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Original Research Article

Experimental examination of a thin-film photovoltaic panel power characteristics under constant load during October-March period in Mersin province

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ABSTRACT

In this study, the power generated by a thin-film photovoltaic panel was measured under real atmospheric conditions in Mersin between October and March. The experimental setup involves a stand with adjustable inclination around a single axis, current meter and voltage meter, pyrometer, and two computers on a mobile rack. The power generated was determined as a function of solar irradiance using the data recorded with three minutes intervals in each measured day, during the six months period. The average generated power, irradiance, and efficiency were calculated for each measured month using the data collected. The generated power and efficiency values are found to be different from that of the values provided in photovoltaic panel manufacturer specifications.

Keywords: Mersin; Solar Energy; Photovoltaic Panel

1. Introduction

Today, global warming and pollution have reached a level that threatens the vital activities in the world mainly due to the usage of fossil-based fuels as the primary source of energy. Therefore, the production, transmission and consumption of electrical energy that is compulsory to be used in daily life and in industry in a way that is optimally beneficial for both the environment and the public health and safety, have become one of the major challenges. One of the most prominent one among the renewable and clean energy technologies is photovoltaic technology, which enables the generation of electrical energy by using unlimited source of solar energy [1].

Photovoltaic panel manufacturers provide the electrical and performance specifications of the panel manufactured according to the conditions under which the radiation is 1000 W/m², the temperature is 25°C and the sunlight transmittance rate of the atmosphere (AM) is 1.5 under standard test conditions [2]. There can be significant differences between the conditions in which the manufacturer tests the panel and the actual conditions that the panel is operated, where the environmental effects are less controlled. These differences affect the performance of the photovoltaic panels. The energy production values of the photovoltaic panel can be determined more precisely by performing the tests on the panel in the relevant area where it will be operated. Environmental factors such as temperature, solar radiation level, and dust reduce the production values of photovoltaic panels.

In planning of production facilities, the values obtained in actual site conditions should be used for determining the efficiency, capacity, and cost elements of the facility. There can be significant errors in calculations using the photovoltaic panel specifications provided by the manufacturer. In the October-March period, when solar values fall and environmental conditions get worse, panel performance declines rapidly. Determination of the performance of photovoltaic panels in the October-March period, when their production capacity decreases, will be an important factor in determining the overall production capacity of the panel.

In the literature, numerous studies have been conducted regarding the performance of both thin-film photovoltaic panels in actual site conditions and in theoretical modeling [3-26]. The most important factor in the realization of solar energy investments is the production amount in October-March period, especially when the solar radiation values are low. In the literature, there is no study regarding the October-March period when the solar radiation values are at the lowest level.

In the present study, the data were obtained from the measurements performed in the October-March period, when the solar irradiation values are the lowest, by establishing the experimental setup at 36º 51’ 48’’ N and 34º 36’ 56’’ E coordinates at Toroslar district of Mersin province. By using these data, the production performance of the thin-film photovoltaic panel under the constant load during the October-March period was investigated.

2. Experimental Method

2.1. Measurement and Acquisition Systems

The data measurement and acquisition components are schematically shown in Figure 1. The experimental setup includes a photovoltaic panel placed on a stand with adjustable angle with the vertical axis (Figure 2), two multimeters to record current and voltage, bolometer to measure irradiance, computers, and bulbs on the voltage measurements were taken. The current and voltage values produced by the photovoltaic panel were measured with digital multimeters and automatically stored on the computer with three-minute intervals. The corresponding solar radiation was calculated for each current and voltage readings.

2.1.1. Stand with adjustable inclination around a single axis

Figure 2 shows the design of the adjustable stand whose inclination can be adjusted with an angle with respect to the vertical axis. The height of this stand was 1103 mm. Width of the external frame surrounding the panel was 1422 mm. 25 mm angle brackets were used in the frameworks. Diameter of the main supporting pipe was 173 mm, and the wall thickness was 3 mm. The locking and adjustment bars on the sides having a diameter of 25 mm were used to lock the stand in order to keep it at constant angle with the vertical axis. The optimum angle of the photovoltaic panel made with the horizontal plane in the south direction varies depending on the seasons. However, in this study, the photovoltaic panel was positioned with an angle of 25°, which is the standard angle used at commercial facilities.

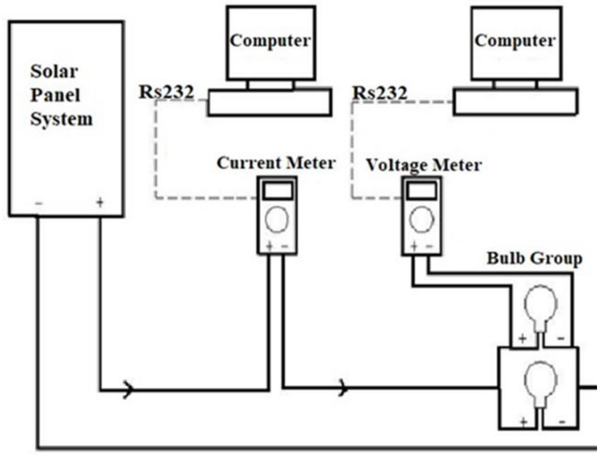

Fig. 1. Measurement and data acquisition components

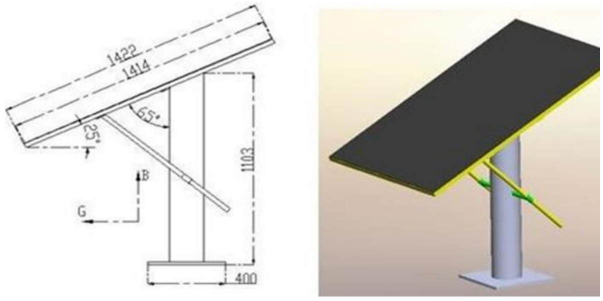

Fig. 2. Design of the adjustable stand

2.1.2. Carrier vehicle

Figure 3 shows general view of the photovoltaic panel and the data recording system. In order to ensure that the multimeters and computers used during measurements are kept together in a regular manner, a carrier vehicle that can be kept in the immediate vicinity of the panel was designed and produced. The dimensions of this carrier vehicle was (30 mm x 30 mm x 1030 mm) so that the computers and measurement equipment can comfortably fit in the carrier.

Fig. 3. A picture of solar panel and data acquisition system

2.1.3. Photovoltaic panel

In the present study, a thin-film MT 130 model photovoltaic panel was used. This panel has a size of (1414 mm x 1114 mm). The default tolerance of the MT 130 model photovoltaic panel, which can produce a maximum electrical power of 130 W, was specified as +/- 5W in power generation. Panel efficiency specified by the manufacturer was 8.25%. Figure 4 shows the current measurements as a function of voltage for different irradiances.

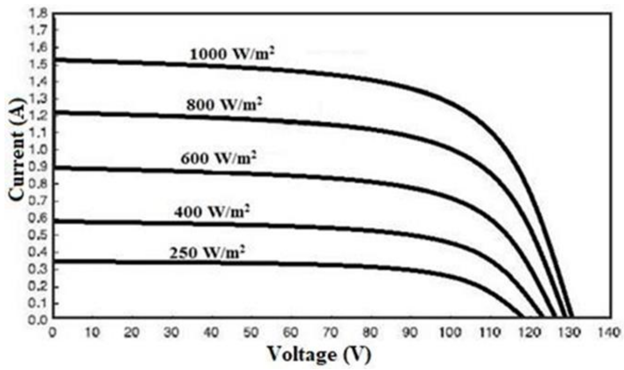

Fig. 4. Current versus voltage curves of the MT 130 photovoltaic panel for different irradiances

2.1.4. Current and voltage meters

In order to take current and voltage measurements produced by the panel at desired time intervals, a multimeters was used. The errors in voltage and DC current measurements are specified to be 0.08% and 0.2%, respectively. The current and voltage meters were connected to a computer via an RS-232 cable and the digital readings were automatically recorded on the computer using an interface program.

2.2. Analysis of uncertainties in experimental data

The precision method developed by Kline and McClintock was used for the error analysis of the data obtained by using the experimental methods [20]. According to this technique, the power values and the uncertainty rates of these values were calculated by using the current and voltage data produced by the photovoltaic panel.

3. Results and Discussion

3.1. Generated power

The average value of the generated power during the six months period reached the maximum value on 15 October 2014 and the minimum value on 22 January 2015. Figure 5 shows the evolution of power as a function of time during the days corresponding to the minimum and maximum power generation. As shown, the generated power on 15 October 2014 was maximum 100 W as specified by the manufacturer, while the measured power caused by radiation reached to a maximum of 1400 W. Similarly, on 22 January 2015, the specified power was maximum 50 W, whereas the measured total power caused by radiation was maximum 550 W. Low solar radiation value, rainy days and solar panel tilt and azimuth degrees effect production.

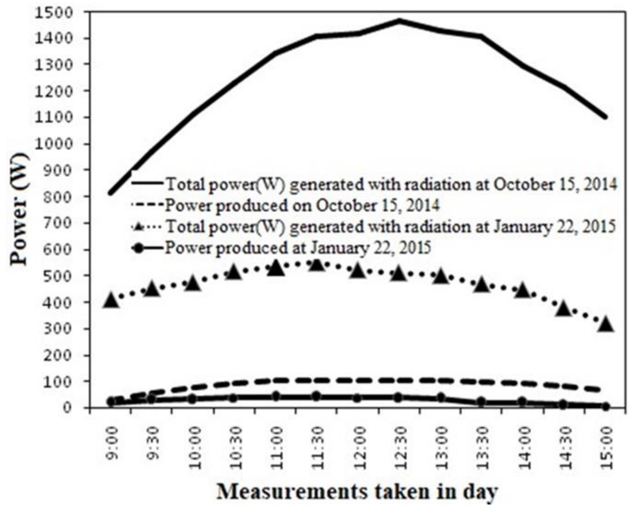

Fig. 5. Total power versus generated power relationship on October 15, 2014 and January 22, 2015

Figure 6 shows the uncertainty rate calculated for the days with maximum and minimum power production. The uncertainty rate was calculated to be between 0.18% and 0.27% when power production was maximum on 15 October 2014. When power production was minimum on 22 January 2015, the uncertainty rate ranged from 0.39% to 0.74%.

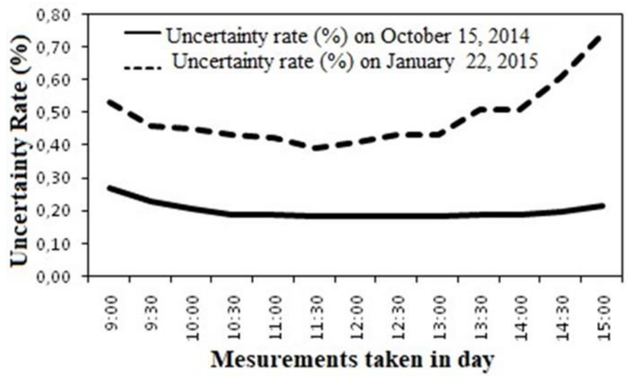

Fig. 6. Uncertainty rate in percentage as a function of time on October 15, 2014 (solid line) and January 22, 2015 (dashed line)

3.2. Monthly average power and efficiency

Figure 7 shows the average power and temperature values during six-month period.

The power generated varied from “52 W to 75 W”, with the lowest power measured in January and the highest power measured in October. During this period, the ambient temperature varied from “13 °C to 26 °C”, corresponding to lowest and highest powers generated, respectively. Since the ambient temperature was low in measurements period, it could not be determined that the temperature values affect production performance negatively. Ambient temperature is one of the important factor affecting panel efficiency.

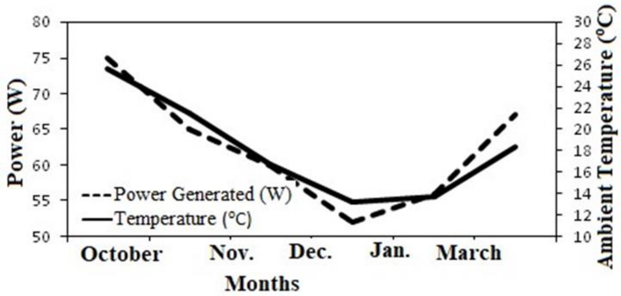

Fig. 7. Monthly averaged generated power (dashed line) and ambient temperature (solid line) shown for the six months period

Figure 8 shows the monthly averaged total power generated by radiation and efficiency during the six months period. The monthly averaged total power generated by the radiation ranged from "834 W to 1145 W", where the minimum and maximum powers are recorded in January and October, respectively. The monthly average efficiency of the panel varied between 6.24% and 6.55% with the minimum and maximum efficiencies observed in January and October, respectively. The reported efficiencies, obtained under site conditions, are approximately 20% below the panel efficiency (8.25%) specified by the manufacturer. This is because there are differences between the environmental conditions under which the panel was tested and the actual measurements taken. The environmental conditions such as low radiation levels during October-March period, wind, clouds, rain, snow, excessive pollution of the panel, and the stationary panel position were the main factors decreasing panel efficiency and thereby the power generation.

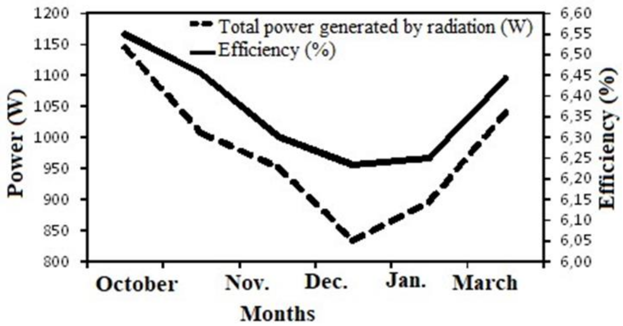

Fig. 8. Monthly averaged total power generated by radiation (dashed line) and efficiency (solid line) shown for the six months period

Figure 9 shows six-month average values of radiation and monthly average value of the uncertainty error rate. According to the graph, the monthly average radiation varied between "530 W/m² and 730 W/m²" as a result of the measurements made in this period. The minimum average radiation value belonged to January and the maximum average radiation value belonged to October. The radiation, which started to decrease in the October-January period, started to increase in the January-March period. The monthly average uncertainty error rate varied between 0.23% and 0.31% and it was inversely proportional to the radiation amount.

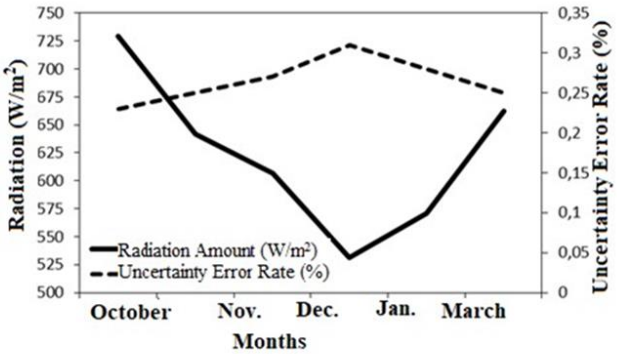

Fig. 9. Monthly averaged radiation (solid line) and uncertainty error rate (dashed line) shown for the six months period

4. Conclusions

In this study, the performance of a thin-film photovoltaic panel under a constant load at a fixed angle of 25° with horizontal plane was investigated experimentally under the site conditions during the October-March period in the city of Mersin. Accordingly, we have noted following observations:

- The most important factor affecting the performance of photovoltaic panels was the solar radiation value. As a result of the measurements, it was determined that the power generated by the panel increased as the solar radiation increased.
- The power generated by the photovoltaic panel varied between "52 W and 75 W".
- The photovoltaic panel showed maximum performance on 15 October 2014 and minimum performance on 22 January 2015.
- The most efficient month during the six-month period was October.
- The measured efficiency of the photovoltaic panel (6.25%-6.55%) was found to be approximately 20% lower than the catalogue value (8.25%).
- Performing the cost and capacity calculations made in solar energy investments with the catalog values can result in significant errors in the estimations. The operation efficiency especially in October-March period would reach the minimum levels.
- Nominal operations test conditions (NOCT) is similar than standard test conditions (STC) to real conditions.
- The uncertainty error rate of the current and voltage data obtained by the experimental method varied between 0.2% and 0.4%.
- The uncertainty error rate of the power produced by the photovoltaic panel varied between 0.23% and 0.31% with lower rates corresponding to high radiation levels and vice versa.
- The ambient temperature varied between "13 °C and 26 °C", which corresponds to the lowest and highest powers generated, respectively.

- During the measurement period, the constant angle of the panel affects the production value negatively.

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