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ANALYSIS OF THE ENERGY INDICATORS OF THE 70 kW PHOTOELECTRIC STATION CONNECTED TO THE ELECTRIC NETWORK

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Abstract. *In the article, the one-year monitoring results of the 70kW on-grid solar station (SS) in the city of Termez, located in the southernmost part of Uzbekistan, are presented. Annual, monthly and daily energy production graphs were analyzed and it was determined that the annual energy production amount is 62.77MWh. Through calculations, the values of the installed coefficient utilization factor (ICUF) were calculated for the solar station and its annual and monthly average values were found. Even though the average ICUF is 10.32%, the on-grid solar station can be considered a promising project. The biggest factor causing system energy losses is pollution, which is related to the climate of the region. The main factor in the sharp difference in the results is the stationarity of our station and the fact that the technique of cleaning the panel's surface from pollination was not used. However, the payback period of such a station by calculation included 7.5 years if inflation is not taken into account.*

Keywords: *on-grid system, solar station, installed coefficient utilization factor, yield energy, renewable energy, efficiency, pollution.*

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ELEKTR TARMOG‘IGA ULANGAN 70 kW QUVVATLI FOTOELEKTRIK STANSIYANING ENERGETIK KO‘RSATKICHLARI TAHLILI

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Annotatsiya. *Maqolada O‘zbekistonning eng janubiy qismida joylashgan Termiz shahridagi 70 kW quvvatga ega quyosh stansiyasining (QS) bir yillik monitoring natijalari keltirilgan. Yillik, oylik va kunlik energiya ishlab chiqarish grafiklari tahlil qilindi va yillik energiya ishlab chiqarish miqdori 62,77 MWh ekanligi aniqlandi. Quyosh stansiyasi uchun belgilangan quvvatdan foydalanish koeffitsiyenti (BQFK) qiymatlari hisoblab chiqildi va uning yillik va oylik o‘rtacha qiymatlari topildi. O‘rtacha BQFK 10,32% bo‘lishiga qaramay, tarmoq quyosh stantsiyasini istiqbolli loyiha deb hisoblash mumkin. Tizimning energiya yo‘qotilishiga olib keladigan eng katta omil bu hududning iqlimi bilan bog‘liq bo‘lgan ifloslanishdir. Natijalardagi keskin farqning asosiy sababi stansiyamizning statsionarligi va panel sirtini changlanishdan tozalash texnikasidan foydalanilmaganligidir. Ammo, inflyatsiya hisobga olinmasa, bunday stantsiyaning o‘zini oqlash muddati hisoblashlarga muoffiq 7,5 yilga teng ekan.*

Kalit so‘zlar: *tarmoq tizimi, quyosh stantsiyasi, belgilangan quvvatdan foydalanish koeffitsiyenti, ishlab chiqarilgan energiya, qayta tiklanadigan energiya, samaradorlik, ifloslanish.*

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АНАЛИЗ ЭНЕРГЕТИЧЕСКИХ ПОКАЗАТЕЛЕЙ ФОТОЭЛЕКТРИЧЕСКОЙ УСТАНОВКИ МОЩНОСТЬЮ 70 кВт, ПОДКЛЮЧЕННОЙ К ЭЛЕКТРИЧЕСКОЙ СЕТИ

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Аннотация. *В статье представлены результаты годового мониторинга сетевой солнечной станции (СС) мощностью 70 кВт в городе Термез, расположенном в самой южной части Узбекистана. Были проанализированы годовые, ежемесячные и ежедневные графики производства энергии и установлено, что годовой объем производства энергии составляет 62,77 МВтч. Путем расчетов рассчитаны значения коэффициента использования установленной мощности (КИУМ) для солнечной станции и найдены его среднегодовые и месячные значения. Несмотря на то, что средний КИУМ составляет 10,32%, сетевую солнечную станцию можно считать перспективным проектом. Самым большим фактором, вызывающим потери энергии в системе, является загрязнение окружающей среды, которое связано с климатом региона. Основным фактором резкого различия результатов является стационарность нашей станции и то, что не использовалась методика очистки поверхности панели от опыления. Однако срок окупаемости такой станции по расчету составил 7,5 лет, если не учитывать инфляцию.*

Ключевые слова: *сетевая система, солнечная станция, коэффициент использования, установленная мощность, произведенная энергия, возобновляемая энергия, эффективность, загрязнение.*

Introduction

Against the background of world development, the demand for energy is increasing year by year. This makes it necessary to pay attention to renewable energy sources from year to year. For this reason, the government has been paying attention to this field in recent years. A number of decisions and decrees are being adopted in this area. Among the renewable energy sources, the use of solar energy is the most convenient. In comparison to the PV installations in 2018 (481 GW), the world's PV installed capacity is projected to increase almost six times by 2030 (to 2841 GW) and almost 18 times by 2050 (to 8519 GW) [1]. Today, while using solar energy, it is necessary to reduce the demand for energy and take care of the environment. Electricity plays an important role as a secondary energy source in energy transitions. Compared to traditional fossil fuels, electricity is cleaner, more efficient in production and consumption, and easier to transmit and utilize. So, electricity has significant potential for driving the transition to green energy [2]. The use of solar energy causes the reduction of green house gases (GHG) released into the environment [3]. The opportunities provided for the use of solar energy in recent years will greatly contribute to the improvement of the above-mentioned energy supply and the reduction of the release of harmful gases into the environment.

In addition to the energy problem, the problem of climate change is becoming very important all over the world. Effective use of solar energy is one of the main solutions to these problems. In this regard, the construction and use of Solar Stations (SS) of various sizes around the world are in full swing. Reduction of CO2 gas emission into the atmosphere due to the energy obtained from photovoltaic (PV) and its analysis are considered in works [4,5].

There are many dimensions that characterize the solar station. Based on the system, analyzing its yearly, monthly and daily energy production and the coefficient of use of the installed capacity using its one-year results. Scientists such as Muyiwa S. A., Emil E.T. analyzed the PV plant in

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Norway and obtained a value of 10.58% for the annual CUF [6]. In addition, the annual average daily PV module efficiency, system efficiency and inverter efficiency were 12.7%, 11.6% and 88.8%, respectively. Ramesh Chaudhary and Pratiksinh Chavda have reviewed the influence of climatic factors on CUF in their article [7]. In this case, the strong dependence of CUF on radiation was mentioned in the conclusion and varied between the values of 16.96% and 22.41%. Quantities related to the energy produced by the PV system, and system losses [8] were considered in detail in the works. Various economic indicators of SS were also analyzed.

The high temperature of the panel and pollution of the panel surface has a great impact on the sharp decrease in the panel efficiency [9, 10]. However, for effective use of the roof of the building, it is advisable to test green energy sources. As a result of research carried out in natural conditions, monocrystalline PV panels were found to be the most efficient among the three types of panels [11]. And this is the basis for the use of monocrystalline PV panels in SS today. The main purpose of the work is to analyze the annual energy amount produced by 70kW SS, to get the analysis of daily energy amounts and to find the daily, monthly and annual values of CUF for SS installed in the area.

Research methods and materials

The 70kW solar plant in study is located on the territory of Termez State University (longitude of 37° 13'57"N, latitude of 67° 17'8"E). The PV panels are installed at a tilt angle of 21° facing south and connected to a 100 kW inverter inside the building (Figure 1).

Figure 1. Overview of on-grid solar system.

Termez is one of the cities with the most open sunny days and the largest annual solar radiation, as it is located in the southernmost part of our country. Based on the geographical and climatic conditions of Termez, we can conclude that it has a huge potential for renewable solar energy [12].

The duration of annual solar sunshine exceeds 3000 hours per year. Termez has a high solar energy potential, which indicates that it can become one of the future green energy areas for the installation of photovoltaic energy systems. You can get information about the average sunshine hours in months and years from table 1 below [13].

Table 1

Average sunshine hours in Termez City in months and years

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean monthly sunshine hours	139.5	144.1	189.1	246.0	334.8	375.0	384.4	362.7	315.0	257.3	195.0	139.5	3082.4
Mean daily sunshine hours	4.5	5.1	6.1	8.2	10.8	12.5	12.4	11.7	10.5	8.3	6.5	4.5	8.4

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In the study, the installed power utilization coefficient of the 70kW on-grid solar plant installed on the territory of Termez State University was analyzed. This system is installed on the roof of one of the university dormitories facing south. 450W and 540W monocrystalline panels were used in the on-grid solar system, and their electrical characteristics are given in Table 2.

Table 2

Electrical characteristics of the PVs

Model Type	LS450HC (LA Solar)	LS540BF (LONGI)
Peak Power (Pmax)	450W	540W
Module Efficiency	20.6%	20.95%
Maximum Power Voltage (Vmp)	41.00V	41.55V
Maximum Power Current (Imp)	10.98A	13.00A
Open Circuit (Voc)	49.60V	49.5V
Short Circuit Current (Isc)	11.53A	13.81A
Power Tolerance	± 3 %	± 3 %
Maximum System Voltage Nominal	1500V	1500V
Maximum Series Fuse Rating	20A	25A
Panel Dimension (H/W/D)	2108*1048*40 mm	2279*1134*35
Number of panels	50	88

In this solar system, solar panels will generate the DC electricity by absorbing sunlight and the solar inverter will convert the same DC electricity into AC electricity which can then be used directly at home or business. If the system will produce more power than is being consumed, the surplus is fed into the main electrical grid via solar net metering. The diagram of the 70kW on-grid solar plant is shown in Figure 2. In this case, the inverter is connected to the Internet via Wi-Fi, and it is possible to monitor the daily energy produced by the solar system, the energy produced and its consumption at any time of the day. Invertor SUN2000-100KTL-M1 is used for the system and it is considered modern equipment for the solar energy section. Information is given about the characteristics of this inverter in Table 3. It is considered a modern 3-phase inverter, reducing excess losses. It should also be noted here that there are almost no power outages in cities, and the fact that the city grid can be used as an unlimited capacity accumulator battery is appropriate. In this case, the high costs of the battery will be reduced.This method is widely used in large power stations being installed today.

Table 3

Inverter electrical and technical specification

Technical Specification SUN2000-100KTL-M1	
Max. efficiency	98.8% @480 V, 98.6% @380 V / 400 V
Dimensions (W x H x D)	1,035 x 700 x 365 mm
Weight (with mounting plate)	90 kg
Operating Temperature Range	-25°C ~ 60°C
Cooling Method	Smart Air Cooling
Max. Operating Altitude without Derating	4,000 m
Relative Humidity	0 ~ 100%
DC Connector	Staubli MC4
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP66

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Full reports of daily and monthly power generated by the system can be accessed through https://region02eu5.fusionsolar.huawei.com using mobile phones or computers. This information was directly utilized in the article.

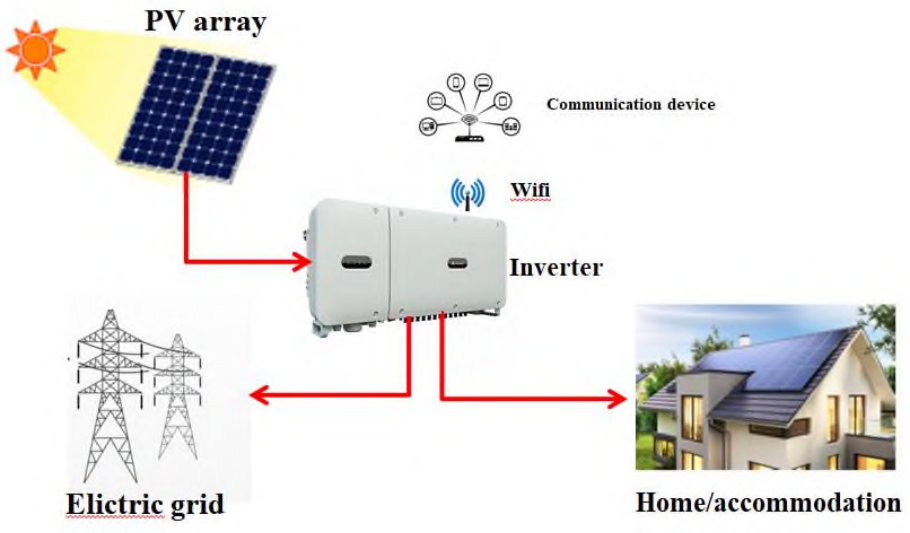

Figure 2. Diagram of the on-grid solar system

The CUF is defined as the ratio of the AC actual energy output to the amount of energy that the PV system would generate if it operated at nominal power [14]. An alternative definition is the duration an electrical system operates at 100 percent capacity. The coefficients calculated over short time intervals differ significantly from one another; consequently, the results obtained from calculations spanning a week, month, or year become increasingly accurate as the time period extends.

Results and discussions

The data collected from 17 October 2022 to 16 October 2023 to study the photovoltaic plant's performance were obtained at Termez State University (latitude 37°13′). All information is recorded in the on-site database as the inverter is connected to the Internet. Based on the overall results, the annual electricity produced by the solar system (SS) and its Capacity Utilization Factor (CUF) coefficients for months and years are analyzed. The energy produced by the SS during each month is shown in Figure 3.

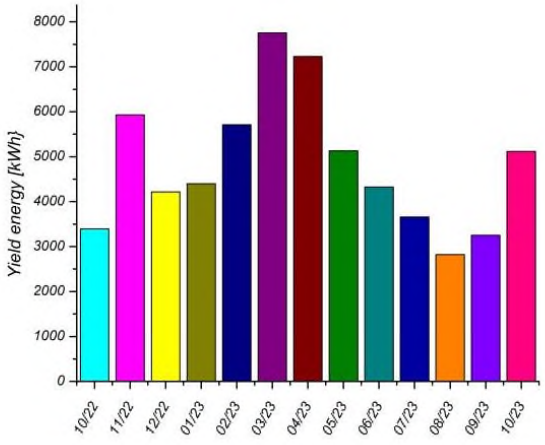

Figure 3. The total energy manufactured in the months

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Using the graph, the largest energy was produced in March, which is equal to 7.755MWh. The most energy produced day of the year also belongs to this month, 379.25kW of energy was produced on this day. The energy distribution by time on this day was given in Figure 4. It can be seen from the graph that the day was sunny and clear, and therefore the energy graph has the characteristic of symmetry.

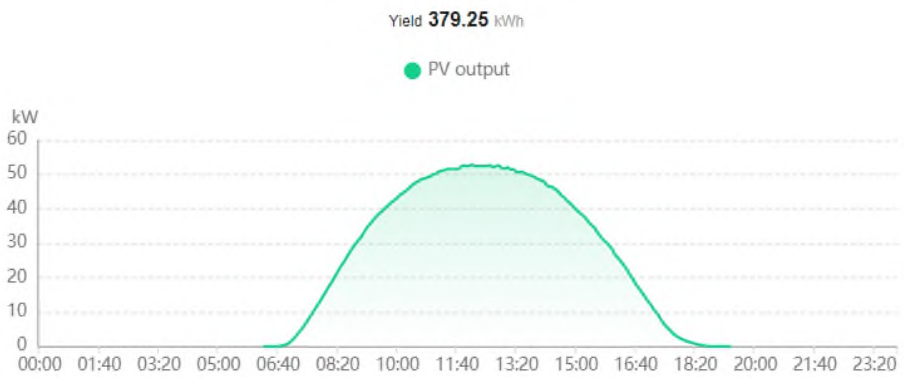

Figure 4. Dependence of energy distribution on 15.03.2023 on the duration of the day

Using the energy function, a general summary of the day's information can be obtained. Although the installed capacity of the station is 70 kW, it could not reach this maximum value at any point during the day because it was installed as a stationary system. In stationary stations, but also a separate PV panel, the panel cannot reach its maximum power in a stationary state [15]. The reason is that as the temperature of the PV panel increases, the open circuit voltage drops sharply, which causes the power to drop. Since March, the amount of monthly energy production has been decreasing month by month. This lasted until October. The main reason for this is pollution of the panel surface, which once again confirms that pollution is one of the main factors that cause energy losses. In addition, the anomalous heat of the summer months also contributed to this energy loss. Since the surface of the panels was cleaned of dust and pollution due to the rain in October, 5.5MWh of energy was produced in 16 days of October, more energy was produced than the 3.25MWh of energy produced in September. This requires the use of the technology of cleaning the panels installed on the roof of the building. CUF (Capacity Utilization Factor) is one of the main parameters of our photoelectric system, which produced 63.3MWh of energy in one year, and its average value was 10.32%. This coefficient changes over the months and its average value in Figure 5.

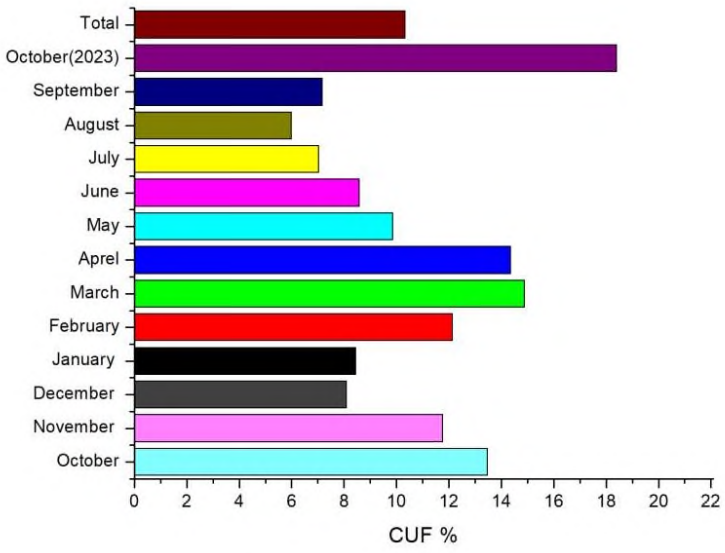

Figure 5. CUF in months and total

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Although the average value of CUF in our station is equal to 10.32%, it was close to 15% in March and April. In October 2023, it showed the maximum value of 18.4%. Based on this, daily produced energy in October 2023 was analysed, Figure 6.

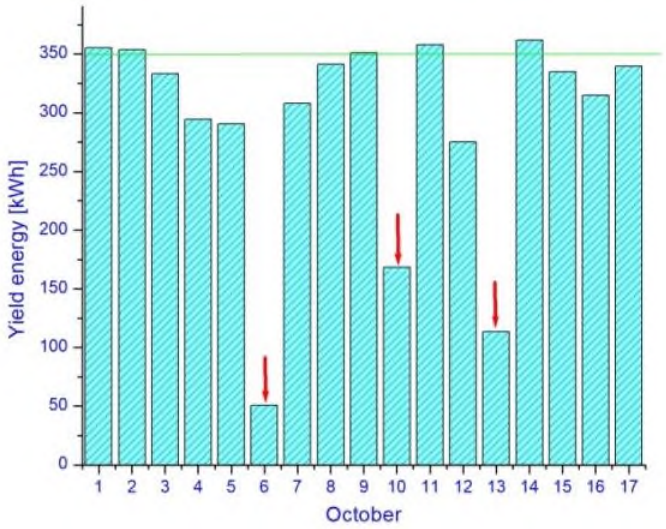

Figure 6. Energy analysis in October 2023

As mentioned, in October, the value of CUF was the maximum for the considered period. And this led to a review of the daily analysis of the energy produced this month. From Figure 6, we can see that on October 6, at least 50kWh of energy was produced, and it was a day known as "Afghan wind" in Termiz city. The surface of the panel was cleaned due to some rain after the wind. Therefore, energy on October 5 and October 7 was 308.03kWh and 341.17kWh, respectively. On October 10 and October 13, the weather was cloudy and it rained during the day, and therefore the amount of energy produced on this day was small, and the results of the next day increased and more than 350 kWh of energy was produced. The changes in energy distribution during these days depending on the time of day were given from Figure 7.

From the graphs above, the October 13rd and 14th cases are given. The date October 13 the weather was generally cloudy and rainy. That's way energy distribution was changed very different shape. The maximum power was about 32kW. The total energy produced on this day is the basis for making clear conclusions about this day. On October 14, the weather was sunny. After the rain, the PV panel surface was cleaned from dust and different pollution. Energy distribution was nearly symmetric and maximum power 55kW was recorded. From the analysis of two consecutive days, the cleaning of the PV panel surface by rain has a positive effect on the energy production process.

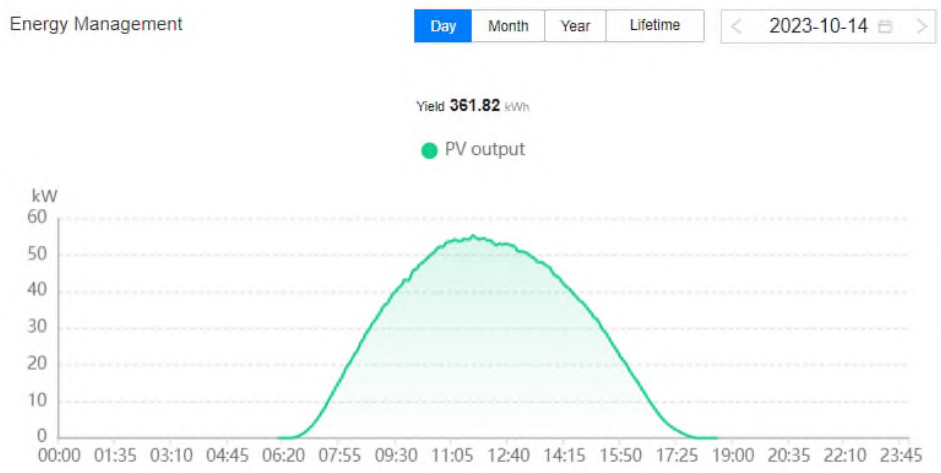

Figure 7. Dependence of energy distribution on time of day

Conclusion

In today's modern world, the demand for energy from renewable energy sources is also increasing every year. One of the main reasons for this is the attitude of people to green energy, and on the other hand, the sharp increase in the efficiency of this type of energy against the background of the development of technologies. The attention paid to this type of energy in our country is certainly contributing to the development of this sector. As a result of the research carried out in the article, the annual energy produced by the solar plant with a total capacity of 70kW located on the territory of Termez State University, CUF values are quoted. The monthly values of the total annual energy production of 62.77MWh are shown in the graphs, and the best energy production was in March when 7.755MWh of energy was produced. In the article, the solar station's CUF was identified using the monitoring system. Based on the results of research and monitoring, the following conclusions were reached:

- When building stationary solar plants, it is important to accurately set the appropriate angle of installation instead of their location and, if possible, change the angle of installation during the seasons, which will increase the amount of energy produced,
- Since the grid works as an infinite battery for such a system, the cost of the battery is saved,
- From the continuous monitoring of panel pollution, it was found that 2-3 months of pollution can reduce the efficiency of the system by 30-50%,
- According to the annual energy produced by the system, its CUF was 10.32%, and the best monthly indicator was 18.4% in October.

The payback period of such a station installed in the southernmost part of Uzbekistan is 7.5 years, which is much shorter than the 25-year panel life. Among the conclusions, it should also be said that pollution is the biggest problem that needs to be solved. In our studies, a general analysis of this station was carried out based on the results of one-year monitoring.

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