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Assessment of the Impact of Partial Shading on the Performance of the Photovoltaic System

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Abstract- *In this paper we study the effect of shading, partial or total, on the function of a photovoltaic system in order to be able to detect this shading in time. Indeed, the presence of partial shading can damage the photovoltaic system and therefore its detection in time is of paramount importance to ensure the proper functioning of the system. We consider the problem of detection disturbance of a dynamic system and we analyze the effect of this shading through numerical simulations validated experimentally.*

General Terms- *PV array, Partial shadow*

Keywords- *PV array; Partial shadow; Detection of partial shadow.*

1. INTRODUCTION

Photovoltaic solar energy is the conversion of sunlight into electricity within semiconductor materials such as silicon or coated with a thin metal layer. These photosensitive materials have the property of releasing their electrons under the influence of external energy. This is the photovoltaic effect. The energy is provided by photons, (components of light) which collide with the electrons and release them, inducing an electric current. Photovoltaic systems are considered to be the very beneficial systems of solar energy, which find applications in rural or remote areas, which are not connected to the electricity grid.

The performance of photovoltaic systems is dependent on several meteorological parameters, solar irradiation, temperature, wind speed, in addition, photovoltaic panels are exposed, throughout the year, to total or partial shading which has different effects on the energy produced and on the stresses on the cells.

Actual shading is a case where the different modules of the array have received different levels of irradiance. This shading may be expected due to different conditions: nearby building, tree nearby or difficult to predict due to clouds or the building [4]

It is well known that partial shading of photovoltaic panels can proportionally reduce the output power of the system; it has been identified as a major reason to reduce the energy yield of grid-connected photovoltaic systems. The low efficiency of partially shaded solar cells in a PV module leads to the operation of a bypass diode and results in the reduction of the maximum power in the PV module [1]

In the worst case, frame shadow can lead to a 39.3% decrease in photoelectric efficiency [2]

The results show that frame shading reduces the photovoltaic efficiency of the system to 2.6% (normal efficiency, 13.0%)[3]

Photovoltaic systems are very sensitive to partial shading. The maximum power output of a PV system can be significantly reduced when partial shading occurs [4]

Under partial shading, not only the voltage and output power are reduced, but also instead of obtaining a single peak of maximum power, several peaks are obtained. The presence of bypass diodes also affects the characteristics of the PV generator [5]

Photovoltaic systems are very sensitive to partial shading. The maximum power output of a photovoltaic system can be significantly reduced when partial shading occurs. The sensitivity of partial shading may vary depending on the partial shading patterns, the amount of shading, and the configuration used to connect all the PV modules in the PV system. In a fixe configuration and a partial shading model, the maximum power output of a partially shaded PV system is assumed to tacitly decrease at a constant rate as the amount of shading increases.[6]

This problem can be considered as a source detection/disturbance problem, which has been widely studied in systems theory for linear dynamical systems.

[7] To approach this problem, the modeling phase is essential.
The modelling of the solar panel under partial shading is a two-step process. In the first step, for each module Mi subjected to a different irradiation its own (I-V)i curve that covers the operating regions between the short-circuit and open circuit points is plotted; the second step is the formation of the I-V curve of the panel by combining these (I-V)i curves based on the electrical connections. [8]
In this work, we study the effects of partial shading on the power supplied and on the P-V curve of a photovoltaic source consisting of solar panels connected in series.

2. PHOTOVOLTAIC SOURCE AND POSITION OF THE PROBLEM

The one-diode electrical model of a photovoltaic cell, known as the 5P 5-Parameter model, used in the literature is shown in Figure 2. It takes into account the series resistance Rs and the parallel resistance (shunt) Rsh as expressed in the following equation:

$$I = I_{ph} - I_0\left(exp\left(\frac{V + R_s I}{V_t}\right) - 1\right) - \frac{V + R_s I}{R_{sh}}$$

Where Vt = n.KT/q is the thermal voltage

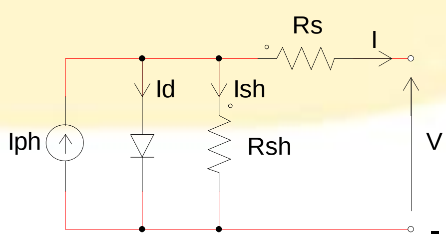

Figure 1: Electrical model of a single-diode cell

Practically the cells are associated in series to obtain high voltage values. By this association called "String", the cells are crossed by the same current and the resulting voltage corresponds to the sum of the voltages generated by each cell.

The curve I(V) of the panel formed by Ns cells in series is given by the following equation:

$$I = I_{ph} - I_0\left(exp\left(\frac{V + R_{s,s} I}{V_t N_s}\right) - 1\right) - \frac{V + R_{s,s} I}{R_{sh,s}}$$

Where N_s is the number of cells in series, $R_{s,s}=R_s*N_s$, and $R_{sh,s}=R_{sh}*N_s$.

The generated photon current is calculated by the following formula:

$$I_{ph} = [I_{scr} + k_i(T - T_r)].\frac{S}{100}$$

Where:
Iscr: The short-circuit current at the reference temperature and solar irradiation,
Ki: Coefficient of the short-circuit current
Tr: The reference temperature
S: Solar irradiation in mW per square centimetre

P(V) curve :
Figure 2 shows the power variation (in W) as a function of the voltage of the photovoltaic source consisting of eight photovoltaic panels, the curve of which are given below:

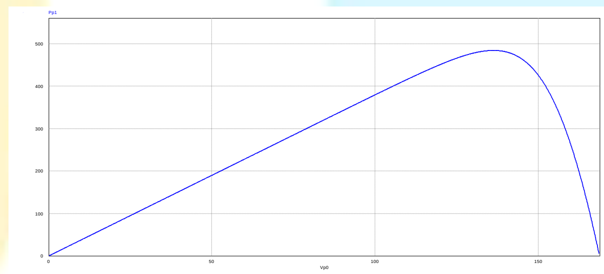

Figure 2 : P(V) graph of a photovoltaic panel

Position of the problem:
During the operation of photovoltaic sources for the production of electrical energy, partial shading is very harmful, and if not detected in time, it can cause, in addition to the reduction of the power supplied, damage to the shaded cells (temperature rise and destruction).
We consider the following problem: Can we detect and locate partial shading during operation?

3. PROBLE APPROACH AN SIMULATION

3.1. Problem approach:

Shading could be considered as a perturbation on the photovoltaic system that could be represented as a dynamic system (S) whose input and outputs are voltage V and current I respectively.
We can then consider the undisturbed and disturbed dynamic system (see Figure 3).

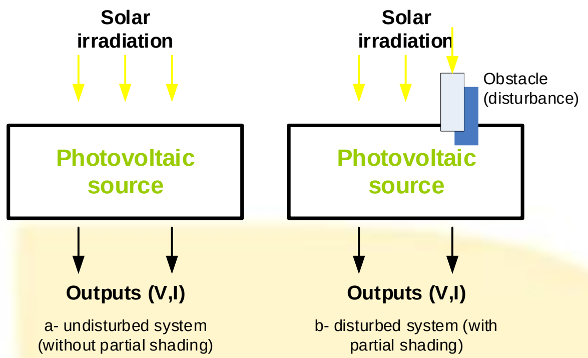

Figure 3: Representation of the system: a- the undisturbed case and b- the disturbed case

The approach of the problem then consists in highlighting the impact of partial shading on the operation of the photovoltaic source, through the outputs of the system, in order to characterize the parameters that indicate the presence of a given shading.

It is a problem of source detection, disturbances, widely studied in system theory for linear academic systems [9]. For this purpose, the authors have considered a measurement function, output, assuming that the system dynamics are known, whereas in our case we do not explicitly have the system dynamics but we know the input, irradiation, and the outputs V and I.

We then consider an output function, measurements, which here is the power (I(v) and or P(V)) that will give us the measurements in both cases; without shading and with shading.

As we do not have the explicit form of this measurement function according to the various parameters of the photovoltaic system, we will consider simulations.

Thus, to approach this problem, we would first have to use simulations to see the effect of partial shading on the operation of the photovoltaic source. For this we consider simulations for the same photovoltaic system for two situations:

- The autonomous case: without presence of disturbance (without partial shading);
- The disturbed case: with partial shading.

In the following we present the simulations obtained.

3.2. Simulations

Simulations are made on a solar source consisting of 8 photovoltaic panels connected in series. The electrical characteristics of the panel are given in Table 1.

Table 1 : Photovoltaic panel characteristics

Number of Cells Ns	36
Maximum Power Pmax	60W
Voltage at Pmax	17.1V
Current at Pmax	3.5A
Open-Circuit Voltage Voc	21.1V
Short-Circuit Current	3.8A

Irradiation effect :

Figure 4, shows the characteristics I(V) and P(V) of the photovoltaic panel under different irradiation conditions S(W/m²).

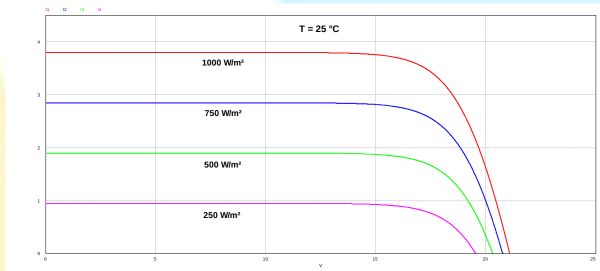

Figure 4 : I(V) characteristic for different solar irradiations

Irradiation effect:

Without shading, with different irradiation values, at a constant temperature of 25°C, the P(V) graph always shows a single maximum whose value is a function of the irradiation intensity (see Figure 5).

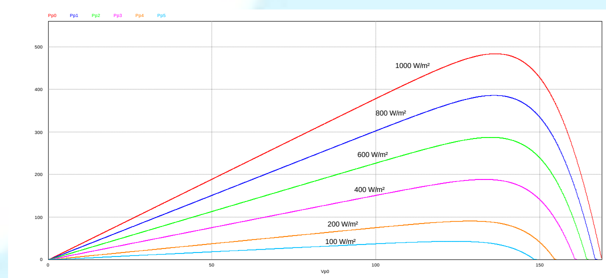

Figure 5 : P(V) characteristic for different solar irradiations

Temperature effect:

Photovoltaic cells operate better in low temperatures, as the temperature of the panel cells increases, the power decreases.

Figure 6 : P(V) characteristic for different temperature values

Load effect:

When a photovoltaic panel is connected to a load, the operating point (I0, V0) depends on the impedance of the load (see Figure 7).
The power supplied by the panel is dependent on this impedance.

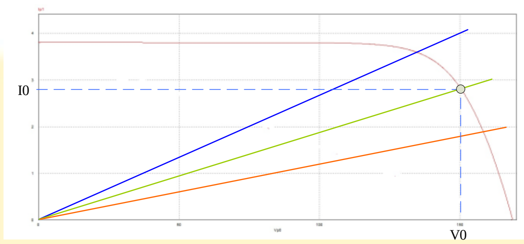

Figure 7 : Operation point of the PV-Charge association

Partial shading:
Let's consider the case of two cells in series, one illuminated with S irradiation, and the other shaded with Ss<S irradiation (see Figure 8).

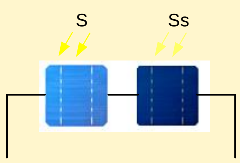

Figure 8: Configuration of two cells in series

Figure 9, shows the case of two cells connected in series. The cell exposed to an irradiation S generates a photon current Iph, the other one exposed to an irradiation Ss<S, generates a photon current Iphs, such as Iphs<Iph.
Let Im be the current supplied by the module to the connected load R.
If the current Im is lower than the photonic current Iphs, then the diode Ds is biased in direct, and no risk appears. On the other hand, if the current Im is higher than the current Iphs, then the diode is reverse biased, and the current flows through the resistor Rshs and Rss, causing a drop in the output voltage.

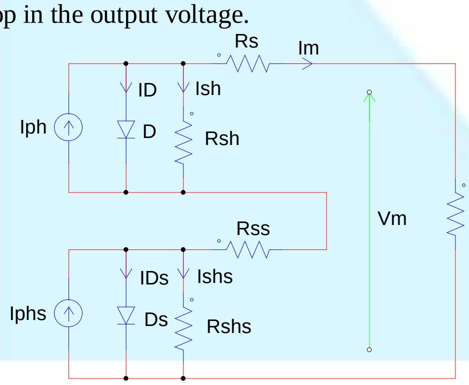

Figure 9 : Model of two cells in series at different irradiations

To solve this problem (but only partially), a by-pass diode connected in parallel on each serial connection of the multiple PV cells is used. If such a bypass diode was connected in each cell then the problem induced by shading would be greatly reduced. However, this is not a commercially feasible solution.
The studied system consists of 8 panels with diode, connected in series (see Figure10). Different irradiations are applied to the panels according to each case, and the P-V curve is drawn.

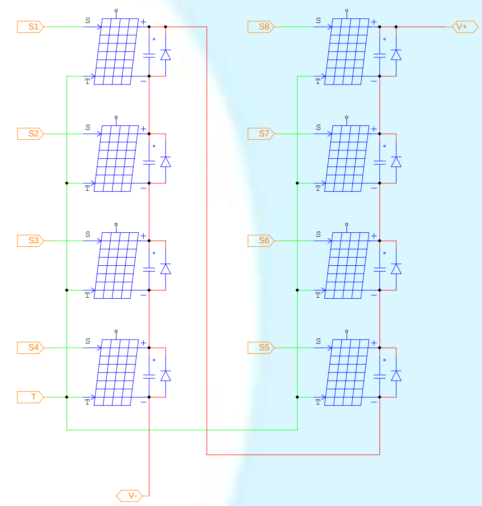

Figure 10 : Studied configuration, 8 panels in series

The results of the simulations carried out under the PSIM software, for the different scenarios of partial shading. We simulate the effect of the shading irradiation intensity on the P-V curve of the photovoltaic source.

a. Case of single shading on several panels
Case of 500W/m² shading on 1, 2, 3, or 4 panels forming the string. Another maximum power is observed (see Figure 11).

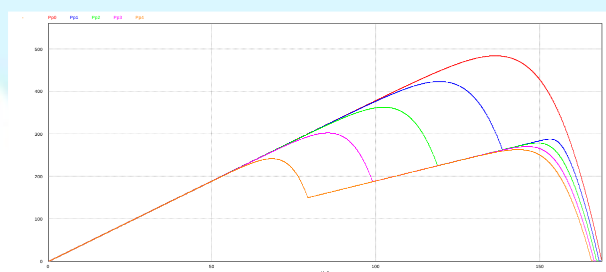

Figure 11: Shading 500 W/m² applied on 1, 2, 3 or 4 panels

b. Cases of different shading on a single panel
Case of a single panel under different values of partial shading, of 200W/m², 400W/m², 600W/m² and 800W/m² (see Figure 12).

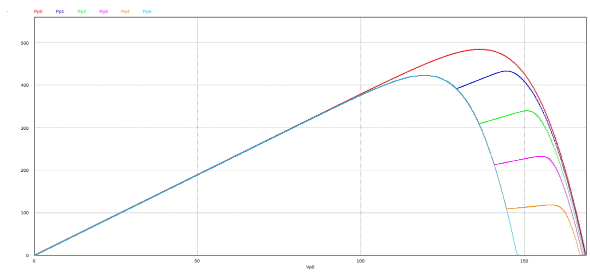

Figure 12: Different shading values applied to a single panel

c. Case of 2 panels exposed to shading

Case of 2 panels with different partial shading values of 200W/m², 400W/m², 600W/m² and 800W/m². The two panels are each exposed to the same shading value (see Figure 13).

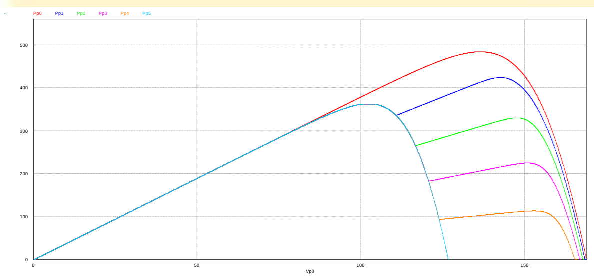

Figure 13 : Two panels with different shading values

d. Case of 4 panels exposed to shading

In the case of 4 panels subjected to the same shading, the shading value is modified each time by 200W/m², 400W/m², 600W/m² and 800W/m² (see Figure 14)

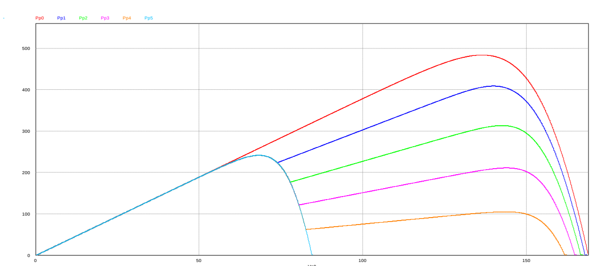

Figure 14: 4 panels with different shading values Case of several simultaneous shading values

Case of several shades with different intensities, two different values, ...

- 1 panel at 800W/m², the others at 1000W/m²,
- 1 panel at 800W/m², 1 panel at 600W/m², the others at 1000W/m².
- ….

We took a 200W/m² step.

One notices on the P-V curve the appearance of a number of maximums equal to the different intensities of the irradiations on the string (see Figure 15).

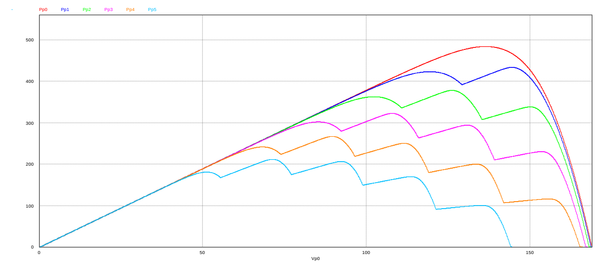

Figure 15: Several shades with several intensities

Simulation of the MPPT in the presence of partial shading :

The system consists of the 8 photovoltaic panels, a DC/DC Boost converter driven by an MPPT Perturb and Observe P&O algorithm. (see Figure 16)

Through this simulation, we aim to show the ability of the MPPT to search for maximum power in the presence of partial shading.

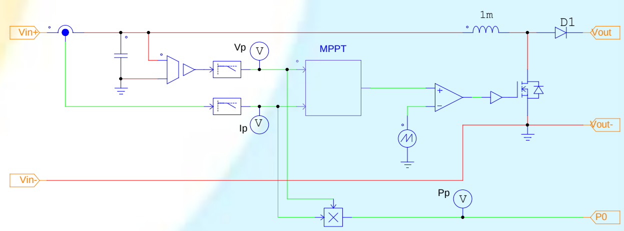

Figure 16 : Convertisseur DC/DC Boost avec MPPT P&O

Two cases are dealt with:

- Case n° 1: A 25% shading (2 panels out of 8 shaded) with an irradiation of 800W/m², the others illuminated at 1000W/m².
- Case n°2: 25% shading (2 panels out of 8 shaded) with an irradiation of 400 W/m², the others illuminated at 1000W/m².

The results are shown by the curves below.

Figure 17 shows the P-V curve of the photovoltaic source without partial shading under 1000W/m², it shows a maximum power of 484W.

Shading of case 1 produces a P-V curve with two extremes of 425W and 363W (see Figure 18), while shading of case 2 produces two extremes of 363W and 225W (see Figure 19).

The position of the large maximum is different in the two cases.

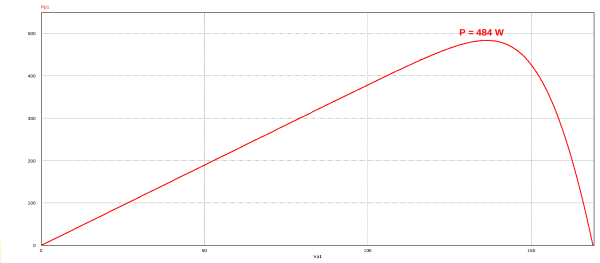

Figure 17 : P(V) curve without partial shading

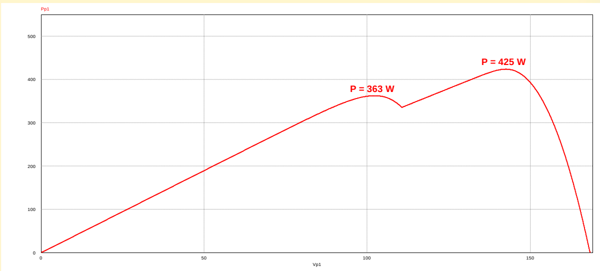

Figure 18: P(V) Curve of partial shading in case 1

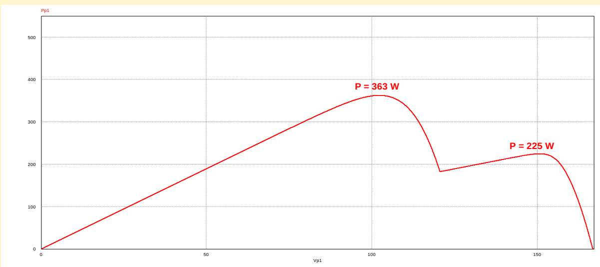

Figure 19: Courbe P(V) en cas 2 d'ombrage partiel

Behavior of the MPPT:

The figures below show the maximum power calculated by the MPPT algorithm.

Without partial shading, the MPPT works well, the maximum has reached 484W (see Figure 20).

In the presence of partial shading, the largest maximum of 424W is reached in the first case (see Figure 21), but in the second case the largest maximum of 363W is not reached, but the MPPT has reached the extremum closest to the operating point before the shading appeared, i.e. 225W (see Figure 22).

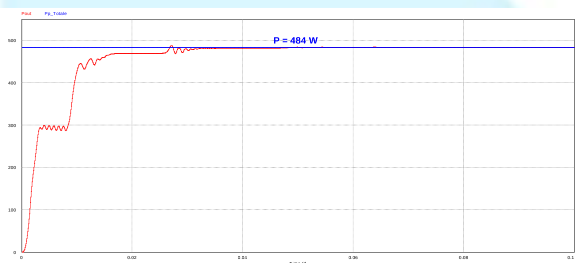

Figure 20 : P(V) curve of partial shading in case 2

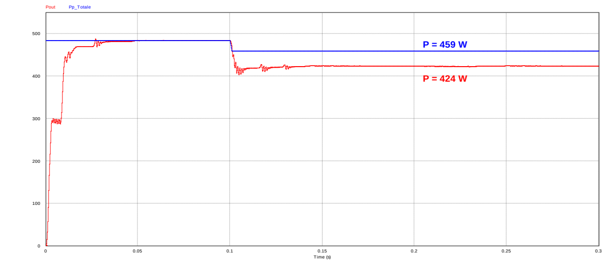

Figure 21 : MPPT response in case of shading n°1

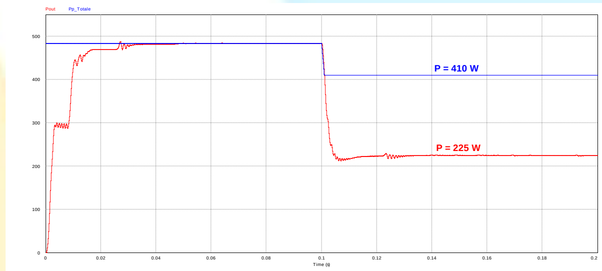

Figure 22 : MPPT response in case of shade n°2

4. DISCUSSION

According to the simulation results, we can see that during partial shading on a photovoltaic panel, there is a decrease in the power produced, and there are several maximums on the P-V curve, whose power remains lower than that without shading. There are as many maximums on the P-V curve of the panel as there are areas with different irradiations.

The position of the largest maximum relative to the other maximums depends strongly on the configuration of the partial shading. This is detrimental to the operation of conventional MPPT maximum tracking algorithms such as Perturb and Observe P&O.

5. CONCLUSION

In this work we considered the problem of shadow detection during the operation of a photovoltaic system. This problem could be considered as a problem of source detection, or disturbance, which is widely studied in system theory in the linear case assuming known system dynamics, which is not our case. This is why we have approached this problem through the characterization of the existence of shading by highlighting its impact on the operation of the photovoltaic system through different simulations validated in the laboratory. It would also be interesting to be able to locate such shading in space. This is a work in progress.

It has also been demonstrated that the MPPT algorithm is limited to the pursuit of maximum power in the presence of partial shading, whether instantaneous or progressive.

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REFERENCES

[1] A. Mohammedi, N. Mezzai, D. Rekioua , T. Rekioua, “ Impact of shadow on the performances of a domestic photovoltaic pumping system incorporating an MPPT control: A case study in Bejaia, North Algeria”, Energy Conversion and Management 84 (2014) 20–29

[2] Yunyun Wang, Gang Pei, Longcan Zhang, “Effects of frame shadow on the PV character of a photovoltaic/thermal system, Applied Energy 130:326-332, October 2014

[3] Yunyun Wang, Shanming Ke, Fengshou Liu, Junfei Li, Gang Pei, “Performance of a building-integrated photovoltaic/thermal system under frame shadows”, Energy and Building 134, October 2016

[4] A.DJALAB, M.M.REZAOUI , N.BESSOUS , I. MERZOUK, “Study of the Effects of Partial Shading on PV Array”,

[5] A. Chaudhary, S. Gupta, D. Pande, F. Mahfooz, G. Varshney, “Effect of Partial Shading on Characteristics of PV panel using Simscape”, Journal of Enginneering Research and applications, Vol 5 Isuue 10, October 2015, pp.85-89

[6] J. C. Teo , Rodney H. G. Tan , V. H. Mok , Vigna K. Ramachandaramurthy and ChiaKwang Tan, "Impact of Partial Shading on the P-V Characteristics and the Maximum Power of a Photovoltaic String”, Energies 2018, 11, 1860

[7] AFIFI, Larbi, EL JAI, Abdelhaq, et MERRY, Malika. Regional detection and reconstruction of unknown internal or boundary sources. International Journal of Applied Mathematics and Computer Science, 2001, vol. 11, p. 319-347.

[8] H. Patel, V. Agarwal, “MATLAB-based modeling to study the effects of partial shading on PV array characteristics”, IEEE Trans. Energy Convers., 23 (1) (2008), pp. 302-310 March

[9] El Jai, A., & Afifi, L. (1995). Spy-sensors and detection. International Journal of Systems Science, 26(8), 1447-1463.

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