Evaluation the Influences of Temperature, Dust and Shading on Photovoltaic System Performance

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Abstract The proliferation of the use of Photovoltaic PV systems, as one of the sources of electricity that comes from renewable energy resources, attracting the researchers to investigate on the factors that have an effect on the performance of it. This paper presents an analytical study for evaluating the performance of PV system that generates 2.5 kWp through the deployment of this system to supply the electricity for the Engineering Consultant office, of the College of Engineering at Wasit University, Iraq (32.497 N, 45.842 E). The evaluation is conducted by monitoring the pre-defined system which consists of 10 PV modules as an array of two rows. The system is supervised for six months from 1\textsuperscript{st} of Feb. until 31\textsuperscript{st} of July, to assess the impact of temperature, shading, and dust on its output power and performance. The PV array is omitted to 8˚ south-west, and 40˚ in elevation. The results shows that the PV array is operated at efficiency of 12.12\% and the maximum efficiency reached 13.01 during April. The average daily power of it, for the months from Feb. until July are: 1.347 kW, 1.421kW, 1.436, 1.215 kw, 1.045kW and 1.042 kW, respectively. The minimum average output power is recorded in summer season (June and July), because of the high ambient temperature in these months. The maximum reduction of power due to shading at 4 pm is 52.77\% in February followed by March 47.7 \% and April 22.93 \%. while the maximum reduction in efficiency due to shading were 51.82 \%, 44.71\% ,23.01\% in February, March and April, respectively. The reduction in power due to the dust accumulated after 54 days exposure to environments conditions was 7.88\%.

Keywords: Photovoltaic system, solar cells, solar energy, renewable energy.

1. Introduction

The use of photovoltaic systems, as a good alternative for supplying electricity from renewable energy resources instead of the generated electricity from fossil fuel is proliferated, that the PV systems have a role in reduction the global warming and pollution [1]. Also these systems can be deployed for supplying electricity to remote and rural populated villages [2,3]. Because of all the preceded reasons, these systems need to continues supervision, evaluation and assessment to its performance by means of output power and efficiency, through the investigation on the factors that have a direct effect on its’ work. Many researches were conducted to assess the effect of different climate conditions on the performance of PV.

2. The effects of temperature and irradiance

Solar cells are influenced by environments conditions. There are two important factors affected the solar cell performance, which are: ambient temperature and solar radiation. When the temperature of the ambient of the cell rises above 25°C, the power of the cell will drops due to decrease of output voltage with a slight increase in current, but when the value of solar radiation increases the output current increases significantly while the output voltages increase very slightly. Therefore, the increase and decrease in power and efficiency are directly related to these two factors. The nature of the drop and rise is understood by calculating the temperature coefficients of voltage, current and power. Power and voltage coefficients are negative because the voltage is dramatically reduced by heat and consequently
lowering the output power. While the temperature coefficient of the current is positive because as we mentioned, there is a very slight increase of the current with high temperature.

3. System’s description and components
Figure 1 presents the solar array under test. Which represents an off-grid 2.5 kWp PV system consists of 10 poly-crystalline modules, 250Wp (Euronet) each. The array is tilted at 40° and oriented toward south-west 8° azimuth at Al-Kut city, Iraq (32.497 N, 45.842 E). Each two modules in the array are connected in series to form a string, then the resultant strings are five pairs of panels connected in parallel. The experiment was done at Wasit University, College of Engineering. The inverter used in this work is (MUST PV18-5048 MPK, 5KVA, 4KW) including charge control. The battery bank consists of 4 batteries (FARBER SMF-VRLA, 12V, 100AH) are connected in series as shown in figure 2. The specifications of modules and inverter including charge control specifications are tabulated in tables 1 and 2.

![Figure 1: Off-grid PV array 2.5 kWp](image)
Figure 2: Inverter (right) and battery bank (left)

Table 1: Modules specifications presented by manufacture

| Specification       | Value                          |
|---------------------|-------------------------------|
| $P_{\text{max}}$   | 250W $P_{p}$                  |
| Tolerance           | $\pm 3\%$                     |
| $V_{mp}$            | 30.8V                         |
| $I_{mp}$            | 8.12A                         |
| $V_{oc}$            | 37.6V                         |
| $I_{sc}$            | 8.94A                         |
| Dimensions          | 1600mm*992mm*35mm              |
| NO. of cells in series | 60                            |
| Test condition      | 1000 W/m$^2$, AM 1.5, 25°C    |

Table 2: Inverter and charge control specifications

| Specification   | Value                     |
|-----------------|---------------------------|
| Model Name      | PV18-5048 MPK             |
| Rated power     | 5KVA/4KW                  |
| DC Input        | 48VDC, 93A                |
| AC output       | 230VAC, 50 Hz, 22A, 1φ, power factor: 0.8 |
|----------------|------------------------------------------|
| AC charge mode | DC Output: 54 VDC, 60A (max)             |
| Solar charge mode | MPPT Voltage range: 64~130VDC |
|                 | Max. Solar voltage (V<sub>oc</sub>): 145VDC |
|                 | I<sub>sc</sub> PV: 50A |
|                 | Max. Charge current: 120 A |

4. The methodology of the work
The measurements were taken from 08:00 am to 04:00 pm daily, for the period from Feb. 1st to July 31st. The measurements were including Irradiance, Ambient temperature, module temperature, and the output parameters (PV power and efficiency).

5. Efficiency of solar cell
The solar module efficiency (η) is the ratio between the output produced power "P" and the solar power "P<sub>solar</sub>" available on the panel surface "A<sub>c</sub>" [4]

$$\eta = \frac{p}{P_{solar}} = \frac{V \cdot I}{A_c \cdot G_t}$$  \hspace{1cm} (1)

Where V and I are voltage and current, respectively which represent the output power, A<sub>c</sub> is the surface area of module (m<sup>2</sup>), and G<sub>t</sub> is the total irradiance falling on module surface (W/m<sup>2</sup>)

6. Results and discussion
The ambient temperature during the period of the test was found to be in the range from 17ºC in Feb. to 47ºC in July as shown in figure 3. The heat generated in the module depends on the amount of solar radiation incidents on the module, conversion efficiency of module and the properties of the panel material (absorption and reflection). In this study the average difference between module temperature and ambient temperature ranges between 15ºC and 16 ºC approximately. During June and July, at the afternoon when the ambient temperature ranges from 44 ºC to 47 ºC, and when the wind is absence; the module temperature reached 70 ºC.
Figure 4 presents average PV efficiency at each month. The efficiency was gradually increased from minimum value 11.68 % in February (due to the cloudy and rainy weather which is leading to reduce the irradiance), reaching the highest value 13.01% during April., then the efficiency decay gradually from May, and showed the lowest value 11.36% in July.
**Figure 3**: Average ambient and module temperature

**Figure 4**: Average PV efficiency at each month
Figure 5, shows that the minimum output power through the six months, is recorded until an 08:00 am, that the solar irradiance is low, due to partially shading that caused by the building of College of Engineering from the right until about 08:00 am. In February through March, all of the modules become completely sunny at about 08:30 am. While in the period from April until July the panels becomes completely sunny at 08:00 am. After 08:00 am, the power is gradually rise due to the continuous increase in solar radiation up to 12:00 midday and reach its peak at 01:00 pm where the radiation is at its peak at this time. And then the power is gradually decreases due to the decrease in solar radiation. The average maximum module temperature lies between 12:00 midday and 01:00 pm (this is for the period of study), because at this time the sun is perpendicular on the surface of the earth and we get at the same time the highest incident solar radiation.

The average of daily PV power for six months from (February to July) was 1.347 kW, 1.421kW, 1.436 kW, 1.215 kW, 1.045kW and 1.042 kW respectively. The minimum average output power was in summer season (June and July), because the average module temperature in these months is about 58°C. The module temperature sometimes reaches 70°C, during the days without winds. The maximum average power were recorded at April, because the average module temperature is about 45°C, and this is lowers than in other months (May, June and July) and higher incident irradiance than (February and March). Figure 5 shows that the large drop in power is at 04:00 pm, because of the shading that happens at this time in February, March and April, as the shading pattern on the modules is shown in figure 6.
Efficiency does not take a linear pattern of ups’ and downs’ such as power, because it depends on two important factors; namely radiation and power. The more radiation, leads to increase in power, and this is causes a decrease in efficiency according to equation No.1. Since the ratio of the output power to the radiation is not constant (because the radiation leads to increase the temperature of the module, and when the temperature reaches a high value, the power begins to decline despite the high radiation) so the curve of efficiency will be different from power curve.

It is noted that the efficiency of the module which is shown in figure 7, is at the lowest value when the temperature at its’ peak from 12:00 midday to 01:00 pm except in the months of February, March and April, where the lowest efficiency is at 04:00 pm which happens due to the shading caused by the building of consultation office on the modules from left. In most months during the experiment, the highest efficiency is confined in two periods: the first period is in the morning from 08: am to 11:00 am, while the second period, is from 02:00 pm to 04:00 pm, because the temperature during these two periods is low compared to the period from 11:00 am to 01:00 pm in which the efficiency at the lowest value.

![Figure 6: Shading on modules at 4 pm (left) and 07:30 am (right)](image)

from figures 5 and 7, it can be seen that the highest drop in power and efficiency is at 04:00 pm in (February, March and April) due to the decrease in irradiance in shaded areas which is lead to a greatly reduced short circuit current. The difference in the level of radiation between the shaded and un-shaded areas is large, and the rate of decay in radiation intensity is approximately 23%. The highest reduction in power and efficiency due to the shading are in February, where the proportion of shading is almost one-third of the PV array area, and then the rate of shading decrease gradually during March and April.

| Month   | power   | efficiency |
|---------|---------|------------|
| February| 52.77 % | 51.82 %    |
| March   | 47.7%   | 44.71 %    |
| April   | 22.93   | 23.01 %    |
Figure 7: Daily average PV efficiency and module temperature
From Figure 8, it can be seen that the maximum incident irradiance for the six months is during the time between 12:00 midday and 01:00 pm while the minimum irradiance is at 08:00 am. The minimum average daily irradiance is at February, where it reaches about 560 W/m² due to the cloud and rain during the days in this month. While the maximum is at May where it reaches about 615 W/m², then the irradiance decreased gradually during June and July. This is because there is an error in omitting of solar panels which leads to loss of absorbing the solar energy in the summer season, especially (June and July). In order to get high radiation in the summer when the sun is high, the tilt angle of the system must be less than 40°, and azimuth must be 0° toward south exactly.
optimum tilt and azimuth must be 30° and 0°, respectively according to PVsyst software as in figure 9.

![Optimum orientation of PV array from PVsyst software](image)

**Figure 9:** Optimum orientation of PV array from PVsyst software

7. The effect of dust accumulated on PV

Figure 10 shows the state of modules after 54 days exposure to the different weather condition without cleaning for interval (from 9/5/2019 to 1/7/2019). In order to calculate the decrease in PV power due to the accumulation of dust and other pollutants on the panels, we took the data for a whole day before cleaning the modules and after cleaning them with water. All the modules were cleaned with water on 2/7/2019 as shown in figure 11.

![The modules are soaked with dust after 54 days (1/7/2019)](image)

**Figure 10:** The modules are soaked with dust after 54 days (1/7/2019)
From figure 12; it can be seen that the average daily output power in dirty module case is decreased by 7.88 % compared to the output power in clean module case.

Table 4 presents the reduction in power due to the dust with time exposure for previous studies that conducted by various authors, compared with our work results. from the table It is noted that the percentage of reduction in power in this work is acceptable compared with the rest of the results, except the result of ref. 5 that it is conducted in desert area (Saudi Arabia), and also the exposure period is longer.
Table 4: Effect of dust in previous studies and present study

| Authors             | Time exposure | Power reduction |
|---------------------|---------------|-----------------|
| Kaldellis et al. [4]| Four weeks    | 5%              |
| Adinoyi and Said [5]| Six months    | 50%             |
| Appels et al. [6]   | Five weeks    | 4%              |
| Ali et al. [7]      | Three months  | 16%             |
| Present work        | 54 day        | 7.88%           |

8. Conclusions

This paper presents the performance of an off-grid 2.5 kWp under various environment conditions (temperature, dust, shading, cloud and rain).

From the results, we can observe that the performance of the PV system is strongly dependent on the following:

1- the ambient temperature: where the increase of it leads to a decrease in efficiency of PV system from 13.05% to 11.01% during July.
2- the dust: where this factor affects the performance of the PV system, that it is reduced by 7.85% for 54 days.
3- the shading: where this factor has a significant effect on the performance of the PV system that it is reduced by 51.8% during February.

9. References

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