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Research Article/Araştırma Makalesi

An Evaluation of Overcast Weather on Generation of a Grid Connected PV Power Plant

Kenan SAKA[1]

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Abstract
Photovoltaic power plants are environment friendly and renewable energy powered systems. They can be sustainable energy systems in almost everywhere in Turkey. Global solar radiation values are lower in the northwest regions of Turkey than the south regions. Bursa is one of the northwestern provinces Turkey. The Soğuksu photovoltaic solar power plant which was established in Soğuksu village of Bursa is the first large-scale solar power plant with a capacity of 7 MW. The plant is grid-connected and has started to generate power in March, 2017. Cloudy weathers have negative impact on reducing the electricity generation of solar power plants. In this study, electricity generations of the Soğuksu photovoltaic power plant were analyzed using the daily and monthly recorded data. This data was used to determine the number of cloudy days for the time period from April, 2017 to March, 2018. According to results, the most number of cloudy days was observed in December and only 3.5% of annual generation was realized in December.

1. Introduction

Fossil fuels like petroleum and coal are finite in nature and the major source of greenhouse gas emissions. There are growing environmental problems in Turkey as in the world due to increasing energy demand by use of fossil fuels. Nowadays, global warming and climate change brings renewable energy sources especially solar energy to the forefront. Solar energy technologies can be primary solutions for sustainable and environmentally friendly energy usage. In Turkey, solar energy was realized as an alternative energy in the early 1960s and domestic solar water heating technology was accepted by The Turkish public. Also utilization of solar energy started in 1988 at industrial scale. Studies have been increasingly continuing on solar technologies. Hepbaslı et al. (2004) have emphasized the significant increasing in installed capacity of the photovoltaic (PV) in Turkey.

Turkey is one of the world's best geography for sunlight. Besides PV solar power systems and concentrating solar power (CSP) technologies offer interesting opportunities like sustainable electricity generation. CSP systems use parabolic trough collectors for concentrating purpose (Kaygusuz, 2011).

[1] Corresponding Author. ORCID: 0000-0002-2296-894X. Bursa Uludağ Üniversitesi, Yenişehir İbrahim Orhan Meslek Yüksek Okulu, kenansaka@uludag.edu.tr

Hrayshat (2009) has studied the viability of solar PV as an electric source for Jordan. Merrouni et al. (2016) have discussed the possibility of installation of large scale PV power plants in the Eastern region of Morocco. They reported that the Eastern region of Morocco receives a high amount of solar irradiation with a maximum of 1930 $kWh.m^{-2}$ and also offers a big capability to host PV farms with a surface of 44.863 km^2, which represents about 75% of its total surface. Doljak et al. (2017) have focused on the PV potential in a city of Serbia. Their results have showed that it would be possible to generate about 43% electricity produced by two thermal power plants by construction and work of PV power plants in proposed locations. Edalati et al. (2017) have carried on solar PV power plants in five top oil-producing countries in Middle East. Kumar and Sudhakar (2015) have pointed out that grid-connected PV systems are the best choice among renewable energy sources. They have studied on performance evaluation of a 10 MW grid-connected solar PV power plant in India. Some studies have focused on the solar energy of Turkey in the literature. Incekara and Ogulata (2017) have studied on Turkey's energy planning considering global environmental concerns. They have reported that solar energy will have the second place in Turkey's electricity generation until 2030. Some analyses have been prepared for some cities of Turkey. Ulgen and Hepbasli (2003) have studied on evaluating the power generation of solar and wind hybrid systems for Izmir. Yilmaz (2013) has an estimation of horizontal solar radiation for Bolu. Bezir et al. (2010) have estimated it similarly for Isparta. Boran et al. (2010) have suggested the best location of PV system as Bodrum in Turkey. The location has satisfied sun hour and mean temperature criteria at the best level as compared with other candidate sites.

The electricity generation for the Soğuksu solar power plant on a number of cloudy days has been presented in this study. The power plant is a PV type and grid-connected and located in the northwestern part of Turkey. The Soğuksu solar power plant has importance due to being the first large-scale plant installed in Bursa. The monthly global radiation values of the region are below the nationwide average thus it can be a risky investment. There is a requirement on examining the effect of cloudy weathers on the power generation especially for autumn and winter seasons. The electricity generation of the power plant was observed under practical conditions and the data were recorded continuously by the power plant. The number of cloudy and days for the time span from April 2017 to March 2018 was demonstrated.

2. Methodology

The Soğuksu solar power plant is a large solar farm including seven different power plants each has a 1 MWp capacity. Description and location of the power plant are important from methodological aspect. In the plant installation a single type of panel was preferred. The panels are connected to strings having 22 panels in series. Inverters are important components in the power plant and each inverter has 10 strings. There are 20 inverters in each 1 MWp plant. The market name of the panel is UP-M270P. It is made from polycrystalline silicone. The other properties of the panel taken from the product catalogue are given in Table 1. There are also more efficient panels according to producer such as UP-M275P or UP-M280P.

Table 1. Properties of PV solar panels used in Soğuksu solar power plant

Model	UP-M270P	UP-M275P	UP-M280P
Max. Power (W)	270	275	280
Max. Voltage (V)	31.4	31.6	31.8
Max. Current (A)	8.60	8.70	8.81
Open Cir. Volt. (V)	38.6	38.7	38.9
Short Cir. Cur. (A)	8.88	8.98	9.09
Module Efficiency	16.6%	16.9%	17.2%

An engineering work, suitable area and financing are necessary to the installation of a power plant like in every investment. The Soğuksu solar power plant has all the necessary processes and legal permits since March 2017. The general characteristics of the power plant are shown in Table 2 with optimum tilt angles of the region (Yılmaz, 2018).

Table 2. General characteristics of Soğuksu solar power plant

Total installed area	170,000 m^2
Number of panels used	30,800
Total panel surface area	50,108 m^2
Total cell surface area	44,972.9 m^2
Plant Power	7 MWp
Inverter Efficiency	97 %
Optimum tilt angles of the region	36.55°
Generation Commencement Date	20 March 2017
Plant Coordinates	40° 12’ 57’’ N and 29° 25’ 50’’ E

The Soğuksu solar power plant is located within the boundaries of Bursa. Its geographical location is near to the Yenişehir plain. In Figure 1, the map shows the location of the power plant.

Figure 1. Location of the Soğuksu solar power plant

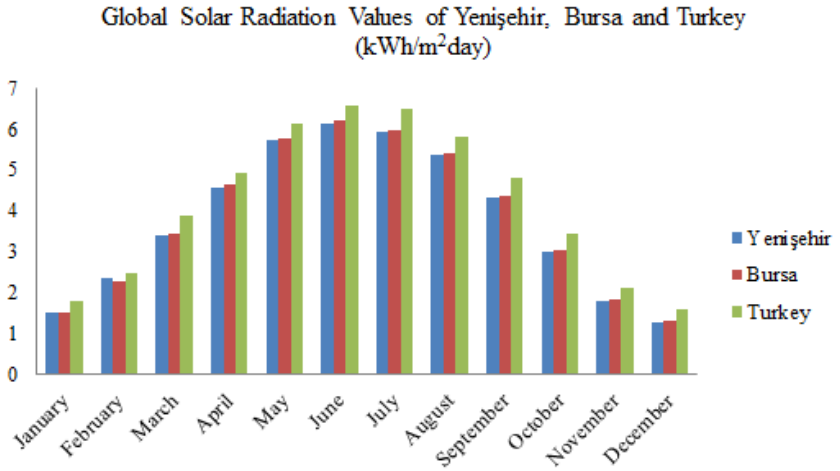
There is no cooling application performed on the panels. The location of the power plant has the advantage of natural ventilation due to its altitude relative to the plain.

Theoretically, the amount of generated electricity by a solar power plant can be calculated according to the panel surface area of the plant, the number of days it produces electricity, the panel and inverters efficiency used in the plant. Also generated electricity is directly related to the energy carried by the sunrays coming onto the power plant panels under cloudy weathers. In Figure 2, the image shows the view of the power plant from satellite.

Figure 2. The satellite view of Soğuksu solar power plant

The theoretical capacity of the power plant can be calculated using global solar radiation values to gain a horizon. Equation (1) shows this relation. For example global solar radiation value in April is 4.59 (kWh/m^{2}day) and day number of April is 30. If global solar radiation value, day number, peak efficiency of the panel and the cell area is multiplied with each other the potential of the plant can be found as 1028 MWh for April. Result of the theoretical capacity calculation of a power plant is not equal actual generation. Actual generation of the Soğuksu power plant was observed as 1100 MWh in April, 2017.

Figure 3. Global solar radiation values of Yenişehir, Bursa and Turkey



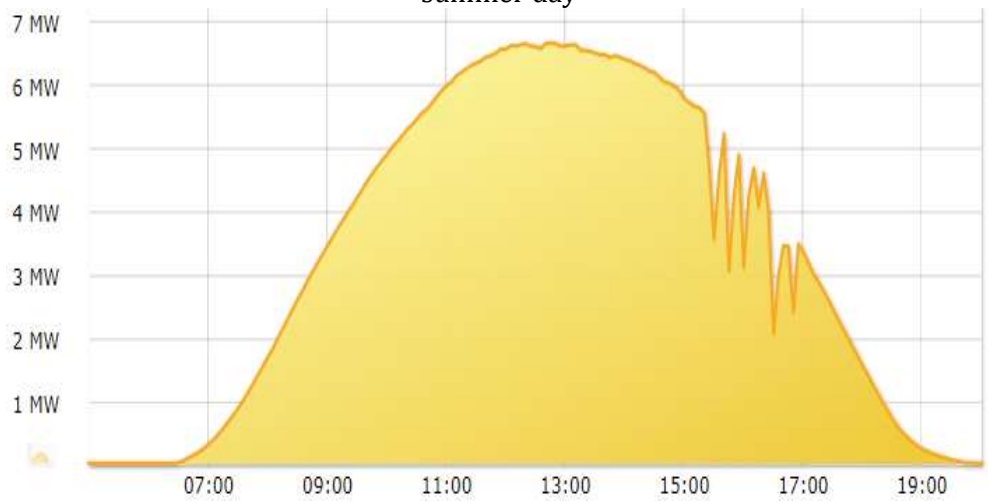
Potential generated electricity (kWh) = GSRV (kWh/m^{2}day) × day number × cell area (m^2) × efficiency of the panel (1)

Consequently GSRV can give an idea about a region for solar energy potential. Solar potential values of anywhere can be demonstrated with solar potential maps. Figure 3 presents the global solar radiation values (GSRV) of Yenişehir, Bursa and Turkey. The average radiation value of the region is lower than the average radiation value of the country.

3. Results and Discussion

The design power of the Soğuksu solar power plant is 7 MW but the maximum observed peak power has been 6.8 MW up to now in a clear day. It is possible to observe 7 MW in some instants. Figure 4 shows the changes in daily power generation of the plant on a clear day. A day with clear sky can be described as the perfect day for a power plant. On the 25th August 2017, with sunrise, the plant wakes up and generation begins. The power generation increases during the day and reaches peak value at midday as expected. For a perfect day there is no disconnection between generation values but there is very little disconnection afternoon on the figure. The decreasing generation power afternoon falls to zero with sunset.

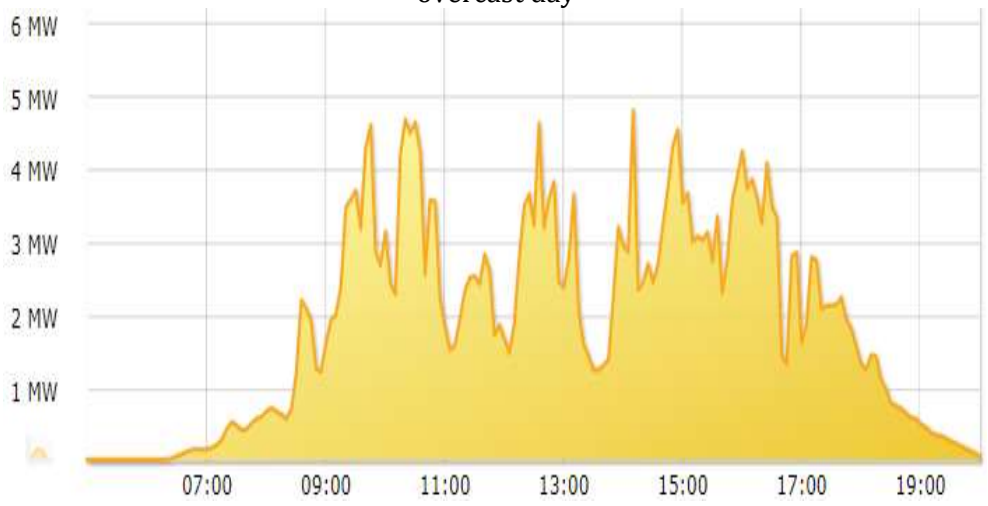
Figure 4. Daily electricity generation distribution in Soğuksu solar power plant on a clear summer day



In the distribution given in Figure 4, the day is very close to the perfect day. The power plant starts up before 7:00 am in the morning. Right after 13:00 noon, the peak generation power reaches about 6.5 MW. There is some fluctuations on power generation afternoon. Electricity generation continues until 20:00 and reaches a total value of 50.2 MWh throughout the day.

Figure 5 shows the changes in daily electricity generation on a cloudy summer day in the power plant. On the 5th August 2017, electricity generation continues until 20:00 reached a total value of 28.12 MWh throughout the day. This value is less 44% than from the first day which given above. Daily difference can be seen easily on this comparison at the same season.

Figure 5. Daily electricity generation distribution in Soğuksu solar power plant on an overcast day



Although the electricity generation distribution given in Figure 4 is an expected generation, it is not always possible to talk about such an electricity generation capacity and the number of perfect days is very low. Especially in winter, the effect of cloudy and rainy weather on the power plant is significant. The daily electricity generation distribution of a winter day that can be interpreted as a bad day for generation is given in the Figure 6.

Figure 6. Daily electricity generation distribution in Soğuksu solar power plant on a winter day

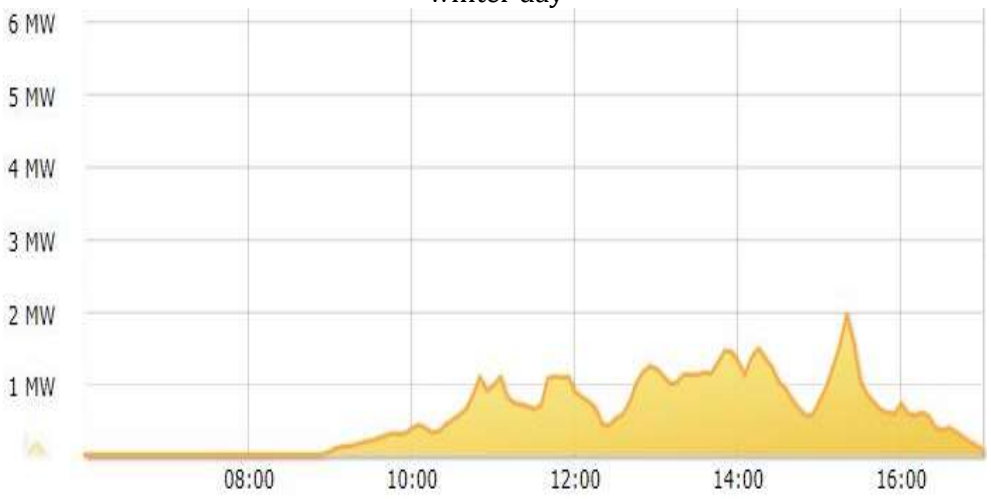
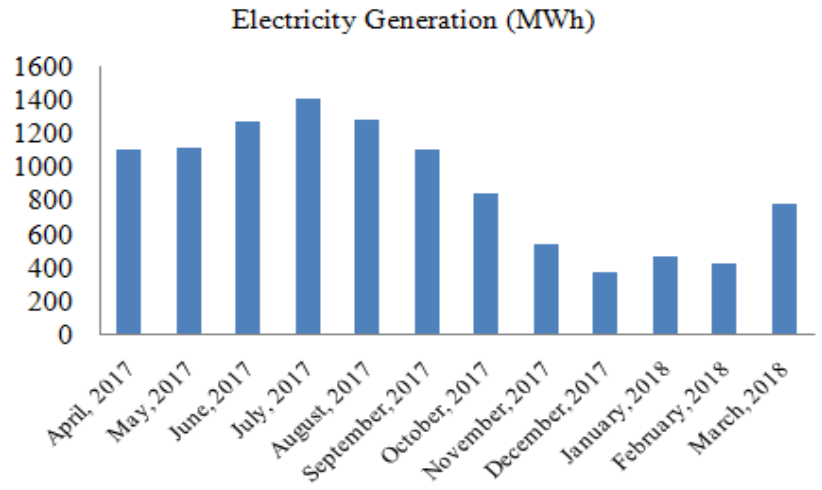


Figure 6 shows the daily electricity generation distribution in the Soğuksu solar power plant on a winter day. The generation values given in the figure belong to 20th December 2017. The weather condition has a significant effect the power generation as easily seen on the figure. 5.95 MWh of electricity was generated throughout the day and worse days were experienced during the period evaluated in this study.

In Figure 7, monthly electricity generation distribution in the Soğuksu solar power plant is given. Total electricity generation is revealed depending on the number of days with clear and cloudy weather affecting the electricity generation in the plant.

Figure 7. Monthly electricity generation distribution in Soğuksu solar power plant for a year



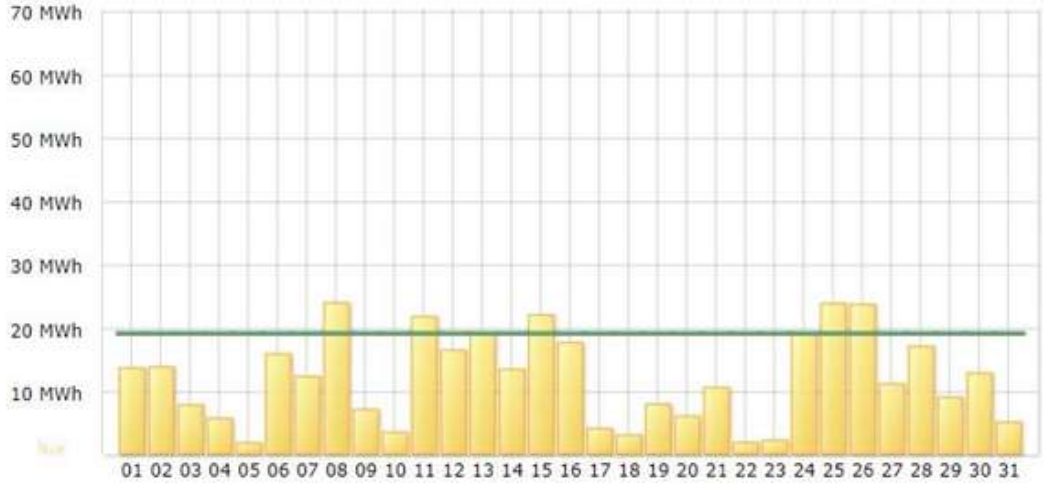
Total electricity generation of the plant is 10.7 GWh annually. The maximum electricity generation was observed on July with 1410 MWh. The minimum electricity generation was observed on December with 370.18 MWh and only 3.5% of annual generation was realized in December. From April to October, average daily electricity generation is higher than the targeted daily electricity generation. But from November to February, average daily electricity generation is lower than the targeted daily electricity generation. The best month is July. The number of days under targeted value is only 4 in this month. The most number of cloudy days was observed in December so the worst month is December. 24 days was under targeted value in this month. Numbers of days under targeted values in December and February are equal but the monthly electricity generation of December is lower.

Table 3. Number of days under targeted values according to months

Months	Average Daily Generation (MWh)	Targeted Daily Generation (MWh)	Number of days under target
April, 2017	36.67	31	10
May, 2017	36.13	34	12
June, 2017	42.33	35	7
July, 2017	45.48	34	4
August, 2017	41.29	30	5
September, 2017	37.00	31	7
October, 2017	27.04	26	12
November, 2017	17.98	24	19
December, 2017	11.94	20	24
January, 2018	15.10	22	21
February, 2018	14.97	25	24
March, 2018	25.27	26	15

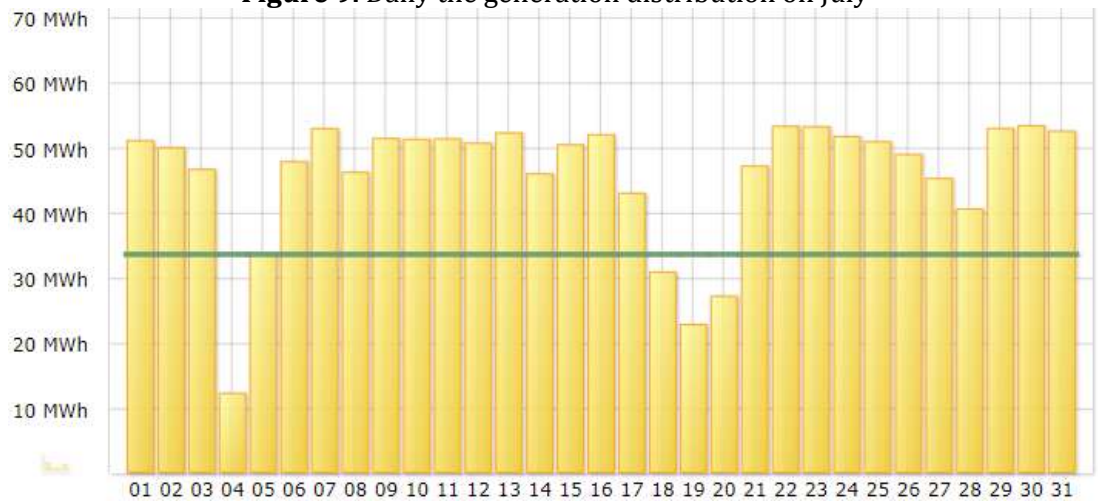
Numbers of days under targeted values with targeted daily generation values according to months are given in Table 3.

Figure 8. Daily the generation distribution on December



The daily amounts of electricity generation on December are given in Figure 8. As mentioned before the minimum electricity is generated in December with 370.18 MWh. Only eight days are close to the targeted value. The average daily production is 11.94 MWh for this month. Interpretation of the electricity generation values given in Figure 8 will show the effect of external influences on the solar power plant electricity generation such as winter season and clearness. The straight line shown on the figure indicates the amount of production target during system operation. This value is 20 MWh for December.

Figure 9. Daily the generation distribution on July



In Figure 9, the daily amounts of electricity on July in the Soğuksu solar power plant are given. As mentioned before the maximum electricity is generated in July with 1410 MWh. Only four days are under the targeted value. The average daily generation is 45.48 MWh for this month.

4. Conclusions

In this study, a full year performance of a solar power plant installed in Bursa was analyzed. As a result; it is possible to observe 7 MW in some instants. The number of clear sunny days is very low. Especially in winter, the effect of cloudy and rainy weather on the power plant is significant. The minimum electricity generation was

observed on December with 370.18 MWh and only 3.5% of annual generation was realized. 24 days was under targeted value in this month. The maximum electricity generation was obtained in July. Only four days are under the targeted value and 1410 MWh electricity was generated. Total electricity generation of the plant is 10.7 GWh yearly. From April to October, average daily electricity generation is over than the targeted daily electricity generation. From November to February, average daily electricity generation is lower than the targeted daily electricity generation. Finally, Turkey government has some effective actions in terms of renewable energy such as keep out of license the plants which are under 500 kW capacities. This condition also applies to solar power plants. However, community investment has occurred in parallel to this action. Especially in the grid connected power plant the generated energy is transferred to the grid. In other words, the proper grid conditions to which power is supplied are a prerequisite for the installation of the power plant. Therefore, the other result of this study is the necessity to strengthen the infrastructure of the grid.

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