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The Impact of Partial Shading on the Photovoltaic Outcomes

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Abstract**—** *Photovoltaic cells operate outdoors subjected to various climatic conditions such as solar radiation, temperature, dust and shade. The partial shadow resulted from clouds, dust, buildings and trees adjacent to the cell has a negative impact on the productivity of these cells. This paper examines the low photovoltaic performance caused by partial misrepresentation of solar panels. Partial shading leads to reduced cell productivity from electricity. The experiments were performed using artificial shading and the voltage and current of the cell were measured in each case. The results of the study showed that there is a difference in the generated voltage of the photovoltaic cell and the resulting energy depending on the type of shade and its relation to the area of the solar panel. The results showed that the effect of shadow on the group of cells connected respectively, parallel, and the mixture of the two cases completely depends on time and temperature.*

Keywords**—** *Shadow impact, potovoltaic, open circuit voltage, power, environmental parameters.*

I. INTRODUCTION

Human activities have caused great environmental problems for mankind as the excessive burning of fossil fuels has caused the emission of dangerous pollutants that caused climate change on the Earth's surface and caused global warming [1-3]. Fossil fuels and the development of arid roads, whether in incinerators or steam engines, and then internal combustion engines, are the greatest development of energy and transport [4-6]. Air pollution has become the biggest concern of humanity as a whole, and the available and appropriate solution is to use clean renewable energies that are environmentally friendly [7, 8]. Renewable energies are abundant and available around the world including wind power [9, 10], geothermal energy [11, 12], hydrogen [13, 14], biofuels [15, 16], fuel cells [17, 18], and solar energy [19, 20].

Solar energy is one of the most important of these energies as it is available most of the year and can be used in multiple applications, which is free and environmentally friendly [21]. One of the most important applications is the solar water heater for domestic and industrial purposes [22, 23], heating the air for comfort purposes [24, 25], Trombe wall for heating houses [26, 27], and heat storage using solar ponds gradient salinity [28, 29]. Solar energy is also used in water distillation and this application has begun to spread globally because distillation process consumes a high percentage of fuel [30-32]. Solar power has begun to take up space and power in power plants. Solar power stations are divided into solar chimney stations [33, 34], concentrated power plants [35, 36], and photovoltaic cells [37, 38]. Solar cells are superconductors that convert sunlight into a constant current that is converted to AC using a current [39]. This technique has become popular because of its flexibility in desert areas, semi-desert, mountainous and coastal [40, 41]. In addition to the possibility of connecting to the grid or use without linking to the grid [42]. These systems began to be manufactured and installed less than easy to spread. Photovoltaic cells work in the outside air exposed to different air conditions so they are strongly influenced by solar radiation [43, 44], atmospheric temperature [45, 46], relative humidity [47, 48], wind [49], and dust [50-52]. Solar panels receive solar radiation, part of which turns into electricity and most of it turns into heat, causing the solar panel temperature to increase [53, 54]. The high temperature of the cell causes its low productivity, so researchers have worked to reduce cell temperature using solar/thermal cell systems [55-59]. These systems pull the heat of the cell into a cooling fluid, whether air, water, nanofluid or PCM + nanofluid and produces better electrical energy with thermal energy that can be used in other applications [60-63].

The biggest challenge facing the expansion of PV cells is in dealing with non-linear cell output specifications, which vary with temperature and solar radiation intensity. The properties are more complex in partially shaded (shaded) conditions, such as clouds and dusty days [64, 65].

The electric energy generated by a group of solar cells linked to each other's depends heavily on the temperature of the cell and the solar radiation intensity at a particular place and time. The instantaneous shading affects the cell temperature and the solar radiation intensity falling on PV cells directly [66]. The highest electrical efficiency produced by the solar cell depends entirely on the solar energy available, and because of the cost of the initial constructions of the high solar cell system it needs to reach the panels as much as possible [67]. The shading not only causes a decrease in the generated electrical power but also causes potential safety hazards [68]. An optimal understanding of the effect of shading on the performance of solar cell systems will result in improved system design and increased electrical efficiency. Solar cells operate under different conditions, so the efficiency of the system is usually fluctuating and depending on weather conditions [69].

The shading can change daily from one moment to another causing a clear change in the energy generated by the solar panels [70]. This is a legitimate concern for operators of such systems. Disinformation can occur on a daily basis and cause the output of the photovoltaic cell to fluctuate and its productivity becomes variable due to crossing parts of the instantaneous cloud [71]. The geographic diversity of the areas in which the units are erected and constructed must be measured based on geographic diversity and linked to the time line to reach the best design of the solar system [72]. Many researchers have studied drag speed to improve the accuracy of mathematical correlation models created for this purpose [73] (Hoff and Perez, 2012). The results of the studies showed that the speed of the drag motion depends on the relative direction of the motion of the drag [74].

The aim of this paper is to evaluate the impact of partial shading on the PV outcomes practically. For this purpose, a PV system was used inside laboratory to control the environmental parameters from interfere with the shading effect.

II. EXPERIMENTS AND METHODOLOGY

A multi-crystalline PV panel was used in the practical tests, which were conducted indoor. The lab tests helps in reducing interfere of external parameters. So, in this study, the temperature was maintained at 25°C, Solar Radiation was maintained at 1000 W/m^2 using projector lights. The relative humidity was maintained at 45%, and no air movement was experienced inside the lab. By these conditions, the only variable affects the PV panel is the shadow. Table I illustrates the studied photovoltaic panel properties.

TABLE I. The tested PV cells specifications.

PV panel Type	10(17) P285*350
maximum Power	12 W
Open circuit voltage	20 V
Short circuit voltage	0.67 A
maximum voltage	19 V
maximum current	0.62 A

The voltages and current were measured using voltmeter and meter. Experiments were maintained in standard test conditions for photovoltaic cells (25°C and solar radiation of 1000 W / m^2). Multi-meter was used to measure the electrical voltage. Also, the digital infrared pistol was used with laser pointer (surface temperature), artificial light bulb, and finally cardboard parts in timer.

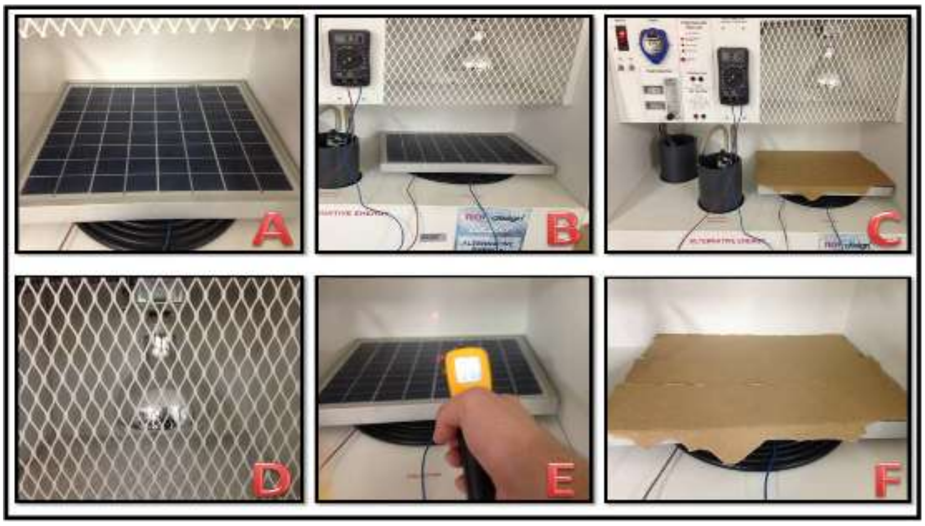

Fig. 1. The used apparatus in the tests: (a) the used PV, (b) the PV location, (c) the PV placed and covered entirely with the paper boards, (d) the light bulb, (e) the laser-IR-temperature gun in the process, (f) the paperboard covering the PV.

The experiments were divided into the following:
1. Apply a partial artificial shadow to the photovoltaic cells that are tied respectively, in parallel, and connected to both the parallel and the parallel. The cell output is recorded from the voltage and the current.
2. Raise the temperature of the atmosphere (inside the laboratory) to 30°C, replaying the tests a previously mentioned.

III. RESULTS AND DISCUSSIONS

Figures 2, 3 & 4 show the results of test number 1. Fig. 2 shows that photovoltaic voltage for photovoltaic cell connected in series is clearly reduced but not significant. One cell was partially covered. The open circuit voltage decreased from 19 volts to 17.99 volts, about 1.001 volts. When the effect of another factor was introduced, which is the time, the amount of decrease is less as the open circuit voltage was at VOC=18.74 volts, less than the zero-shadow state of about 0.26 volts.

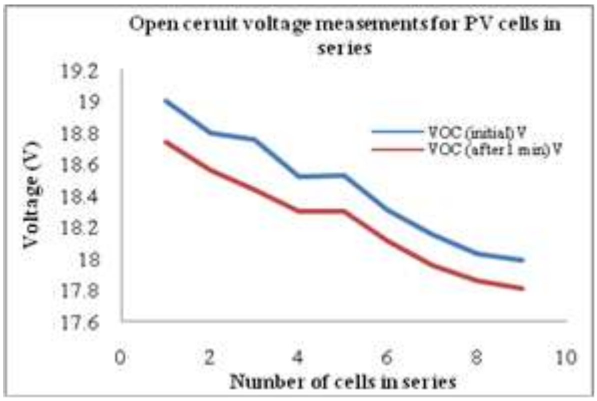

Fig. 2. The open circuit voltage measurement for the PV cells in series.

Fig. 3 shows that the application of shade on a row of parallel PV cells causes a greater reduction compared to the case of PV cells connected in series. The lowest voltage value in the case of the parallel-bound cells was 12.53 volts after 1

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minute compared to the case of the series connected cells with a 17.81 volt difference after 1 minute as well.

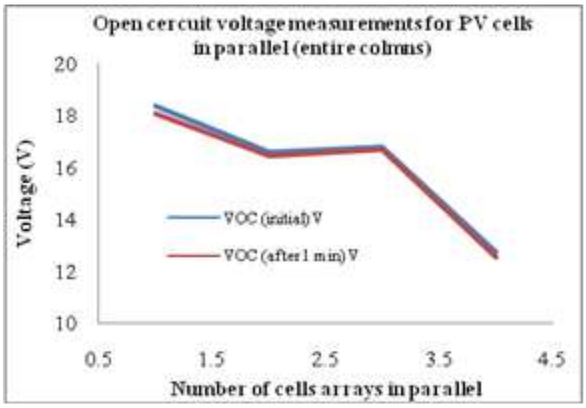

Fig. 3. Open circuit voltage measurements for PV cells in parallel (entire columns).

Figure 4 shows that the presence of shadow on individual cells in a group of cells bound in parallel has a low voltage difference close to the state of the cells in the linked series group. However, when the time factor is taken into account, the time taken by the series connected cells to reach the maximum voltage is about 10 minutes, whereas in the second case, the time needed for the parallel cells reach the maximum voltage is about 4 minutes. This result means that the parallel cell group causes a decrease in the productivity of the associated cells respectively when exposed to shade for the same period of time. When comparing the group of connected cells in parallel with the associated cells respectively, the resulting cell voltages respectively decreased by 0.44 volts while the parallel cells were reduced by 1.19 V.

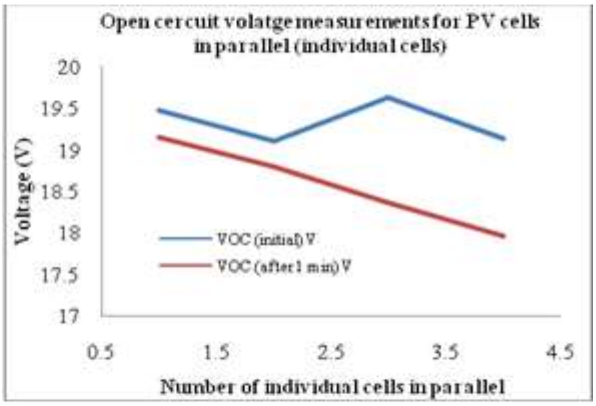

Fig. 4. Open circuit voltage measurements for PV cells in parallel (individual cells).

For the second case, the laboratory temperature was raised to 30°C instead of the time recording of the voltage measurement. The open circuit voltage decreased as shown in Fig. 5 to 18.02 V when the cells are connected in series and partly covered. This decline in the open-cell effort is evident in the figure, but in practice it is not very important.

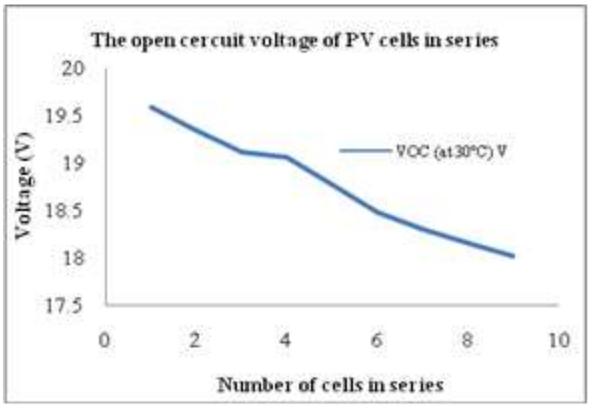

Fig. 5. The open circuit voltage of PV cells in series.

When almost all cells were fully covered, a large and clear decrease in the open-circuit voltage generated as shown in Fig. 6. Here, we must note that a small amount of light is certainly reached to the cell surface and caused a voltage difference of 4 volts instead of 0 volts and prevented the power from cut off. This case means that the solar cells will work in cases of severe shade caused by dust storms or dense clouds, but a low rate of productivity.

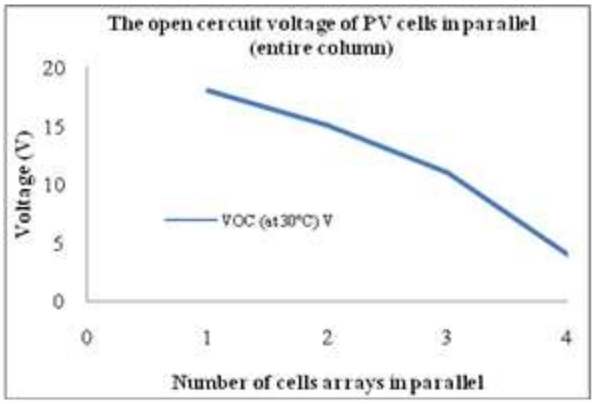

Fig. 6. The open circuit voltage of PV cells in parallel (entire column).

In the case of linking the cells in parallel and subjecting partial shadow on its surfaces, there is a significant decrease in the open circuit voltage of the cells as shown in Fig. 7. This decrease was about 0.54 volts, which is greater than the state of connecting the cells in series, as the resulting open circuit voltage difference was about 0.52 volts.

When exposing the array of parallel connected cells to a complete shadow, there is a significant and clear decrease in the open circuit voltage generated as shown in Fig. 8.

IV. CONCLUSION

Photovoltaic cells are located outside or above the building roofs exposed to all kinds of environmental factors, including the shadow caused by clouds or dust or even the shadow of neighboring buildings. In this study, the effect of shade on the open circuit voltage variation of the cells connected in series and parallel in the laboratory was examined to control other environmental conditions such as temperature, solar radiation, relative humidity, shade degree.

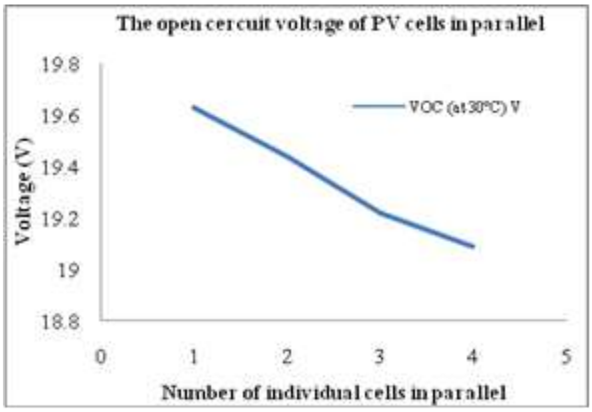

Fig. 7. The open circuit voltage of PV cells in Parallel (Individual Cells).

The results of the study show that the shadow when covering the photovoltaic cells causes a clear reduction in the open circuit voltage, resulting in a negative effect on the cell generated power. The effect of shade on solar cells varies depending on the number of cells involved in the group and how they are linked (in series or in parallel). Experimental results showed that the decrease in the open-circuit voltage generated by the shadow is greater in the case of the photovoltaic group bound in parallel. The partial shade of the cells bound in series caused a reduction in open circuit voltage of 2 volts (as far as time is concerned), but when the array of cells bound in parallel and subjected to the same shadow, the open circuit voltage drops by about 6 volts. These results indicate the importance of reducing the effect of shade on the cells and when designing a system should be put shadow effect in mind.

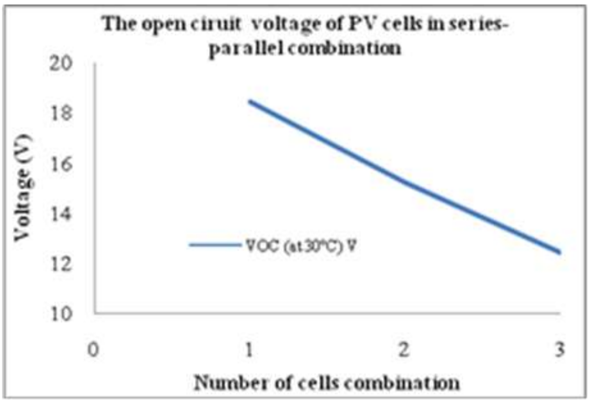

Fig. 8. The open circuit voltage of PV cells in series-parallel combination.

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