Annual Analysis of On-Grid Station with an Installed Capacity of 200.75kW: The Case of the City of Termez

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Abstract: The use of solar energy, which is one of the renewable energy sources, is increasing every year. And the installed capacity of solar plants is also increasing all over the world. This shows that the transition to green energy is accelerating. It will be beneficial to monitor the useful working capacities of such solar plants installed in the world, and in our country, the amount of energy produced, and the performance of months and seasons. In the article, the annual amount of energy produced by an on-grid solar plant with a capacity of 200.75kW is equal to 198.32MWh, and calculations give the payback period is 5.6 years. The maximum value of the installed capacity utilization coefficient was 19.57% in June, the minimum value was 5.41% in January, and the average annual value was 11.25%. In addition, the specific energy coefficient peaked at 4.7 kWh/kW in June. During the winter months, it reached its lowest values, with 1.53 kWh/kW in December, 1.3 kWh/kW in January, and 1.54 kWh/kW in February.

1 INTRODUCTION

Today, the use of renewable energy sources is increasing at a high rate. Solar energy is one of the most important among renewable energy sources. According to the International Renewable Energy Agency (IRENA), it is planned to reach the capacity of 8GW of solar plants in Uzbekistan by 2030 [1]. In addition, Uzbekistan has set a plan to increase the amount of energy obtained from renewable energy sources to 40% by 2030 [2]. As a result of the construction of large-scale solar power plants in recent years, it is possible to determine the energy analysis, economic payback period and many other indicators of this type of power plant by calculating their capacity utilization factor (CUF) [3]. Many on-grid solar stations are based on efficiently using the building's roof. However, energy losses caused by high temperatures [4-8] and pollution [9] have not been eliminated. It is possible to monitor the amount of energy produced in real climatic conditions by controlling it through the Internet, which is one of the modern conveniences.

In the research that started several decades ago in European countries, scientists such as Muyiwa S. A., Emil E.T. analyzed the PV plant in Norway and obtained a value of 10.58% for the annual CUF [10]. Ramesh Chaudhary and Pratiksinh Chavda have reviewed the influence of climatic factors on CUF in their article [11]. Quantities related to the energy produced by the PV system, and system losses [12-14] were considered in detail in the works. Various economic indicators of SS were also analyzed.

In the article, the annual energy analysis of the 200.75kW on-grid network station installed in the student accommodation building of the Termez State University in the city of Termez, which has high annual radiation, was carried out.

2 METHODS AND MATERIALS

2.1 Study Location

The 200.75kW 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 1). Termez is a city located in the southernmost part of the Republic of Uzbekistan, the climate here is very hot in summer and short and cold in winter.

Figure 1: Location of on-grid solar system.

2.2 System Configuration and Operation

In the study, the installed power utilization coefficient of the 200.75kW 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. 550W monocrystalline panels were used in the on-grid solar system, and their electrical characteristics are given in Table 1.

Table-1: Physical parameters of photoelectric battery.

Model Type	LF550TU-36MH
Peak Power (P_{max})	550W
Module Efficiency	21.3%
Maximum Power Voltage (U_{mp})	42.11V
Maximum Power Current (I_{mp})	13.06A
Open Circuit (U_{oc})	50.28V
Short Circuit Current (I_{sc})	13.86A
Maximum System Voltage Nominal	1500V
E=1000W/m^2, T_{PEB}=25^{o}C, AM=1,5 STC conditions	

A total of 365 panels of 550W monocrystalline panels were used in the solar station. The panels were installed in a stationary position at a tilt angle of 30^0 to the south. SS has been working since July 2023.

In this solar system, solar panels generate DC electricity by absorbing sunlight, and the solar inverter converts this DC electricity into AC electricity, which can then be used directly at home or in a business. If the system produces more power than is being consumed, the surplus is fed into the main electrical grid via solar net metering. The diagram of the 200.75kW on-grid solar plant we installed is shown in Figure 2. In this setup, the inverter is connected to the Internet via Wi-Fi, allowing for monitoring of the daily energy produced by the system, the energy generated, and its consumption at any time of the day. The system uses a SUN2000-100KTL-M2 inverter and two SUN2000-50KTL-M3 inverters, 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. This information was used directly in the article.

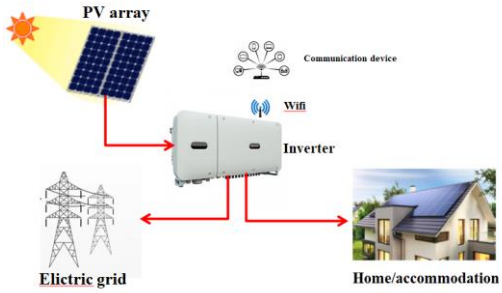

Figure 2: Schematic block circuit diagram of the SS.

2.3 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 [15]. Another way to define it is by measuring how long an electrical system operates at full 100% capacity. Coefficients calculated over short intervals can vary significantly, so the accuracy of weekly, monthly, or yearly calculations improves as the time period increases.

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

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

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.

3 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 annual amount of energy produced is equal to 198.32GWh, and Figure 3 gives full monthly informations.

The highest amount of energy was produced in June, which was 3.5 times more than the lowest amount of energy produced in January 8.08MWh and was equal to 28.29MWh. Considering the economic recovery period of our station and the energy produced by it, we carried out the economic analysis of SS as follows.

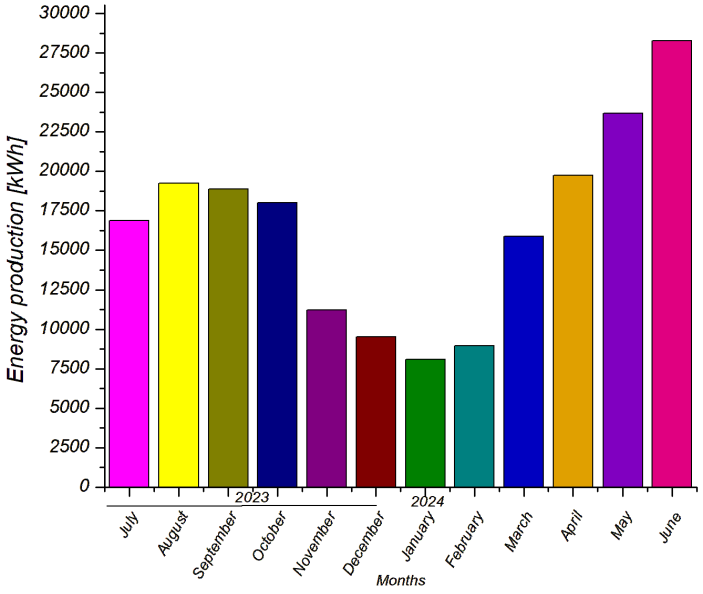

Figure 3: The energy production in one year.

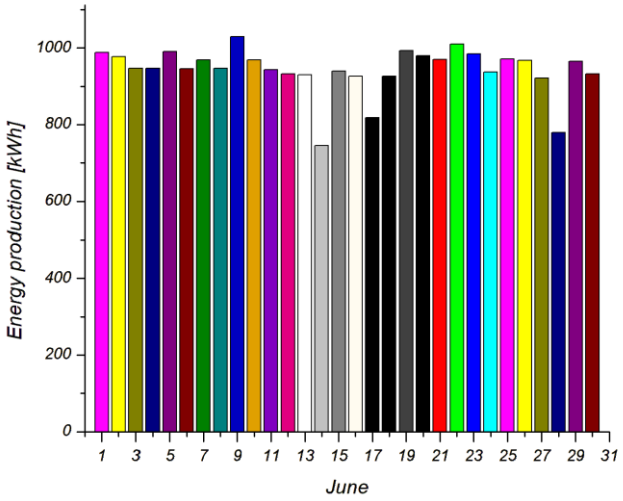

Figure 4: The daily energy reports produced in June.

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

Here: P=200.75kW, $400 is the average price of a 1kW on-grid station, E=198320kWh annual energy production, $0.072 is the price of 1kWh energy in our country. In our 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 installations. The payback period of the solar plant was equal to 5.6 years. Figure 4 reports the amount of energy produced per day in June. In this month, the most daily 1.03MWh of energy was produced on June 9, and the least 745.07kWh was produced on June 14.

Annual and monthly solar plant CUF was calculated using the formula given above, and the results are reflected in graph 5.

The values of CUF are also reflected in accordance with the months of energy production. In this case, the average annual CUF value is equal to 11.25%, due to the smallest values of 6.37% for December, 5.41% for January, and 6.41% for February. In the summer season, due to the length of days, the high amount of falling radiation, and almost all days being open, the CUF value reached its maximum value in June and reached 19.57%.

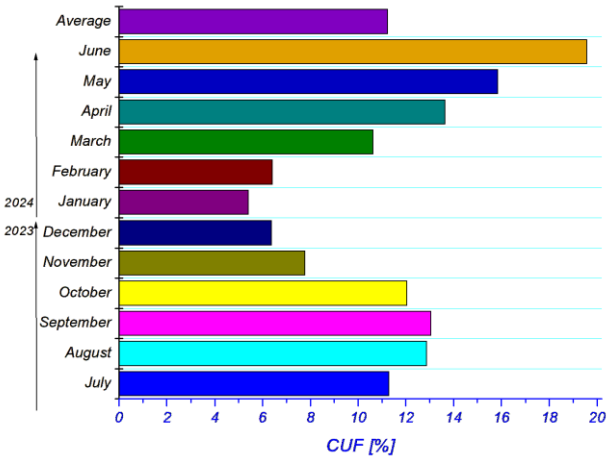

Figure 5: CUF in months.

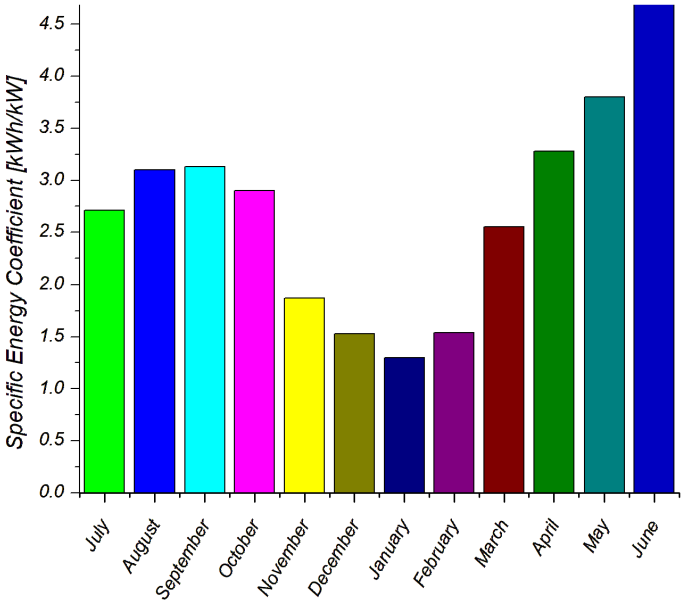

Figure 6: Specific energy coefficient in months.

As sunny days become more frequent, the CUF will undoubtedly rise. The table above indicates that the average sunlight duration in winter is 4.7 hours, which increases to 8.3 hours in spring and 12.2 hours in summer. However, it's important to note that as the temperature of the panels rises, so does the power loss [16-20]. Therefore, it is essential to consider the panels' fixed position and the level of dust accumulation. Our primary objective is to study the CUF of SS, and we have thoroughly examined these aspects earlier. In addition, to evaluate energy efficiency, how many kWh of energy are obtained during the day from 1kW of power is also important. The change in the average values of this quantity over months is given in Figure 6.

The maximum value from the graph is 4.7kWh/kW for June, this indicator reached minimal values in the winter months due to stationarity and no pollution protection. However, this high index in the summer months can be said to be a good result.

4 CONCLUSIONS

It is important to determine the efficiency of the renewable solar plant by the amount of energy it produces in natural conditions and to find the economic payback period. In the article, the annual CUF value of the rooftop on grid solar plant is equal to 11.25% and the payback period is equal to 5.6 years, the average annual energy production is equal to 198.32GWh. Various harmful gases that can be released into the environment have been prevented. Despite the fact that the panels heat up to a high temperature, due to the length of the day in the summer months, the solar plant has achieved a maximum average energy production of 1MWh. The specific energy coefficient also reached its maximum value which was 4.7kWh/kW for June. And for the winter months, this indicator reached its minimum values in December, January and February, respectively 1.53, 1.3 and 1.54kWh/kW.

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