Annual Monitoring Analysis of Four On-Grid Stations in Termez

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Abstract: In the article, a one-year energy analysis of 4 on-grid solar stations with capacities of 49.5kW, 53.76kW, 39.6kW and 52.8kW installed on the roof of the building was carried out. It is important to know the efficiency of the use of such solar plants in the world, gradually abandoning the amount of traditional fuel and switching to green energy. Payback periods and CUF coefficients of the station were calculated using the annual energy production. An average payback period of 4.24 years was found for the stations. The best result for CUF belongs to IV station equal to 17.4%, and the smallest value is equal to 8.21% for II station. The annual amounts of energy produced were 58.79MWh, 38.76MWh, 50.05MWh and 80.67MWh, respectively. Despite the high temperature and pollution, the stations had their best energy production in June. In the future, such solar plants on the roof are considered promising projects, because they do not require additional space and are the reason for the cheapest initial investment.

1 INTRODUCTION

The rapid development of solar energy technologies has led to the widespread installation of photovoltaic (PV) power plants worldwide. In Uzbekistan, the adoption of on-grid rooftop solar stations is increasing as part of the national goal to achieve 7 GW of installed solar capacity by 2030. However, to maximize the efficiency of these systems, it is essential to analyze their performance metrics, including the Capacity Utilization Factor (CUF), energy output, and payback period.

This study focuses on the performance analysis of four rooftop on-grid solar power plants installed at Termez State University. The aim is to evaluate their annual energy production, compare CUF values, and identify key factors affecting system efficiency. By utilizing real-time monitoring data and performance calculations, this study provides insights into the operational characteristics of rooftop solar stations under high-temperature climatic conditions.

2 LITERATURE REVIEW

Among renewable energy sources, the installed capacity of PV modules is increasing year by year. The main reasons for this are the annual decrease in fuel energy reserves and the great importance given to green energy in the modern world. According to the sources of the International Renewable Energy Agency, in 2022, the worldwide installed capacity of photovoltaic modules exceeded 1053GW, and for our country Uzbekistan, this figure was 0.25GW, which is reflected in Figure 1 [1].

While China (393GW), the US (113GW), Japan (78.8GW) and Germany (66.5GW) have the best-installed capacity, China's relative share will be almost 37% of solar installations in 2022 [2]. Uzbekistan aims to have 7 GW of installed solar power by 2030, and many practical works and solar plants are being built for this purpose.

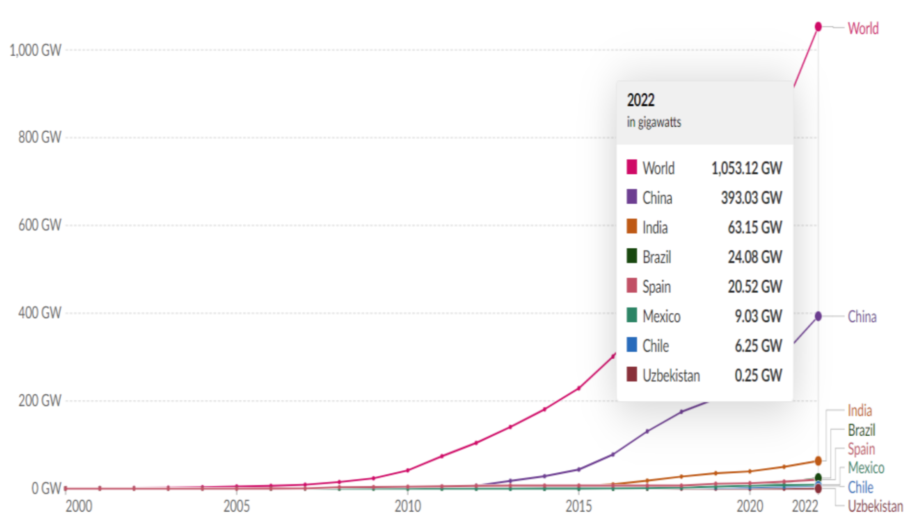

Figure 1: Installed solar power capacity from 2000 to 2022.

To effectively use the roofs of many buildings, rooftop on-grid stations were put into operation last season, and it is important to know the installed power utilization coefficients to evaluate the efficiency of these stations. It is also important to analyze annual, monthly, daily energy production. [3] in the work, in the analysis of this type of 70kW solar station (SS), the result for CUF is 10.15%. Muyiwa S. A., Emil E.T. analyzed the PV plant in Norway and obtained a value of 10.58% for the annual CUF [4]. [5-8] scientific works also states the station performance and the energy analysis are signifie important. The amount of energy produced, daily, monthly, annual monitoring and payback period of the station are important quantities that can be concluded about the station. The influence of radiation and temperature on PV modules [9] has been studied in scientific works, and high temperature has been shown as the main external factor affecting the open circuit voltage of the module.

3 METHODS AND MATERIALS

3.1 Study Location

In the article, an analysis was made based on the annual energy produced by 4 rooftop on-grid solar plants. Solar station in the study is located on the territory of Termez State University (longitude of 37° 13'57"N, latitude of 67° 17'8"E) (Figure 2). Termez is a city located in the southernmost part of the Republic of Uzbekistan, has high temperature and annually high irradiance.

Figure 2: Location of on-grid solar systems.

3.2 PV System Description and System Description

This system is installed on the roof of one of the university building facing south. 550W and 560W monocrystalline panels were used in the on-grid solar system, and their electrical characteristics are given in Table 1.

Table 1: Physical parameters of PV panel.

Model Type	YH550W-36MN	BSM560M10-72HPH
Peak Power (P_{max})	550W	560W
Module Efficiency	21.28%	21.68%
Maximum Power Voltage (V_{mp})	42.13V	42.33V
Maximum Power Current (I_{mp})	13.06A	13.23A
Open Circuit (V_{oc})	50.1V	50V
Short Circuit Current (I_{sc})	13.9A	14.14A
Maximum System Voltage Nominal	1500V	1500V

Information about the number and type of panels used for 4 stations, and the installed power is given in the second table. The panels were installed at an average tilt angle of 30 degrees.

Table 2: General information.

№	PV			Total power	Inverter power (Huawei)
	Type	Power	Quantity		
I	Ipvi Sola	550W	90	49.5kW	50kW
II	Blue Sun	560W	96	53.76kW	50kW
III	Ipvi Sola	550W	72	39.6kW	50kW
IV	Ipvi Sola	550W	96	52.8kW	50kW

3.3 On-Grid Solar System Description

In this solar system, solar panels generate DC electricity by absorbing sunlight, and a solar inverter converts this DC electricity into AC electricity, which can then be used directly at home or in businesses. If the system generates more power than is consumed, the surplus is fed into the main electrical grid through solar net metering. In this setup, the inverter is connected to the Internet via Wi-Fi, enabling monitoring of the daily energy produced by the system, the energy generated, and its consumption at any time of the day. The system utilizes a SUN2000-50KTL-M3 (50kW) inverter which are modern equipment for solar energy applications. Full reports of daily and monthly power produced by the system, as well as daily weather information, can be accessed through the site[1] using mobile phones or computers.

3.4 Capacity Utilization Factor

The CUF (Capacity Utilization Factor) is the ratio of the actual energy output of an AC system to the energy a PV system would produce if it ran at nominal power [10]. Another way to define it is by measuring how long an electrical system operates at full (100 percent) capacity. Coefficients calculated over short intervals can vary significantly, so the accuracy of weekly, monthly, or yearly calculations improves as the time period increases.

$$\eta_{CUF} = \frac{E_{yield}}{P_{PV,rated} \cdot Time_{Fixed}} , \quad (1)$$

where E_{yield} is SS's total energy produced for a fixed time. $P_{PV,rated}$ is the installed power of SS. $Time_{Fixed}$ is the exact time taken for SS to produce E_{yield} energy.

4 RESULTS AND DISCUSSION

The collected data from July 2023 to June 2024 (one year) used to study the photovoltaic plant's performance were carried out at the Termez State University. The installed capacity of each station is different, but close to each other in terms of value. Therefore, in addition to the amount of energy produced, it is possible to compare these stations with the size of CUF. The information about the annual amount of energy produced by the station is given in Table 3.

Table 3: Annual amount of energy produced.

Power	I 49.5kW [MWh]	II 53.76kW [MWh]	III 39.6kW [MWh]	IV 52.8kW [MWh]
July	7.49	4.95	4.81	9.09
August	1.49	5.16	5.14	7.95
September	3.67	1.88	4.46	7.17
October	4.79	0	4.23	6.43
November	4.03	0	3.34	4.96
December	3.95	0	2.54	4.15
January	4.09	2.7	2.87	4.5
February	4.58	3.21	3.04	4.69
March	4.99	4.22	3.8	6.24
April	7.1	5.16	4.65	7.42
May	8.3	5.8	5.55	8.92
June	8.34	5.68	5.62	9.15
Total Energy	58.79	38.76	50.05	80.67
n [year]	4.68	7.71	4.4	3.64

[1] https://region02eu5.fusionsolar.huawei.com

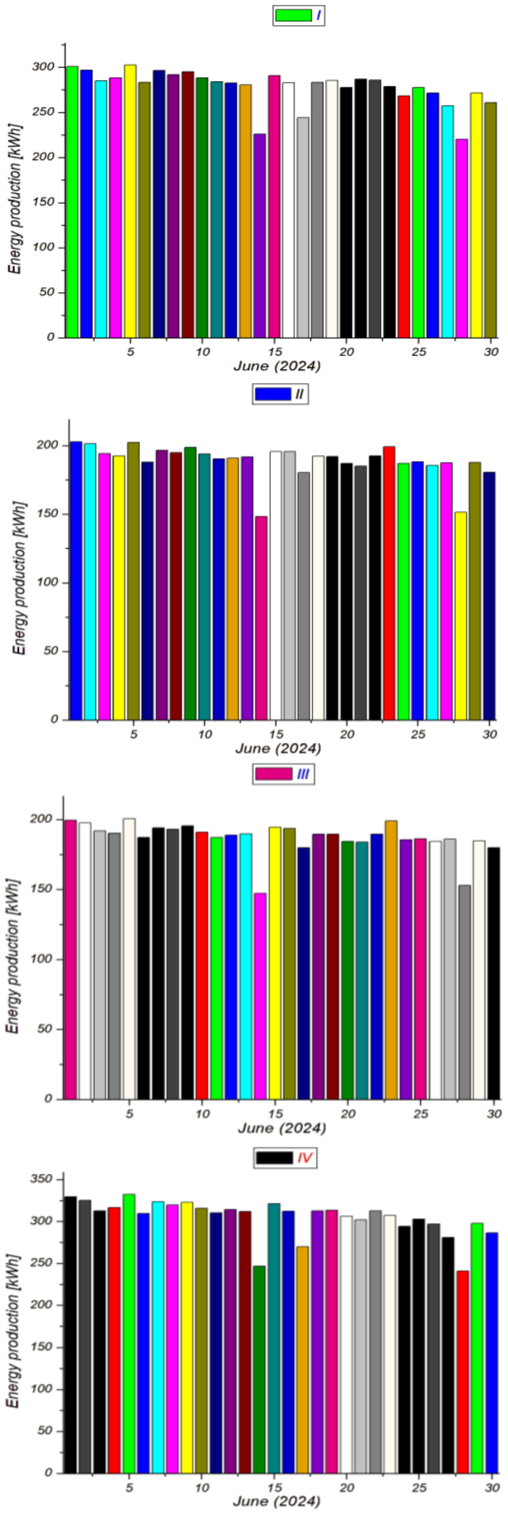

Figure 3: The energy production in June.

The best energy production belongs to the IV station and amounted to 80.67MWh. Station II produced the least amount of energy due to 3 months of technical interruptions. Due to the large impact of this technical outage on the station CUF and payback period, its value was not taken into account when calculating the average stations' payback period. Considering the evaluation of the economic payback period of the station with the energy produced by it, the economic analysis of SS, as follows, was carried out.

$$n = \frac{P \cdot \$400}{E \cdot \$0.072} \qquad (2)$$

Here, P is the installed power, \$400 is the average price of a 1kW on grid station, E - annual amount of energy produced, \$0.072 - this is the price of 1kWh energy in the country. In the calculations, we did not take into account the increase in energy prices and inflation, and we also did not take into account the costs associated with the operation of solar plant devices. The payback period of the solar station was 4.68, 7.71, 4.4 and 3.64 years for each station, respectively. Here, explaining the result of the second station as the absence of production for 3 months, we can get an overall average value of 4.24 years for such stations from the best results. The best production for the stations was in June. Data on daily energy production values for June are given in Figure 3.

The stations produced 8.34MWh, 5.68MWh, 5.62MWh and 9.15MWh of energy this month, respectively. The best indicator belongs to station IV, and the lack of this indicator in stations II and III can be explained by the formation of a shadow in the location of the panels. In the arrangement of the panels, it is assumed that the next row of arrays will be shaded at certain times of the day. Information about station CUF indicators is given in Figure 4.

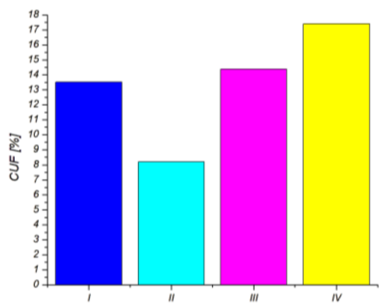

Figure 4: CUF in one year.

Since the CUF of the stations is a quantity that shows how efficiently they worked during the year, the smallest indicator of 8.21% belongs to station II. However, at station IV, this indicator is equal to 17.4%, which is one of the best indicators for SS in Termez conditions.

4 CONCLUSIONS

It is important to determine the efficiency of using the installed power of solar plants, to know the average payback period for a certain area. In the article, a one-year energy analysis of 4 on-grid solar stations with installed capacities of 49.5kW, 53.76kW, 39.6kW and 52.8kW in the Termez region was carried out. The annual amounts of energy produced were 58.79MWh, 38.76MWh, 50.05MWh and 80.67MWh, respectively. The average payback period was 4.24 years. Results of 13.52%, 8.21%, 14.38% and 17.4% were recorded for CUF, respectively. Despite the pollution and high temperature, the stations had their best energy production in June. In the future, such solar plants on the roof are considered promising projects, because they do not require additional space and are the reason for the cheapest initial investment.

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