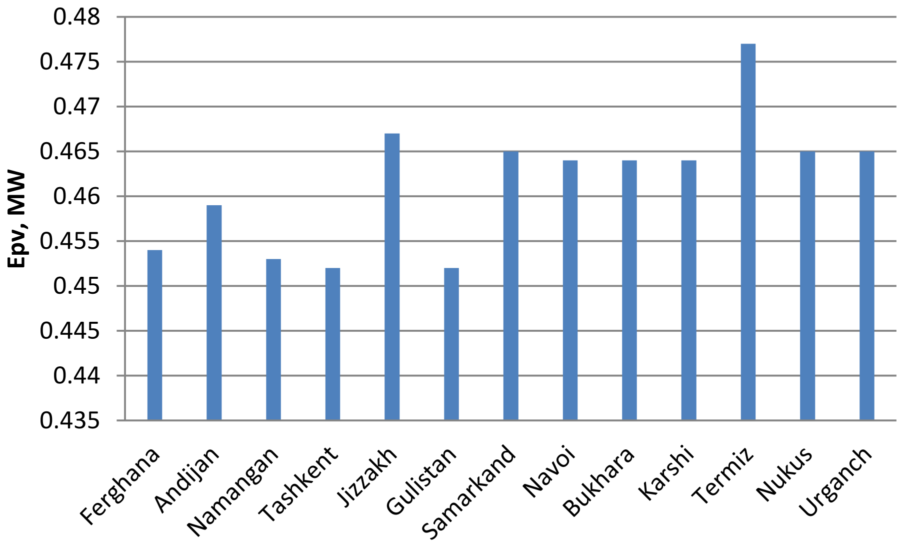

Figure 2. Produced energy.

Economic calculations are made by the energy consumption method based on equation (1). According to calculations, the change in the price of energy as a result of the change in the discount rate is shown in Fig.3. Accordingly, when the discount rate increases from 2 percent to 14 percent, the quoted energy price changes from $0.014 to $0.099[15-18].

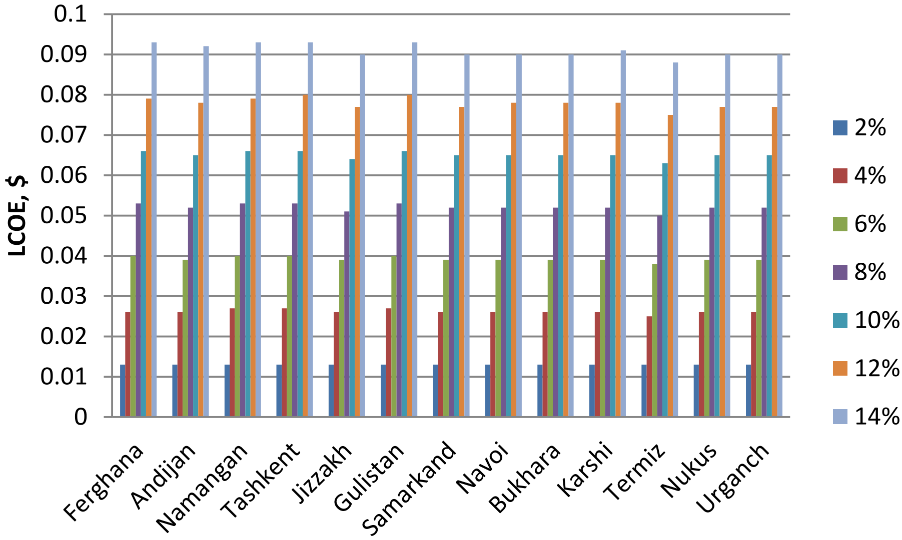

Fig. 3. Dependence of current value of electricity on discount rates.

The payback periods of solar photovoltaic systems with a capacity of 300 kW in different regions of Uzbekistan are presented in Fig. 4. In the section of regions, the region with the shortest payback period is 8.6 years in Termiz, and the payback period is regions in Tashkent and Gulistan are 9 years.

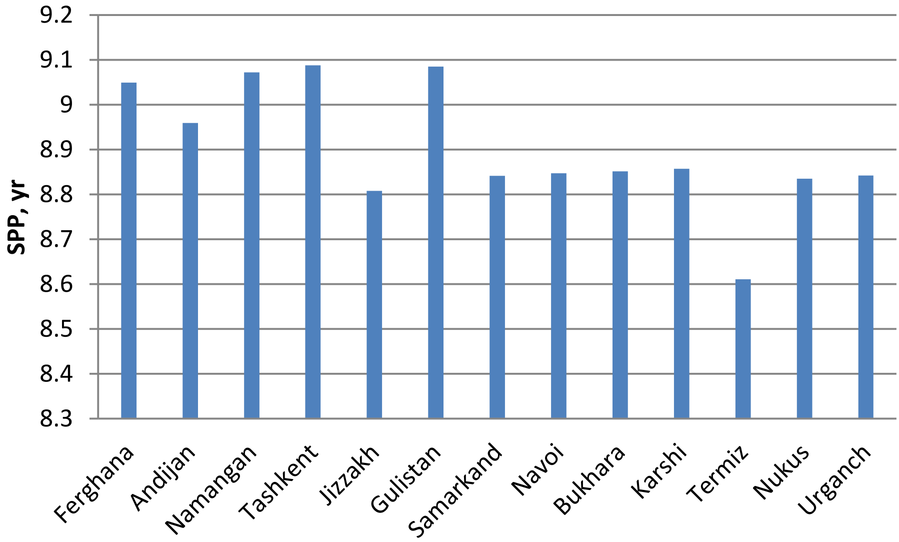

Fig. 4. Coverage period of solar photovoltaic systems in different regions of Uzbekistan

Reduction of CO_2 emissions in different regions of Uzbekistan for one year at the expense of solar photovoltaic systems with a capacity of 300 kW is shown in figure 5 in units of tons in the section of regions. Formula 10 was used in calculations. Calculations show that when using 300 kW solar photovoltaic systems in the regions, CO_2 emissions can be reduced by 95.5 tons in Termiz, 90.4 tons in Tashkent, and 90.5 tons in Gulistan.

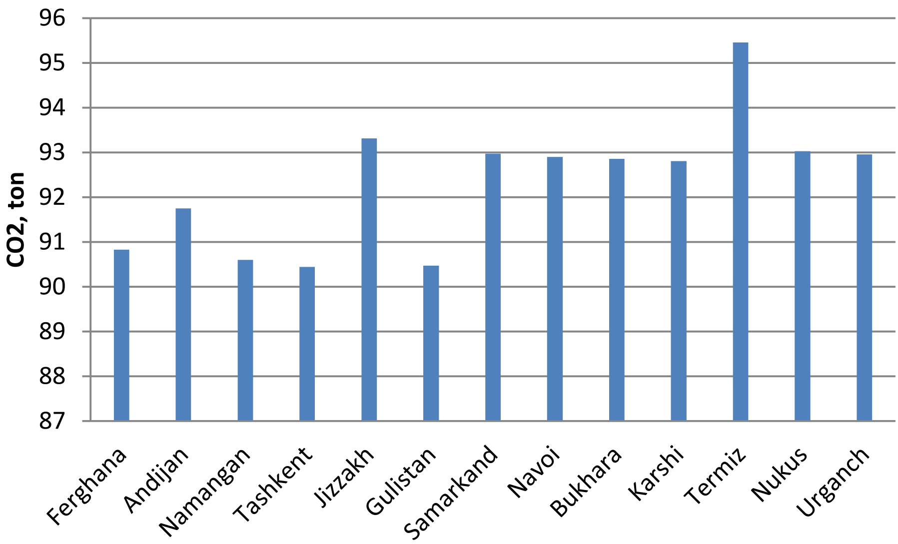

Fig. 5. Reducing CO2 emissions in different regions of Uzbekistan

4.Conclusions.

The effectiveness of the solar photovoltaic system connected to the network with a capacity of 300 kW in the climatic conditions of different regions of Uzbekistan was analyzed throughout the year. The power indicators that can be produced by a solar power plant with a capacity of 300 kW for one year were calculated, and it was stated that the annual maximum value of the produced electric current power was 0.477 MW, and the minimum value was 0.452 MW. According to calculations, the shortest self-payback period of photoelectric systems based on the climate conditions of the area and the generated electricity is 8.6 years, and the longest is 9 years. It was calculated that CO_2 emissions could be prevented from 90.4 to 95.5 tons of CO_2 gases in the region due to solar photovoltaic systems with a capacity of 300 kW.

5.References

1. https://www.sciencedirect.com
2. Owolabi A. B., YakubA.O., Li H. X., Suh D. Performance evaluation of two grid-connected solar photovoltaic systems under temperate climatic conditions in South Korea. Energy Reports 8 (2022) 12227–12236.
3. Ramanan P., Murugavel K.K., Karthick A. Performance analysis and energy metrics of grid-connected photovoltaic systems. Energy for Sustainable Development 52 (2019) 104-115.
4. Raxmatov I. I., Samiyev K. A., Mirzayev M.S. Analysis of the efficiency of 300 kw grid-connected solar photovoltaic systems at Bukhara State University. AIP Conference Proceedings. 2023.

5. Google Earth. https://earth.google.com/web/@39.76184365,64.42172368,223.0598182a,296.08497798d,35y,359.99995618h,0t,0r/data=OgMKATA, 2023.
6. International Electrotechnical Commission, Photovoltaic System Performance Monitoring Guidelines for Measurement, Data Exchange and Analysis, IEC, 1998, 61724.
7. Ayora E., Munji M., Kaberere K., Thomas B. Performance analysis of 600 kWp grid-tied rooftop solar photovoltaic systems at strathmore university in Kenya Results in Engineering 19 (2023) 101302
8. Sathiracheewin S., Sripadungtham P., Kamuang S. Performance analysis of grid-connected PV rooftop, at sakon nakhon province, Thailand, Adv. Sci. Technol. Eng. Syst. J. 5 (4) (2020) 816–823.
9. Ayora E., Munji M., Kaberere K., Thomas B. Performance analysis of 600 kWp grid-tied rooftop solar photovoltaic systems at strathmore university in Kenya. Results in Engineering 19 (2023) 101302.
10. https://bank.uz/uz/currency/archive
11. Kerboua A., Hacene F.B., Goosen M.F., Ribeiro L.F. Development of technical economic analysis for optimal sizing of a hybrid power system: a case study of an industrial site in Tlemcen Algeria, Results in Engineering 16 (2022), 100675.
12. Qadourah J.A. Energy and economic potential for photovoltaic systems installed on the rooftop of apartment buildings in Jordan, Results in Engineering 16 (2022), 100642.
13. Peyvandi M., Hajinezhad A., Moosavian S.F. Investigating the intensity of GHG emissions from electricity production in Iran using renewable sources, Results in Engineering 17 (2023), 100819.
14. www.volker-quaschning.de
15. Menglikulov, B., Umarov, S., Safarov, A., Zhyemuratov, T., Alieva, N., & Durmanov, A. (2023). Ways to increase the efficiency of transport logistics-communication services in Uzbekistan. In E3S Web of Conferences (Vol. 389, p. 05036). EDP Sciences. https://doi.org/10.1051/e3sconf/202338905036
16. Narinbaeva, G., Menglikulov, B., Siddikov, Z., Bustonov, K., & Davlatov, S. (2021). Application of innovative technologies in agriculture of Uzbekistan. In E3S Web of Conferences (Vol. 284, p. 02009). EDP Sciences. https://doi.org/10.1051/e3sconf/202128402009
17. Menglikulov, B., Dusmuratov, R., & Mamadiyorov, D. (2021). Improvement of methodological aspects to calculate the cost of dairy products: a review. In E3S Web of Conferences (Vol. 258, p. 04036). EDP Sciences. https://doi.org/10.1051/e3sconf/202125804036
18. Uralovich, K. S., Toshmamatovich, T. U., Kubayevich, K. F., Sapaev, I., Saylaubaevna, S. S., Beknazarova, Z., Khurramov, A. (2023). 'A primary factor in sustainable development and environmental sustainability is environmental education', Caspian Journal of Environmental Sciences, 21(4), pp. 965-975. doi: 10.22124/cjes.2023.7155