Performance of PV panel under shaded condition

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Abstract. One of the most important technical aspects to consider during the technical study and practical installation of the solar panels is choosing the location of the solar panels, Because it's probable that some of its cells will be shaded. PV characteristics become more complex under partial shade situations, with several peaks.Partial shading affects the performance of the solar cell in proportion to the state of shadow; this negative performance will be reflected on the current generated by the solar cell; of the current value of the other cells (being connected in series) which will decrease the overall performance of the solar panel. The goal of this study is to demonstrate the impacts of partial shade on a PV array by analyzing various shading situations.First, this is done using Matlab/Simulink.

Keywords: partial shading(PS), PV module characteristic.

Introduction

Owing to the effects of global warming and environmental changes arising from rising greenhouse gas emissions since the advent of the Industrial Revolution; as well as a reduction in conventional energy supplies such as coal and oil and gas; Consumption of electricity, on the other hand, is expanding as the world's population density expands; becoming important to search for alternate energy sources[1].Renewable energy is used as an alternative mode of generating electric power to tackle this problem. Photovoltaic solar power is becoming increasingly common among green energy choices nowadays due to its readily accessible and inexhaustible nature, The non-involvement of mechanical or moving parts in a photovoltaic power system often makes it more desirable than other renewables[2] [3].

Furthermore, the use of such energy is not only cheap and inexhaustible, but also simple, noiseless and less environmentally harmful relative to other energy types. Through perfection, it's “green energy” [4]

Photovoltaic effect is power generation by the conversion of solar photons through semiconductor like silicon. The most notable factors influencing the operation of the photovoltaic array are: temperature, solar strength, partial shading, and the PV string configuration.[4]

Photovoltaic modules are connected in series and in parallel to form a PV array to correspond to the voltage and current power requirements [5][6]. However, the total power within such an array is lower than the sum of each module's individually rated power.[4][7] That's for different reasons. The main reason that this paper aims is partial shading. Uniform light intensity in a panel is not nearly satisfied due to shades of buildings or trees, bird droppings, fluctuations in the atmosphere, cloud existence and daily changes in the sun angle as shown in Figure 1. Shade impact depends on the type of module, the fill factor, and the severity of shade bypass diode placement and the configuration of the string.[8]

Figure 1. Partial Shading on the PV Panel

The performance of a series-connected photovoltaic solar module is negatively affected if the cells are not illuminated evenly. All cells in a series group are forced to carry the same current although some shaded cells produce lower photon current. Shaded cells may become biased in the opposite direction, act as loads, and drain energy from fully lit cells. If the system is not properly protected, a hotspot problem may arise and the system may be damaged irreversibly in several cases. The danger of hot spots is that if they continue to exist, they will cause a decrease in the productivity of the damaged panel of electrical energy (due to the transformation of cells affected by hot spots from energy-producing cells to consuming cells) and thus a decrease in the productivity of the solar photovoltaic system as a whole, in addition to the possibility of fires and ignition of the damaged panel. Today, the PV plants are constructed in a fixed series-parallel configuration and the single module is equipped with bypass diodes in various configurations .This is used to bypass the single module when it is lightly irradiated to prevent the single module current from decreasing the current of the entire photovoltaic array.[8]

A bypass diode is connected to be in parallel with a group of cells connected in series and is used to reduce the effects of partial shading on P – V, I-V curves. The Figure 2 shows four solar cells connected in series and each cell has a bypass diode connected with it in parallel, When the shadow falls on the fourth cell - when the diode is not used - it will significantly reduce energy production in the other cells; however, if the diode is used, the shadow's effect will be limited to the shaded cell, and the remaining cells will not be affected by shading, reducing the loss in solar panel productivity, because the diode is biased in the forward direction if the cell connected with it is exposed to shading conditions and thus bypassing the shaded cell, otherwise it remains biased in the back direction in the normal case. [7]

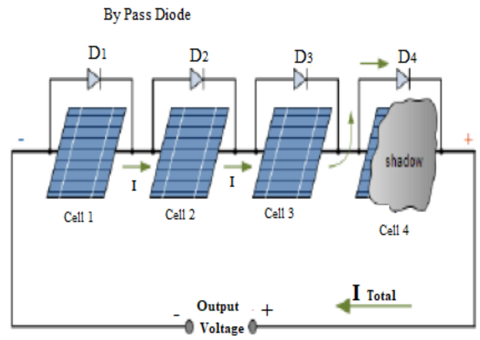


Figure 2. Current Path in Cells at Partial Shading

The use of a by-pass diode is an acceptable solution because it improves the power produced from the entire PV array; However, one of the disadvantages of using it is that the energy produced from the shaded cell must be dispensed with[2]. The main objective of this study is to highlight how partial shading may affect the performance of a PV array by examining various shading cases.This is done initially with Matlab / Simulink simulation.

Modeling of Photovoltaic Cell

The equivalent PV cell circuit is shown in Figure 3 below, the current generated from the single PV cell is[1]:

$$I = I_L - I_O\left(e^{q(V+IR_S)/n_S AKT} - 1\right) - \frac{V+I*R_S}{R_P} \quad (1)$$

Where:
I_L: Photo- generated current.
I_O: Saturation current.
R_S: Series Resistance.
R_P: shunt resistance.
K: Boltzmann's constant
q: Electron charge
n_S: Number of cells connected in series.
T: Cell temperature (in kelvin)

A: diode quality (ideality) factor.

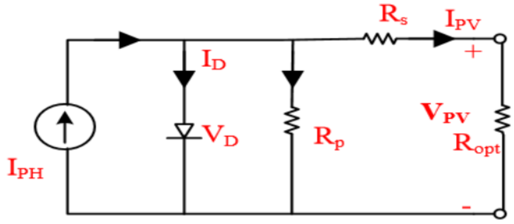
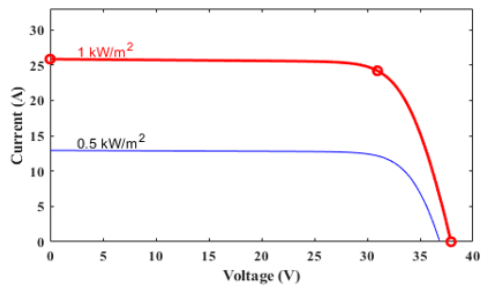
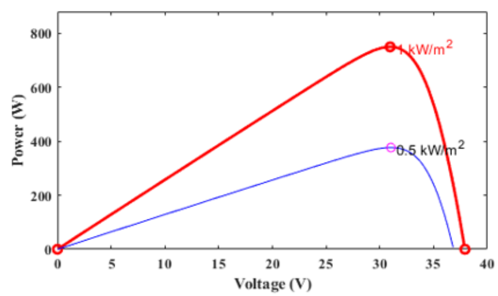


Figure 3. Single-diode circuit model of PV cell

The effect of changes in irradiance and temperature on the characteristic I-V and P-V is illustrated in Figure 4 and Figure 5 shown below.

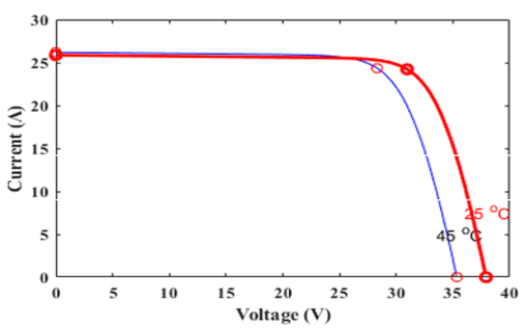


(a)

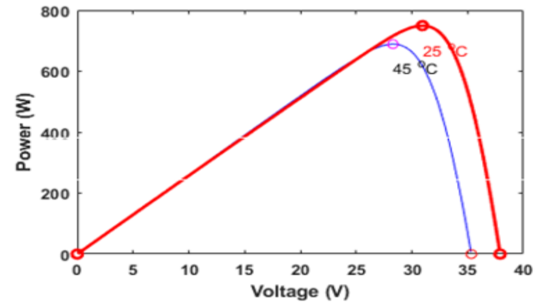


(b)

Figure 4. PV array characteristics affected by irradiance at 25°C (a) I-V, (b) P-V



(a)



(b)

Figure 5. PV array characteristics affected by temperature at 1000 Kw/m^2 (a) I-V, (b) P-V

Simulation Result

PV array as shown in Figure 6 consists of three strings and each of them contains three modules i.e., 3×3. Open circuit voltage and short circuit current of each module is 12.64 V and 8.62A, respectively. Each module contains a single bypass diode.

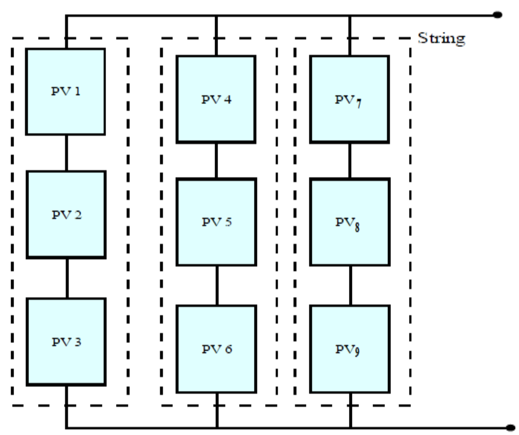


Figure 6. PV array with interconnected of PV modules

The P-V and I-V characteristics of the PV array are simulated under standard test condition and different partial shading, the standard system has one MPP equal to the total maximum power of the nine modules and three times the ISC short circuit current for each module, hence the case for Vo.c. The Figure 7 shown below illustrate the current-voltage (I-V) and Power-Voltage (P-V) characteristics respectively of a typical silicon PV cell operating under normal conditions.

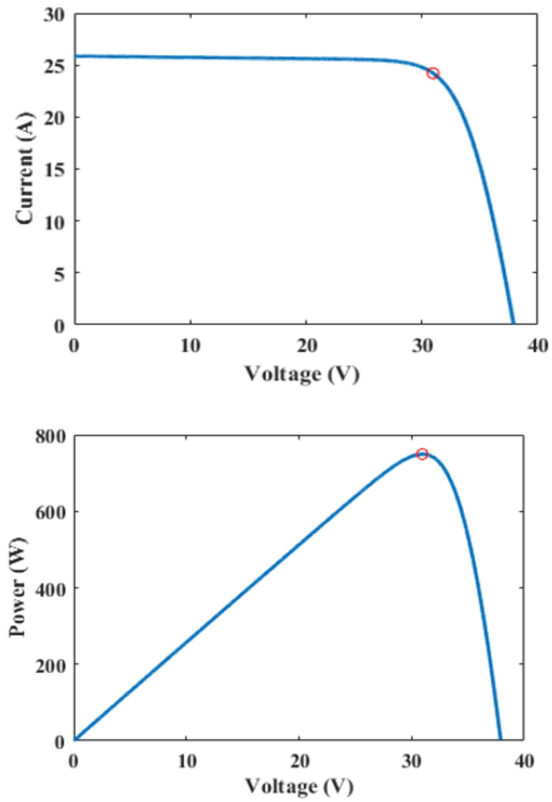


Figure 7. I-V and P-V chcaracteristics of typical photovoltaic under STC (25°C and 1000 W/m²)

In this research, The PV system was tested by partially shading the solar modules with two different patterns:

The first pattern / heterogeneous partial shading: It means the percentage of shading was shed in different proportions on the shaded solar panels, and it was implemented as follows:

A / Shading falls on the solar system vertically from the left: Figure 8 below shows that. The results were taken for three cases: In the first case, the fall of the shadow was only on the PV1 at a rate of 30% of the total radiation, i.e. 300Wb/m2, As for the second case, the shadow will fall on the first and second panels with a percentage of 30% and 60% of the total radiation, respectively. Finally in the third case, the fall of the shade on the first three panels was 30%, 60% and 90%, respectively.

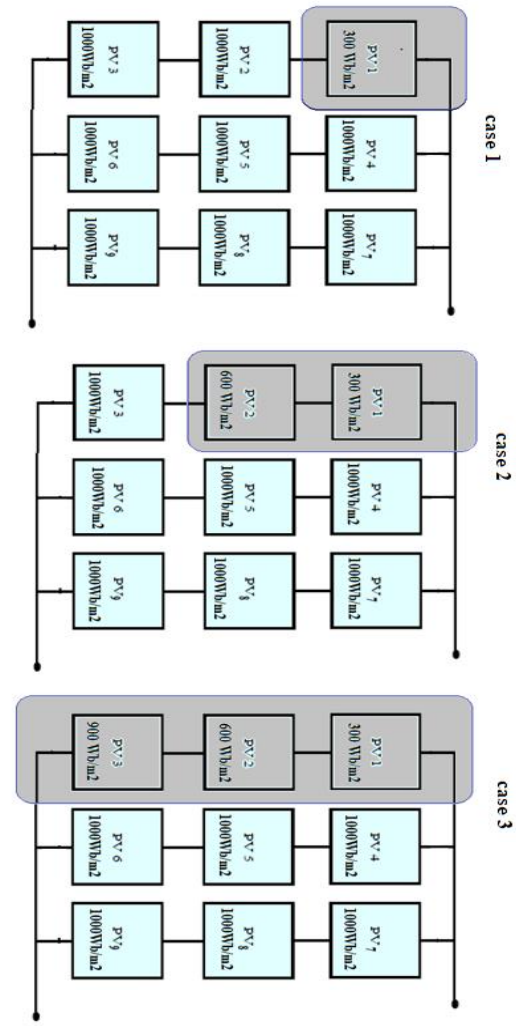
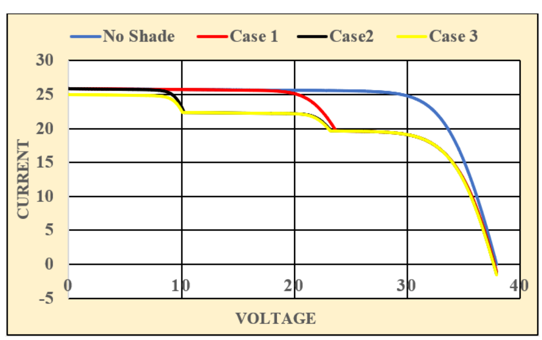
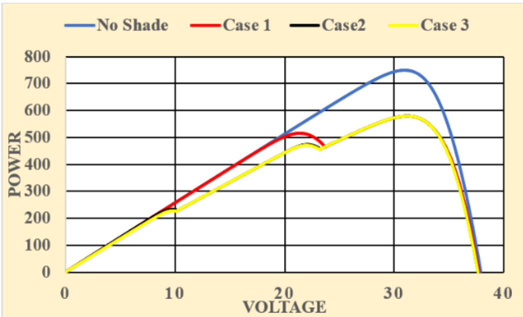


Figure 8. PV array with shading pattern.

The results for this case study shown in Figure 9 , where (a) shows I-V Curve and (b) show P-V curve.



(a) I-V Curves



(b) P-V Curves

Figure 9. I-V and P-V curves of PV array under shading pattern.

We notice from the results presented in Figure 9 that there is a clear effect of PS applied to the solar modules, and the amount of influence varies between the three cases. In the absence of shading, as can be seen from the blue-colored curve, here is only one peak, which represents the GM.

It is also noted through the displayed result that the power produced from PV system decreases when exposed to PS as a result of a decrease in the current generated by the solar modules, Therefore, multi-peak power appear in P-V curve one of them is global maxima GM, while the other called local maxima LM. the number of these peaks increases whenever the level of solar radiation varies between the solar modules connected in series in the same string, in other words, the more the number of solar panels connected within the same string in succession to partial shading, the greater the number of peaks generated. The effect of voltage by PS is almost negligible, while the current affected by PS is large, and the decrease in the current generated by the modules increases as the percentage of PS on the solar panels increases, and thus this negatively affects the power generated by the solar panels. It is noteworthy that there is a somewhat similarity between the curve line in case (2) and (3) in the P-V curve and our interpretation of this case as previously mentioned because the two cases are similar in that they are under the same conditions - the difference between the level of shading percentage is on three levels - while There is a difference between them in the I-V curve because the effect of PS is primarily and greatest on the current produced by the solar panel.

B/ In this case, the partial shade falls on PV system horizontally from the left, the results were taken for three cases: In the first case, the fall of the shadow on the PV1 was only at a rate of 30% of the total radiation, i.e. 300Wb/m2, As for the second case, the fall of the shade Skip the first module to the forth module PV4; reaching 60% of the total radiation, i.e. 600 Wb/m2. In the third and last case, the fall of the shade on the PV1, PV4 and PV7 was 30%, 60% and 90%, respectively. Figure (10) below shows that:

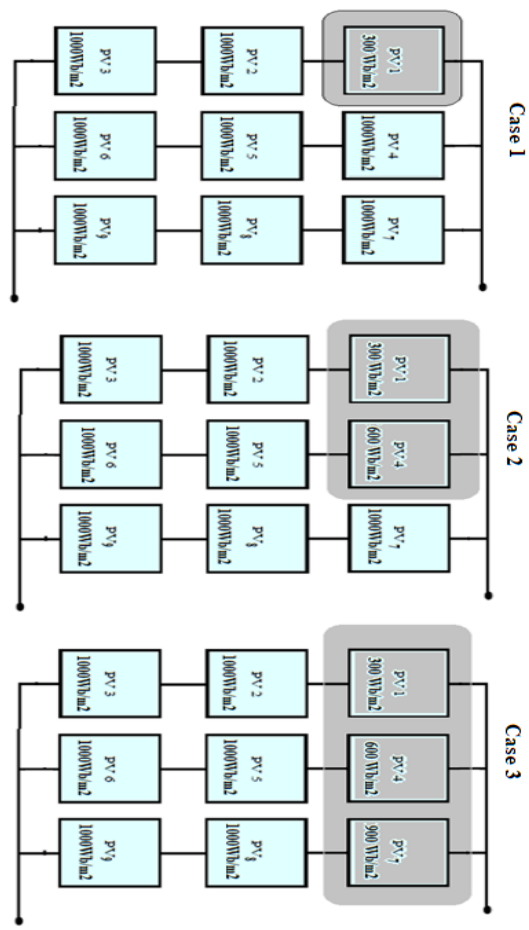
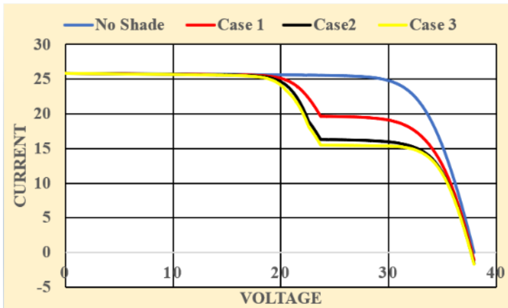
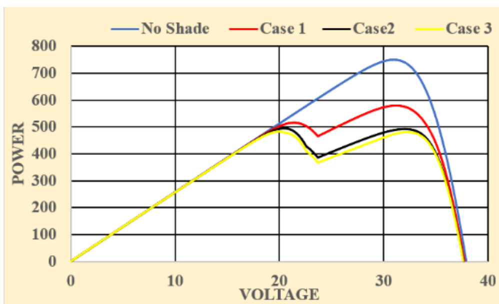


Figure 10. PV array with shading pattern.

Figure 11 shows the results for this case study, where (a) shows I-V Curve and (b) show P-V curve



(a) I-V Curves



(b) P-V Curves

Figure 11 I-V and P-V curves of PV array under shading pattern.

It is evident from the results presented in Figure (11) that the impact of the solar system on horizontal shading on the panels is greater than in the first case - when the shading was in a vertical direction - as the current generated by the modules decreases more and thus the total power produced from the system decreased more compared to in case (A). Only two peaks appeared in the P-V curve, one of which represents G.M, while the other represents L.M, and this confirms the previously explained result, which is that the number of peaks depends on the number of solar radiation levels between the modules connected in series within the same string.

The second patterns /homogeneous partial shading: in this case, Shade falls in equal proportion to the shaded panels, and it was implemented as follows:

A / Partial Shading PS falls on the solar system vertically from the left, the results were taken for three cases: In the first case, the fall of the shadow on the PV1 was only at a rate of 60% of the total radiation, i.e. 600Wb/m^2, As for the second case, the fall of the shade Skip the first module to the second module, reaching 60% of the total radiation for both module, i.e. 600 Wb/m2. In the third and last case, the fall of the shade on the first three panels was 60% for all. Figure 12 below shows that:

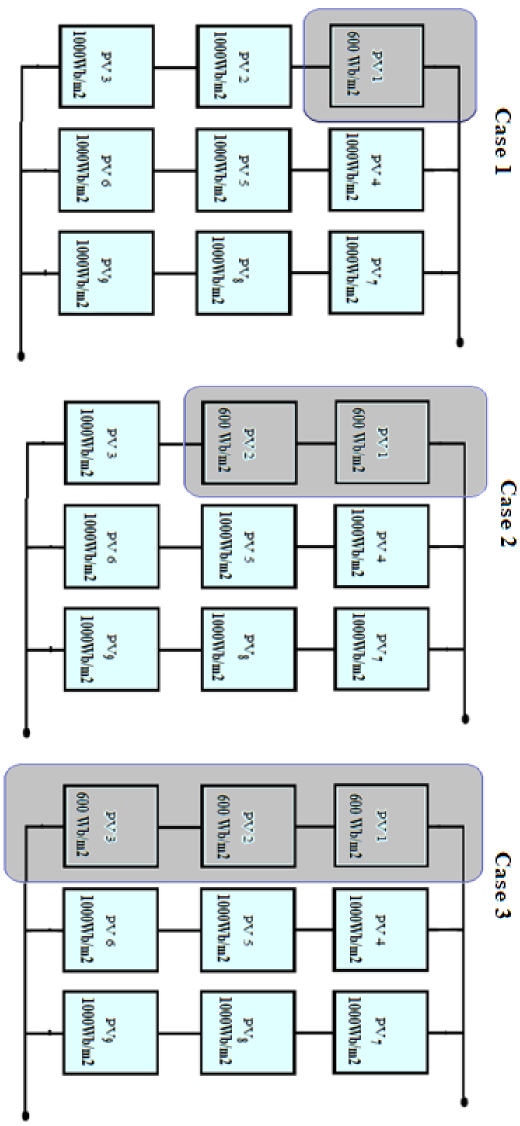
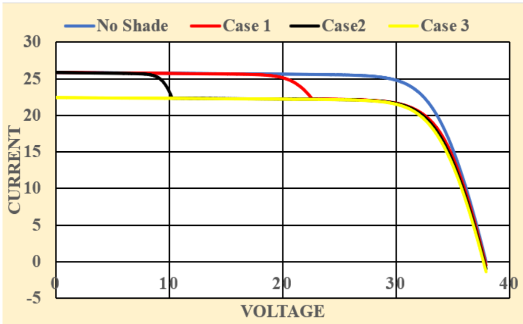
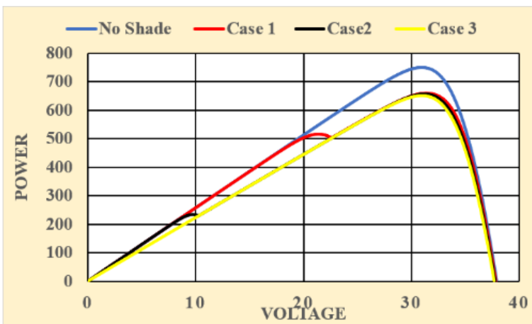


Figure 12. PV array with shading pattern.



(a) I-V Curves



(a) P-V Curves

Figure 13. I-V and P-V curves of PV array under shading pattern 2(a) .

It is clear from the result shown in Figure (13), when the shading partially falls on the PV1 only with solar radiation reaches 60% of the total radiation; the power produced from the PV system as a result of the decrease in the current generated from the system due to shading will decrease, The decrease in the generated power increases when the partial shade covers PV1 and PV2 due to the decrease in the current generated more than the first case, The same behavior occurs in the third case. Multi- Peak power occur in P-V curve in case 1 and case 2, one of them represent GM while the other is the LM. It is noted in case 3, that the multiple peaks in P-V curve have disappeared despite the partial shading on PV1, PV2 and PV3; and as explained previously, the number of multiple peaks depends on the difference in the radiation level reaching the module which is connected in series in the same string.

B/ partial shade falls on the solar system horizontally from the left, the results were taken for three cases; In the first case, the fall of the shadow on the PV1 was only at a rate of 60% of the total radiation, i.e. 600Wb/m^2, As for the second case, the fall of the shade was on PV1 and PV4,reaching 60% of the total radiation for both, for PV1 and PV4. In the third and last case, the fall of the shade on the PV1, PV4 and PV7 was 60%, for all. Figure 14 below shows that:

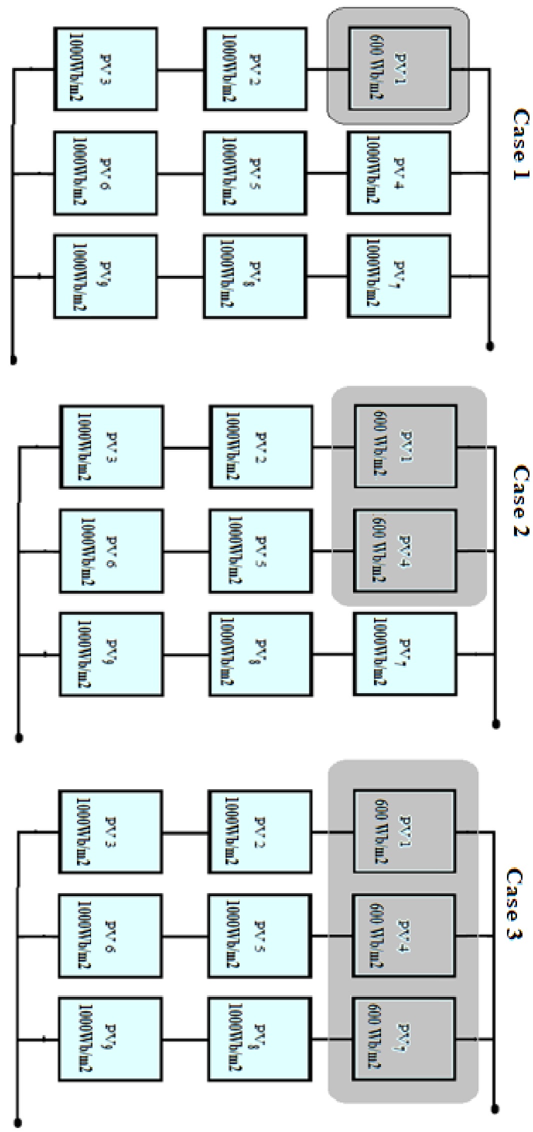
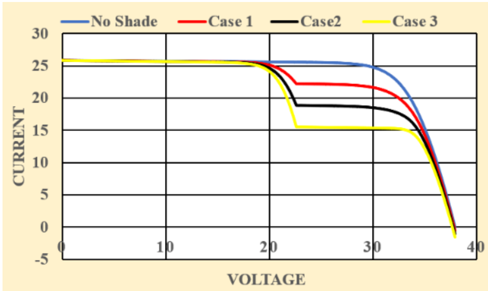
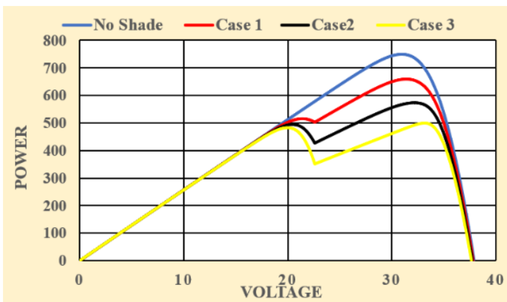


Figure 14. PV array with shading pattern.



(a) I-V Curves



(b) P-V Curve

Figure 15. I-V and P-V curves of PV array under shading pattern.

It notced from figure 15 that the generated power - as shown in P-V curve - is greatly affected and its value decreases due to the great influence of the current - as is clear in I-V curve - due to the partial shading that occurs on the panels in the three cases studied. Two peak power ocuured in this case, one of them represent GM, while the other represents LM; The P-V curve has multiple peaks as a result of partial shading falling on some solar panels and due to the presence of the diodes these peaks are formed.

Conclusion

The software MATLAB / SIMULINK has been developed to Simulate behavior of different configurations of PV modules with variable weather conditions, in the impact of PSin particular. The simulation model is developed based on the mathematical equations derived from a solar cell's single diode equivalent circuit. Model simulation is developed in MATLAB / Simulink Software. Results from the simulation model developed illustrate the suitability of studying the behavior of solar cells working under different environmental conditions.

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