Sustainable Energy, 2020, Vol. 8, No. 1, 1-5
Available online at http://pubs.sciepub.com/rse/8/1/1
Published by Science and Education Publishing
DOI:10.12691/rse-8-1-1

Review of Recent Advances of Shading Effect on PV Solar Cells Generation

Qasim A. Alabdali[1], Abdulwahab M. Bajawi[2], Ahmed M. Nahhas[3,*]

[1]Calibration and Measurements Center, Ministry of Defense, Taif, Saudi Arabia
[2]Department of Distribution and Maintenance, Abaja Contracting Company, Jazan, Saudi Arabia
[3]Department of Electrical Engineering, Umm Al Qura University, Makkah, Saudi Arabia
*Corresponding author: amnahhas@uqu.edu.sa

Received June 09, 2020; Revised July 10, 2020; Accepted July 19, 2020

Abstract This paper presents the recent advances of the shading effect on the photovoltaic (PV) solar cells generation. In addition to the on-site environment which affects the performance of the PV module, the impacts of shading have important effect on the energy supply capacity. The shading effect is generally caused by inter-row configurations of the PV generator, cloudy disturbances, buildings and trees. In this paper, we investigated of different types of the PV module at different shading levels. The characteristics of the I-V acquired were assessed via the Bishop model, and the total output power of the PV module with the power losses.

Keywords: *PV, solar, cells, renewable, shading effect*

Cite This Article: Qasim A. Alabdali, Abdulwahab M. Bajawi, and Ahmed M. Nahhas, "Review of Recent Advances of Shading Effect on PV Solar Cells Generation." *Sustainable Energy*, vol. 8, no. 1 (2020): 1-5. doi: 10.12691/rse-8-1-1.

1. Introduction

In different areas of the world, the solar power generation is growing rapidly, powered by the cost savings, economic opportunities, and the need to meet energy demand growth. Meanwhile, the fossil fuel dependency is being reduced. However, several challenges must be dealt with to allow its successful deployment [1]. In the realistic PV power generation network, a PV array's total maximum output capacity will decrease when one or more PV modules in the array are partially shaded. The clouds or the buildings may cause partial shading. It should be noted that the partial shading will result in a hotspot that damages PV cells. How to tackle the reduced performance of PV systems due to partial shading has therefore been a hot topic of research. Recently, a lot of literature has been published to reduce the negative effects of the partial shading [2]. Some of the world's solar-energy-rich spots such as the Middle East and the Arab Gulf are suffering from climate obstacles like dust. Due to the solar radiation available, solar systems such as PV panels are attractive for these areas. On the other hand, dust can be a significant impediment to the activity of solar panels in two ways:

i. Over time the solar system accumulates.
ii. Presence in the Solar System environment.

In both cases of the dust, most of the solar radiation available will be spread and absorbed by dust particles which are a disadvantage for solar systems. The dust is impossible to be stopped in the atmosphere. However, the problem of dust accumulation on solar systems (mainly solar panels) can be mitigated by using technological developments such as scheduled cleaning methods and special panel covers [3].

2. I-V Characteristics of PV Cells

The general circuit model widely used to describe the electrical behavior of a photoelectric cell is the only diode model as shown in Figure 1.

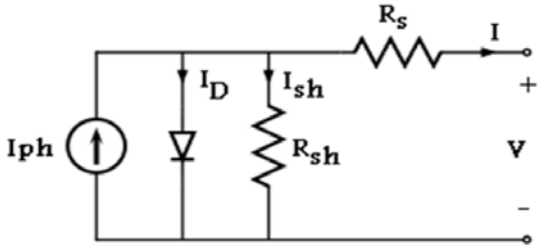

Figure 1. Equivalent circuit of PV cell [4]

The I-V characteristic of the PV model is represented by the equations [4]:

$$I\,ph = Id + Ish + I \qquad 1.1$$

where:
I is the output current [A]
I_d is the current of parallel diode [A]
I_{ph} is the photo current [A]
I_{sh} is the shunt current [A]

The literature on the effect of shading on the output power of the PV array is plentiful, with studies focused on the entire I-V [5]. The open circuit voltage, short circuit

current and various loss sources are found in conventional models of the PV modules or arrays in the form of shunt and series resistors [6]. The PV module has two curves: The current and voltage and the power and voltage are shown in Figure 2 [4]:

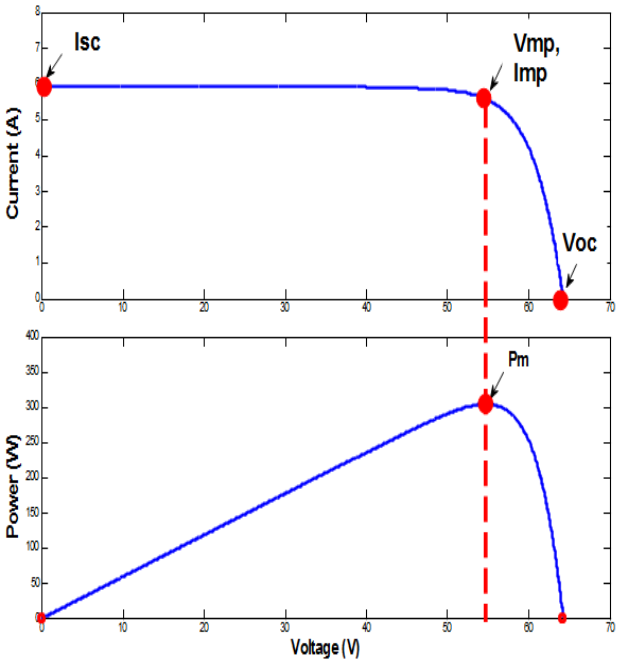

Figure 2. PV module curves under STC (25°C and 1000W/m^2) [4]

3. Reasons for Shading.

Various factors can cause the shading of the solar module and can be removed during the design phase. However, most of them begin to appear after a long period of activity, such as forests or future folds. It happens very often, but even those negative outcomes can be effectively restricted. Dust deposition on the solar PV system modules is a natural process. This dust reduces the radiation entering the solar cell and causes losses in produced electricity [15]. The most frequent explanations for shading of the PV cells are as follows [13]:

1. Landscape features, skyline, trees or posts, which already exist or will occur during the installation's "service life".
2. Construction elements; e.g., chimneys, dormers, doors, waves, or earth installations.
3. Ice, dirt, leaves, excrement for animals.
4. birds, animals.

The performance characteristic of the PV module is nonlinear and very dependent on the temperature and solar radiation (irradiation), making it very complicated to evaluate MPP. Additional issue arises if irradiation is not uniform in the entire PV network due to PSC. The PSC reduces the strength of the PV systems significantly [16].

4. MPPT

There are scientific studies for developing and increasing the energy through the renewable energy sources. Those are used in standalone and grid-connected systems. First, it developed mechanical systems that transfer the PV panels to receive full solar radiation. Another type of tracker, known as MPPT, is based on shifting the current or PV voltage to optimize power [14].

The PV module's efficiency has been extensively studied with respect to the impact of shading. The MPPT techniques can be used to reduce shading impact losses that allow global maximum power point extraction, system architectures, topology converters and configurations for PV arrays. One of the solutions considered in this paper for the effect of shading is the PV array configuration, which can substantially reduce losses associated with shading [7].

5. Impact of Partial Shading on PV Performance and Reliability

Another dominant environmental phenomenon is the partial shading condition (PSC), which significantly impacts the PV output. This phenomenon is triggered by occasional deposition of dust, some of the shadows that clouds make, trees surrounding it, buildings etc. modules Above. The interesting Studies of the negative impacts of the partial shading and its mitigation techniques are very important for future of the efficiency of the PV, because partial shading condition not only affects the PV output but also its reliability [8]. In series and parallel combinations, the PV cells are connected to generate desired photon current at the correct voltage. The cells connected in series must hold the same current; not all of them produce equal photocurrents even in events such as partial shading. The shaded PV cells are reverse biased in these situations and act as a charge to the fully illuminated cells, storing power instead of producing it [8]. The PV array output power is reduced due to mismatch loss which is the difference between the PV array row output power due to partial shading conditions (PSCs). Many current topologies use semiconductor or diodes to reduce these losses [9].

6. Mitigation of Impact of PSC

The most common measure used to prevent shaded cells thruogh reverse breakdown under partial shading condition is connect a string of the PV cells with a diode as parallel and bypass reverse bias current and avoid creating a hot spot in the shaded cells as shown in Figure 3 [8]. In order to reduce the additional cost of the diode, usually one diode is linked to a group of about 20 cells in an anti-parallel manner to limit the reverse fully shaded cell. Unlike other active by-pass circuits previously suggested by Bauwens and Doutreloigne, this method required no control circuit or power supply. However, the bypass arrangements described above limit the amplitude to reverse bias voltage and hotspot temperature; these result in several peaks in the characteristics I-V and P-V.

This makes the method of MPPT complicated. The following paragraph briefly discussed the various MPPT algorithms developed by researchers [8]. Generally, the connection of the bypass diode with PV cells is parallel, its useful to reduce shading effects on P-V, I-V curves. Parallel bypass diodes attached to four sequence linked

cells. Under normal conditions bypass diodes, where the PV module is not affected by colors. When a cell is shaded, the diode will start running and pass the PV cell and thus bypass the shaded cell [4].

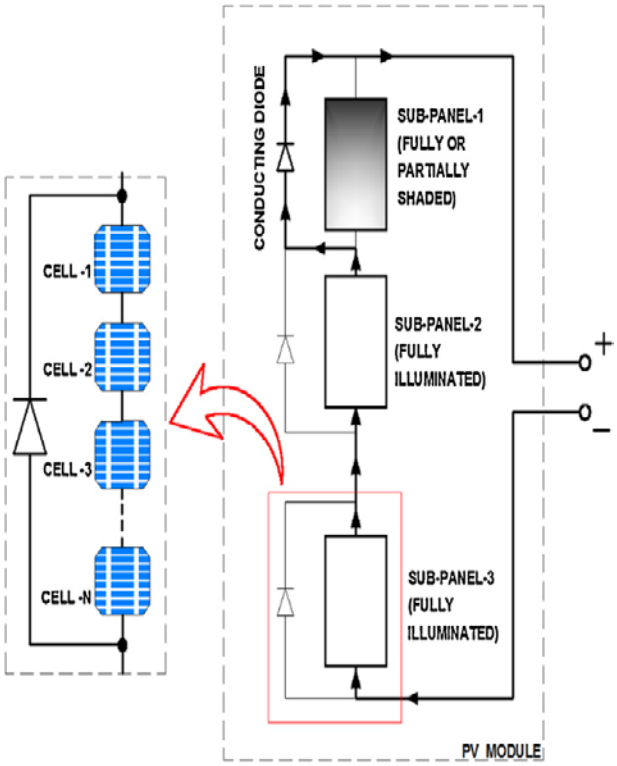

Figure 3. Power flow in PV module under PSC [8]

7. Tilting and Orientation

Techniques for construction, environment and climatic condition are essential factors to be considered to determine the optimal inclination angle of the PV plants [17]. The sun monitoring can be determined by the number and the direction of the axes used to monitor the sun. The single-axis observation is the sun observing system that rotates a single axis to almost follow the direction of the sun. It brings major improvements in efficiency on static surfaces. The dual tracking rotates two axes separately to precisely match the sun direction [17]. The single axis sensor observes the sun from East to West throughout the day; the dual axis tracks the sun during the day, from East to West and from North to South during the seasons of the year. Figure 4 shows the seasonal tilt angle.

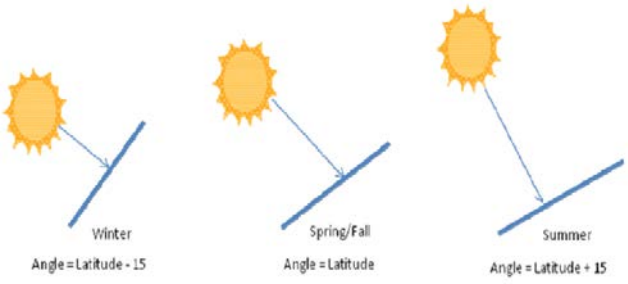

Figure 4. Seasonal tilt angle

8. Passive Emitter Rear Contact (PERC)

The PERC cells incorporate an additional rear dielectric layer that reflects light that did not generate electricity as it initially passed through the CSPV cell back into the CSPV cell. There is, therefore, another opportunity for the CSPV cell to absorb this light. The PERC cells have a higher efficiency, and improved performance in certain conditions, such as low light and high heat conditions [11]. The main difference between the PERC cells and normal solar cells is the presence of the passivation layer on the back surface of the cell, and this layer is a substance present on the back surface of the cell that provides three benefits regarding the efficiency of the solar cell:

1. Dimmable across the cell.
2. Reducing re-union processes for electrons.
3. Reducing thermal absorption.

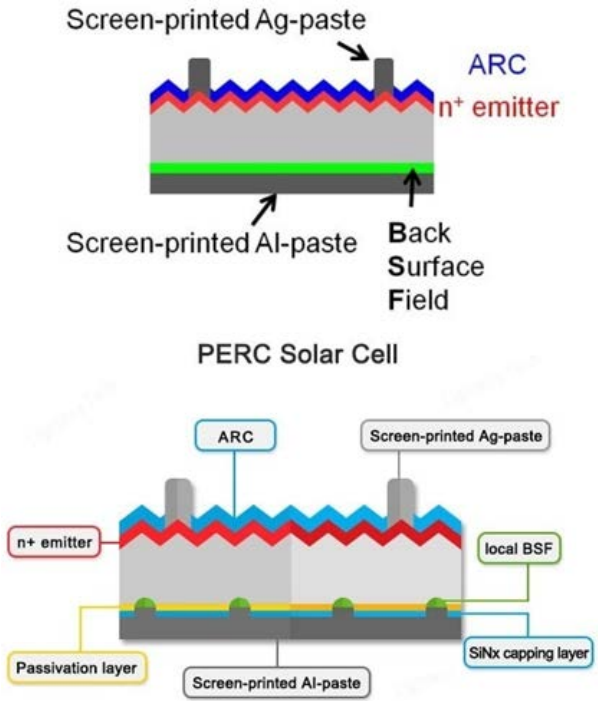

Figure 5. Difference between standard and PERC cell [11]

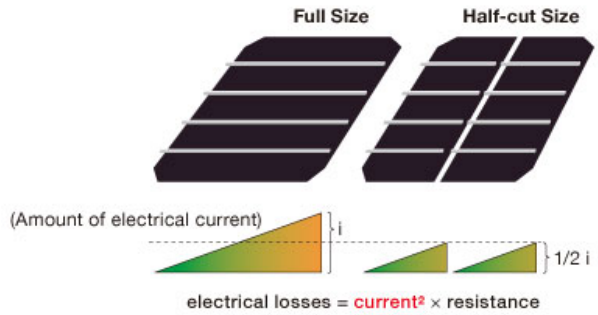

Figure 6. The value of the losses [12]

The energy in the sunlight is the sum of energies of different wavelengths. Therefore, the solar cell should have a good spectral response (the ability to absorb light rays with a different wavelength of radiation). Figure 6 shows the difference in the spectral response between a normal solar cell and a solar cell of type PERC [11].

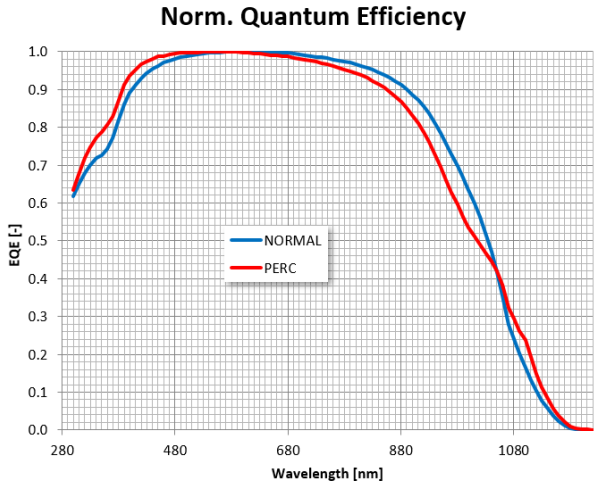

Figure 7. Spectral response between a normal solar cell and a solar cell of type PERC [11]

9. Half Cut Cells

The half-cut cells of the solar cells are obtained from mono or poly solar PV cells, which are completely cut in the center exactly by laser. On the other hand, the half of the solar cell technology offers several benefits compared to full normal solar cells, the most important of which is the increase in performance and increase in endurance. The half-cell technology provides an increase in the efficiency of solar panels that improve production value. On the other hand, these cells are more able to withstand shocks compared to normal full cells, because they are smaller in size, which makes them less prone to cracks and breakage. In general, despite the high price of these panels today, the investor can achieve a better return on investment, especially in places where it is restricted by space in terms of breadth or high cost of land, and in terms of shading, as if passing over the place of installation of the system electrical lines [12]. The half-cell technology improves the performance of solar panels:

• Reducing resistance losses:

Solar panel losses decrease as a result of the cells being cut in the middle and how they are assembled. The fact that the losses are proportional to the square of the current, so cutting the cells in the middle and weighing them from the value of the passing current in half, and thus reducing the value of the losses by a quarter as shown in the following Figure 7:

• Improved bearing capacity for shading:

The half solar cells are characterized by a high tolerance of shading, not only because the cell is cut in the middle because it is due to the different conduction method. The cells are arranged in rows and bound together in traditional panels made of whole cells [12]. For serial communication, if a single row cell encounters shading and does not produce energy (for example, a hotspot), then the row that contains the entire shaded cell stops producing power. In general, there are three rows of cells in normal panels, so for devices, we lose a third of the plate's ability to produce energy when one row stops production.

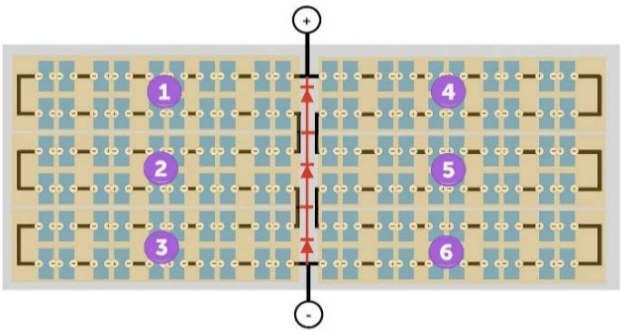

Figure 8. Showing how the normal cells in the solar panels are serially connected and form three lines [12]

Although the half-cells are connected sequentially as well, cutting cells in the middle leads to a doubling of the number of cells on the solar panel (120 cells instead of 60 cells in a panel consisting of whole cells, for example), which in turn doubles the number of rows of cells on the plate Solar. By doubling the number of rows (6 instead of 3), when shading one cell from one of the six rows, this row will stop producing energy, and therefore the productivity of the board will decrease by one sixth. This loss value is half the cells in the half cell panels, compared to the whole cell panels.

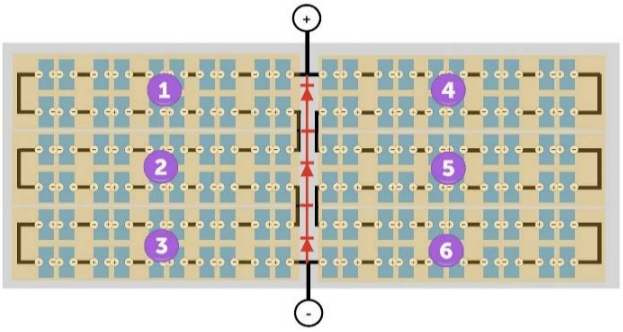

Figure 9. Showing how to connect half of the cells [12]

It is better not making half of the connected cells serial, as in panels consisting of normal cells, due to the disproportionate voltage generated by the plate with the batteries and the adapter.

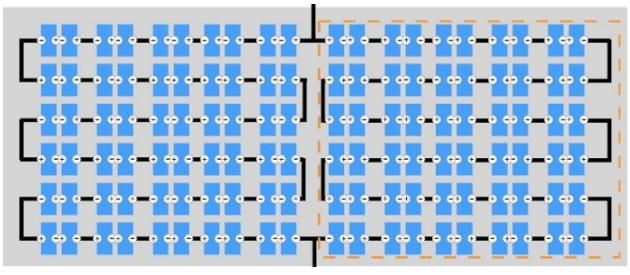

Figure 10. Making half of the connected cells serial [12]

Whereas, for the half-cell plate to function similarly to a regular plate, the connection must be done differently, instead of connecting 120 cells in a row, the plate is divided into two groups of 60 cells, each operating at a voltage of 30 volts. Since the two groups are connected to the branch, the plate voltage remains equal to the voltage of one group which is 30 volts.

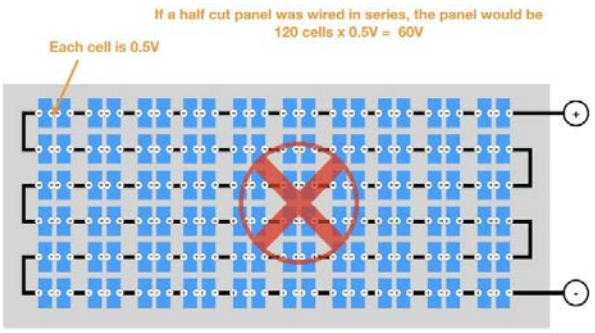

Figure 11. The correct half-cell conduction and how voltage is distributed across cells [12]

It has contributed effectively to raising the efficiency of solar PV panels, and production does not require many additions or complicated manufacturing processes, as they are basically normal solar cells cut in the middle. studies show an increase in the half cut of cells in the market in addition to expectations for an increase in this share in the future. The forecasts in the following chart as solar panels made with half cut-cell technology is expected to account for a quarter of the global panels production by 2022 [12].

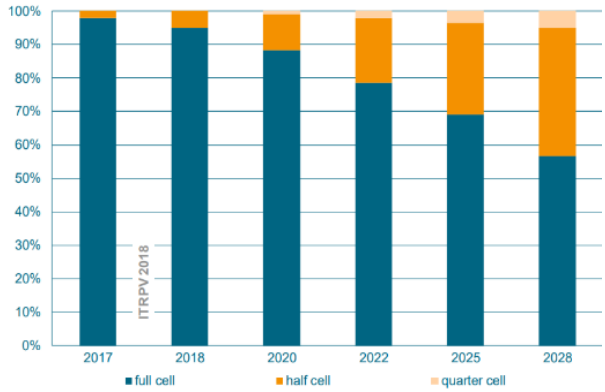

Figure 12. Different cell dimensions in c-Si modules [12]

10. Conclusion

Researchers have been working to increase the efficiency of renewable energy systems for around 20 years, and the MPPT is one of the areas that has drawn the interest of many scientists as it is. The most effects of efficiency of the PV installation factors for example direction of angle, surrounding area and surface of the PV system also the PV module output significantly affected by atmospheric elements like wind, humidity, temperature and deposition of dust. A variety of mitigation strategies have been discovered to minimize dust settling on the surface of the PV module concentrating on discovering new algorithms to obtain as much power from the source. Since half a century ago the Studies traced relating to environmental impact on PV production, but some of research papers show its relevance and importance in improving the performance of PV projects. The shading of the PV systems adversely impacts the current value. Shading of and evaluating the PV installations is not a simple task. The impacts should hard to valuation or forecast. Every project for installation must be evaluated for the probability of various forms of shading to mitigate the potential for its incidence and the impacts on the process of production.

References

[1] Belhaouas, N., Cheikh, M. S. A., Agathoklis, P., Oularbi, M. R., Amrouche, B., Sedraoui, K., and Djilali, N. “PV array power output maximization under partial shading using new shifted PV array arrangements,” *Applied Energy*, 187. 326-337.2017.

[2] Ye, B., Qi, J., Li, Y., Xie, L., and Yang, F. “Research on PV array output characteristics based on shadow image recognition,” *IEEE Conference on Energy Internet and Energy System Integration (EI2)*, 1-6. IEEE. 2017.

[3] Akash, O. “Experiment on PV panels tilt angle and dust,” *5th International Conference on Electronic Devices, Systems and Applications (ICEDSA)*, 1-3. IEEE. 2016.

[4] Djalab, A., Bessous, N., Rezaoui, M. M., and Merzouk, I. “Study of the Effects of Partial Shading on PV Array,” *International Conference on Communications and Electrical Engineering (ICCEE)*, 1-5. IEEE. 2018.

[5] Martinez-Moreno, F., Muñoz, J., and Lorenzo, E. “Experimental model to estimate shading losses on PV arrays,” *Solar Energy Materials and Solar Cells*, 94 (12). 2298-2303. 2010.

[6] Rahman, M., Hasanuzzaman, M., and Rahim, N. A. “Temperature effect of photovoltaic module under partial shading operation condition,

[7] Mehiri, A., Hamid, A. K., and Almazrouei, S. “The Effect of Shading with Different PV Array Configurations on the Grid-Connected PV System,” *2017 International Renewable and Sustainable Energy Conference (IRSEC)*, 1-6. IEEE. 2017.

[8] Bai, J., Cao, Y., Hao, Y., Zhang, Z., Liu, S., and Cao, F. “Characteristic output of PV systems under partial shading or mismatch conditions,” *Solar Energy*, 112. 41-54.2015.

[9] Winston, D. P., Kumaravel, S., Kumar, B. P., and Devakirubakaran, S. “Performance improvement of solar PV array topologies during various partial shading conditions,” *Solar Energy*, 196. 228-242.2020.

[10] Gupta, V., Sharma, M., Pachauri, R. K., and Babu, K. D. “Comprehensive review on effect of dust on solar photovoltaic system and mitigation techniques,” *Solar Energy*, 191. 596-622. 2019.

[11] "PERC TECHNOLOGY," solarabic, 03 06 2019. [Online]. Available: https://solarabic.com/learn/2019/07/solar-cells-technologies-perc-explained.

[12] "half-cell technology," solarabic, 2019. [Online]. Available: https://solarabic.com/learn/2019/07/solar-cells-technologies-half-cut-cells-explained/.

[13] Trzmiel, G., Głuchy, D., and Kurz, D. “The impact of shading on the exploitation of photovoltaic installations,” *Renewable Energy*,153. 2020.

[14] Karami, N., Moubayed, N., and Outbib, R. “General review and classification of different MPPT Techniques,” *Renewable and Sustainable Energy Reviews*, 68. 1-18.2017.

[15] Bhol, R., Dash, R., Pradhan, A., and Ali, S. M. “Environmental effect assessment on performance of solar PV panel,” *International Conference on Circuits, Power and Computing Technologies* [ICCPCT-2015],1-5. IEEE.2015.

[16] Forcan, M., Durisic, Z., and Mikulovic, J. “An algorithm for elimination of partial shading effect based on a Theory of Reference PV String,” *Solar Energy*, 132, 51-63. 2016.

[17] Babatunde, A. A., Abbasoglu, S., and Senol, M. “Analysis of the impact of dust, tilt angle and orientation on performance of PV Plants,” *Renewable and Sustainable Energy Reviews*, 90, 1017-1026. 2018.