Effect of Shadows on the Performance of Solar Photovoltaic

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Chapter 27
Effect of Shadows on the Performance of Solar Photovoltaic

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Abstract This chapter investigates the reduction in photovoltaic (PV) performance due to artificial factors generated by covering each row and column in an array of a solar panel. This covering leads to an overall degradation of the energy produced by that panel. Experiments on the shadow effects of artificial cover, which leads to degraded power generation, were conducted and analyses performed. The obtained results show that the variation in the reduction of PV voltage and power produced from each cell depends on the shadow effect created. Shading causes a decrease in the output of PV, and this chapter's experiments illustrate the extent of that reduction. The difference between shading of cells in series, in parallel, and a combination of series and parallel with respect to time and temperature are also studied. Another factor examined is the artificial thickness of shadows on the surface that is causing the shading.

1 Introduction

As the human population continues to grow, the need for energy, electricity, and water is at an all-time high; energy factories have taken over the world using the best technologies to harvest natural resources. The problem with those natural resources is that most of them are nonrenewable sources; they are depleted. Renewable energy came to be an alternative energy source that could one day replace currently used sources like fossil fuels, that is, oil, coal, and natural gas.

Solar energy is an alternative clean and renewable energy source that could solve the environmental problems facing humanity. Many locations all over the world possess excellent sunshine conditions that make the use of photovoltaic (PV) power generation a viable option. However, PV arrays are affected by temperature, solar

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irradiation, and shading [1, 2]. Shading, whether complete or partial, is caused by clouds, adjacent buildings, towers, or trees; in addition, telephone poles affect cell temperatures and incident solar radiation [3, 4].

Photovoltaic arrays are characterized by the nonlinear instrumental variables (IVs) of PV curves. Stabilizing these curves under variable environmental conditions is a challenging task that becomes more complicated in partial shading conditions when PV arrays do not receive uniform irradiance [5, 6]. Because of the high initial costs of PV systems, the available solar energy must be optimally captured [7]. Although the improvement of PV cell design and fabrication is a crucial issue, the enhancement of the overall performance of PV systems carries the same importance [8].

Shading reduces the power produced by PV arrays and causes a safety hazard [9]. Under partially shaded conditions, the existence of multiple maxima in PV and IV curves makes the PV array characteristics more complicated. The problem in multiple maxima is in the reduction of the PV effectiveness at the maximum power point tracking (MPPT) systems [10]. The drawback of this condition is that it makes it impossibleto discriminate between local and global peaks and the output power reduced as a result [11].

Understanding the shading effects on a PV array's performance is crucial because such an understanding can facilitate amelioration of its design and efficiency [12]. Over the years, many researchers studied PV array characteristics and the influence of many design and operating factors [13–15]. However, studying the shadow effect can follow a methodology similar to those mentioned in the literature and can neglect a number of elements. For example, in this chapter, the effect of light intensity is overlooked. The factors discussed in what follows include time, temperature, and open-circuit (OC) voltage. Knowing that time is related to temperature but not having a particular quantity to relate it, two experiments were conducted to study the effect of shading over time and another under a certain temperature regime.

The primary objective was to explore the shading effect on PV cells to determine the degree to which it would degrade and how serious a problem cell shading is. In addition, it is important to understand issues like series, parallel, and series–parallel shading.

2 Experiments and Methodology

The PV cells used in the tests were multicrystalline PV cells. Table 27.1 illustrates the characteristics of the studied PV parameter.

The studied PV parameter is the OC voltage. Moreover, from the studies that were conducted, the following ideas were taken into consideration: PV parameters, effect of time and temperature, and type of material used to cover the PV. The study procedure was to apply the artificial effect and doing the experiments under

Table 27.1 Tested PV cell specifications

Module type	10 (17) P285*350
Peak power	10 W
Open-circuit voltage	22 V
Short circuit current	0.64 A
Peak voltage	17 V
Peak current	0.59 A
Maximum system voltage	600 V

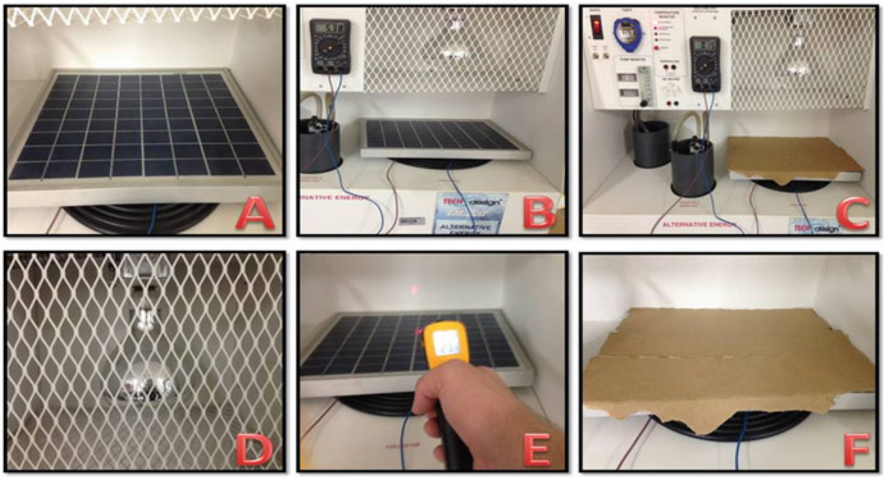


Fig. 27.1 Tools used in experiments: (**a**) PV, (**b**) PV location, (**c**) PV placed and covered entirely with paper boards, (**d**) light bulb, (**e**) laser-IR-temperature gun in process, (**f**) paperboard covering PV

standard testing conditions (STCs). The STCs have a temperature of 25 °C, solar radiation of 1000 W/m^2, air mass of 1.5, and wind speed of 2 m/s.

The following experiments were conducted:

1. Applying artificial shade on PVs for series, parallel cells, series–parallel shading, and alternative arrays registering the initial value of OC voltage and then waiting 1 min to calculate the value again for the OC voltage.
2. Applying artificial shade on PVs for series, parallel cells, series–parallel shading, and alternative arrays registering the value of the OC voltage when the surface temperature of he PV is 30 °C.

A multimeter was used to calculate the electrical quantity (OC voltage). Also, an infrared (IR) digital temperature meter gun with a laser pointer (surface temperature), artificial light bulb, and pieces of paperboard and, as well as a timer, were used in the experiments. Figure 27.1 shows the elements and tools used in the two experiments.

3 Results and Analysis

Following completion of the two experiments, for test number 1, the following results were obtained (Figs. 27.2, 27.3, and 27.4):

Figure 27.2 shows a clear though insignificant reduction in the value of the PV voltage, from an initial value of 19–17.99 V, which is around 1.01 V. When counting the effect of time, the difference is even smaller, with one covered cell having an open-circuit voltage of $V_{OC} = 18.74$ V, which is 0.26 less than the initial value.

Figure 27.3 shows that shadow on the parallel array combination caused a greater reduction than combinations in series or parallel. The smallest value of OC voltage was 12.53 V after 1 min, compared to 17.81 V, also after 1 min.

Figure 27.4 illustrates that the shadow on individual cells in parallel causes a reduction in output voltage close to the production of cells connected in series. If the time taken for cells in series is about 10 min, while for parallel it is about 4 min, this means that the parallel combination caused a greater reduction than cells in series when exposed for the same amount of time. Comparison of the four cells that are covered in parallel to the other four included in the series reveals that four cells in the series have 0.44 V reductions, while the four cells in parallel have 1.19 V reductions.

Fig. 27.2 Open-circuit voltage measurement for PV cells in series

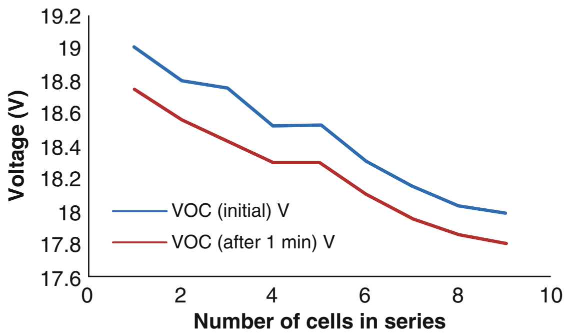
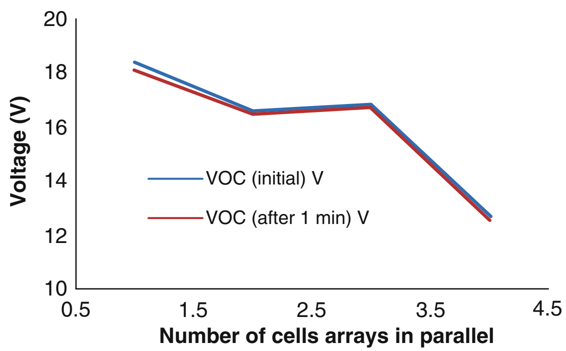


Fig. 27.3 Open-circuit voltage measurements for PV cells in parallel (entire columns)



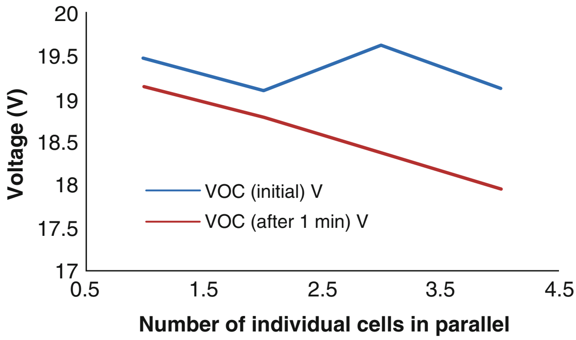


Fig. 27.4 Open-circuit voltage measurements for PV cells in parallel (individual cells)

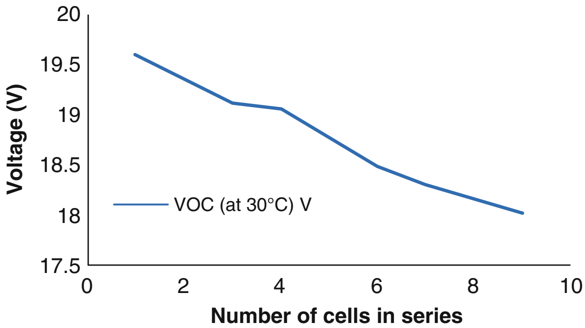


Fig. 27.5 Open-circuit voltage of PV cells in series

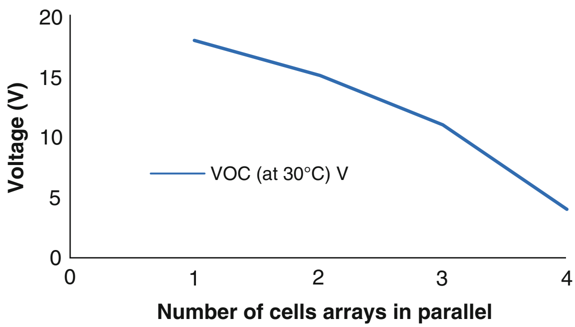


Fig. 27.6 Open-circuit voltage of PV cells in parallel (entire column)

For experiment 2 a different method was used. Instead of recording the time to measure the voltage, a surface temperature of 30 °C was chosen. Once the surface of the PV cell reached 30 °C, the voltage measurement was recorded. Figures 27.5, 27.6, and 27.7 illustrate the results.

Figure 27.5 shows a reduction in the OC voltage of 18.02 when nine cells connected in series are covered. This voltage reduction represents a noticeable decrease, but it is not extremely significant.

Figure 27.6 shows a clear and significant reduction in output voltage when almost all cells are covered (four rows in parallel). It is important to note that the

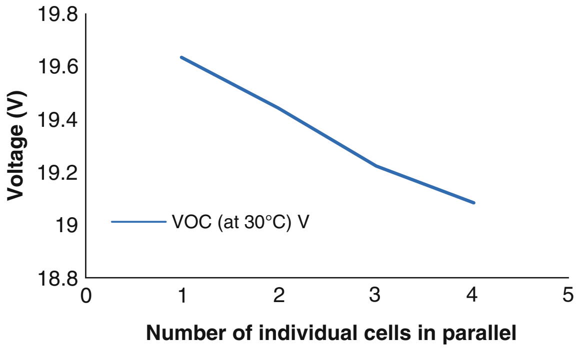


Fig. 27.7 Open-circuit voltage of PV cells in parallel (individual cells)

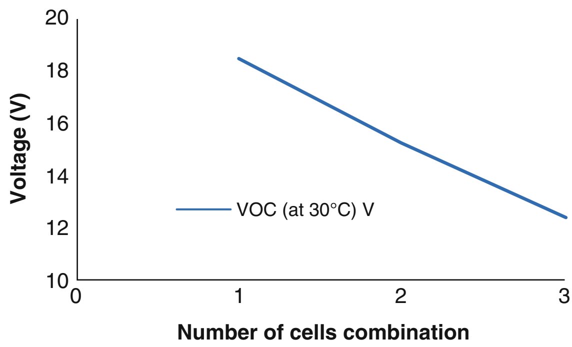


Fig. 27.8 Open-circuit voltage of PV cells in series–parallel combination

small amount of light reaching the cell forced it to produce these 4 V instead of dropping to 0 V.

Figure 27.7 illustrates that the reduction in OC voltage is not significant, but it does exist. It was approximately 0.54 V, which is more than the case with four cells in series, which was approximately 0.52 V.

Figure 27.8 also shows a clear and significant reduction in the output of the PV when four of its cells in series were covered and four of its cells in parallel were included.

4 Conclusion

Shadows covering PV cells do indeed have an adverse impact on PV output voltage; however, the reduction varies depending on how many cells are included and on the cells' combinations. The experimental results show that the largest decrease in output voltage of a multicrystalline PV occurs when parallel combinations of a PV cell are covered by shadows. At the same time, the smallest reduction occurred when the cells involved in series connection.

When nine cells in series were covered, the output dropped to approximately 2 V (with respect to time), but when four arrays of cells in parallel were covered, it fell to almost 6 V. This shows that it is important to compare the effects of shadows in connection with the combinations of cells covered.

References

1. Shaiek Y, Ben Smida M, Sakly A, Mimouni MF (2013) Comparison between conventional methods and GA approach for maximum power point tracking of shaded solar PV generators. Solar Energy 90:107–122
2. Tian H, Mancilla-David F, Ellis K, Muljadi E, Jenkins P (2013) Determination of the optimal configuration for a photovoltaic array depending on the shading condition. Solar Energy 95:1–12
3. Abdulazeez M, Iskender I (2011) Simulation and experimental study of shading effect on series and parallel connected photovoltaic PV modules. In: Proceedings of the 2011 seventh international conference on electrical and electronics engineering (ELECO), pp 28–32
4. Patel H, Agarwal V (2008) MATLAB-based modeling to study the effects of partial shading on PV array characteristics. IEEE Trans Energy Conversion 23(1):302–310
5. Ramaprabh R, Balaji M, Mathur BL (2012) Maximum power point tracking of partially shaded solar PV system using modified Fibonacci search method with fuzzy controller. Electr Power Energy Syst 43:754–765
6. Ishaque K, Salam Z, Syafaruddin A (2011) A comprehensive MATLAB simulink PV system simulator with partial shading capability based on two-diode model. Solar Energy 85:2217–2227
7. Kuznetsov IA, Greenfield MJ, Mehta YU, Merchan-Merchan W, Salkar G, Saveliev AV (2011) Increasing the solar cell power output by coating with transition metal-oxide nano-rods. Appl Energy 88:4218–4221
8. Chou CS, Guo MG, Liu KH, Chen YS (2012) Preparation of TiO_2 particles and their applications in the light scattering layer of a dye-sensitized solar cell. Appl Energy 92:223–224
9. Masters GM (2004) Renewable and efficient electric power systems. Wiley, Englewood Cliffs
10. Koutroulis E, Kalaitzakis K, Voulgaris NC (2001) Development of a microcontroller-based photovoltaic maximum power point tracking control system. IEEE Trans Power Electron 16 (1):46–54
11. Bruendlinger R, Bletterie B, Milde M, Oldenkamp H (2006) Maximum power point tracking performance under partially shaded PV array conditions. In: Proc. 21st EUPVSEC, Germany, pp 2157–2160
12. Koutroulis E, Blaabjerg F (2012) A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions. IEEE J Photovoltaics 2 (2):184–190
13. Alajmi BN, Ahmed KH, Finney SJ, Williams BW (2011) Fuzzy logic-control approach of a modified hill-climbing method for maximum power point in micro-grid standalone photovoltaic system. IEEE Trans Power Electron 26(4):1022–1030
14. Mahammad AK, Saon S, Chee WS (2013) Development of optimum controller based on MPPT for photovoltaic system during shading condition. Procedia Eng 53:337–346
15. Ramaprabh R, Mathur B, Murthy M, Madhumitha S (2010) New configuration of solar photovoltaic array to address partial shaded conditions. In: Proceedings of third international conference on emerging trends in engineering and technology, pp 328–333