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Studies on the Effect of Shadows at the Output of PV modules

KEYWORDS: Photovoltaic Power Generation, bypass diode, Shadow.

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ABSTRACT *The fluctuations occurred in the output of the photovoltaic power generation system depends upon the non-uniform changing of weather conditions due to which losses are occurred at the output power generation. This paper considers the studies on the effect of shadows on the I-V characteristic of the solar module. Also to prevent the power consumption of the PV module bypass diodes are installed, when the PV modules are shaded or damaged.*

Introduction:
The Solar PV array is strongly dependent on the performance of the operating conditions, sun's location, irradiance levels of the sun and the temperature. Each individual solar array is composed of a combination of solar cell internally connected in series and parallel. The performance of the array depends on the behaviour of each individual solar cell. While the performance specifications of solar cell modules are available, the data provided for these arrays does not accurately reflect the amount of electric power that may be generated from the solar panel at time of use.

For example, dust over a portion of solar cells, or a submodule will reduce the total output power of solar PV arrays. Under certain shade conditions, the changes can be dramatic and fast. A method that has been proposed by various authors measures changes in solar insolation over a one minute time interval. With this method, solar insolation values may be measured in the horizontal plane and subsequently used to calculate insolation levels for any desired angle. An estimation method used in proposes that the power output of a PV system is proportional to the insolation levels measured for the surface of a solar cell at any angular position. However, the output power of a solar array is not only dependent on changes in irradiance values, but also depends on factors such as the interconnection of the individual solar cells, the parameters of solar cells, and the use of bypass diodes.

A shadowed solar cell acts like a load because it dissipates input current. In the presence of shadows, where there is no exposure to sunlight, a solar cell will heat up and develop what is called a hot spot. To reduce the overall effect of shadows, bypass diodes are connected across shadowed cells to pass the full amount of current while preventing damage to the solar cell.

Cell Structure:
The cross section and the equivalent circuit of the cell with bypass diode function The cell is designed to flow large reverse current under a low reverse bias voltage through the p+n+ junction connected in parallel to the pn+ (main) junction. The high doped p+n+ junction exhibits a relative large leakage current under a relative low reverse bias voltage. So when the solar cell with bypass diode function is shaded, the reverse current flow through the p+n+ junction as a reverse leakage current.

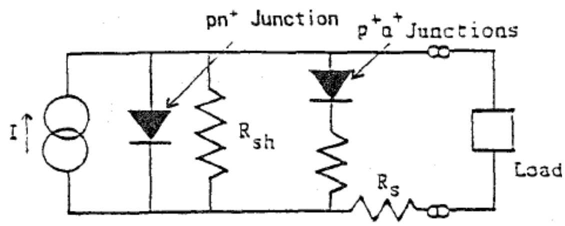

Fig:1 The equivalent circuit of the cell with bypass diode function

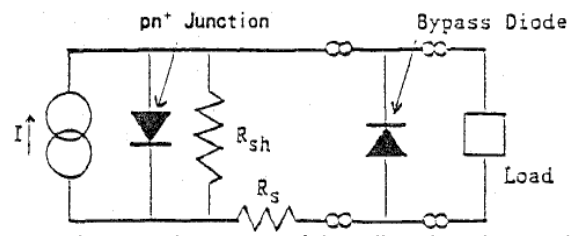

Fig:2 The equivalent circuit of the cell without bypass diode function with external bypass diode.

DEVELOPMENT
A. Behaviour of a PV cell
So as to analyse the behaviour of a module partially shaded, it is necessary to know:

- The curve of the cells forward and reverse biased Fig. 2
- The curve of the cells in terms of radiation Fig. 3
- The curve of the bypass diodes

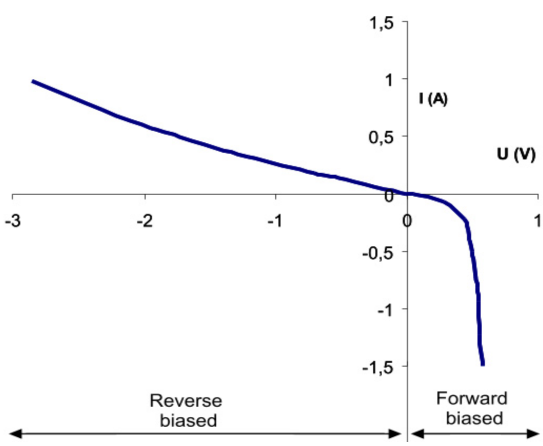

Fig.3 Curves of a cell forward and reverse biased PV cell for 0 w/m²

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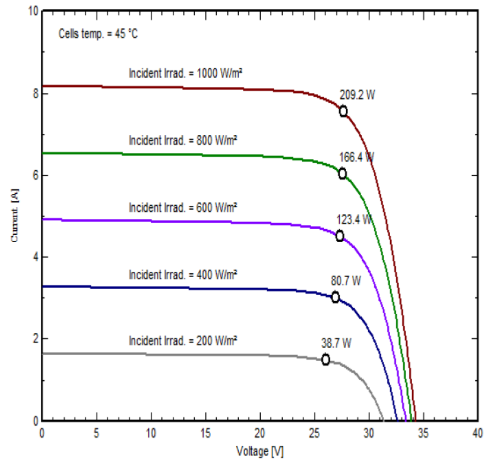
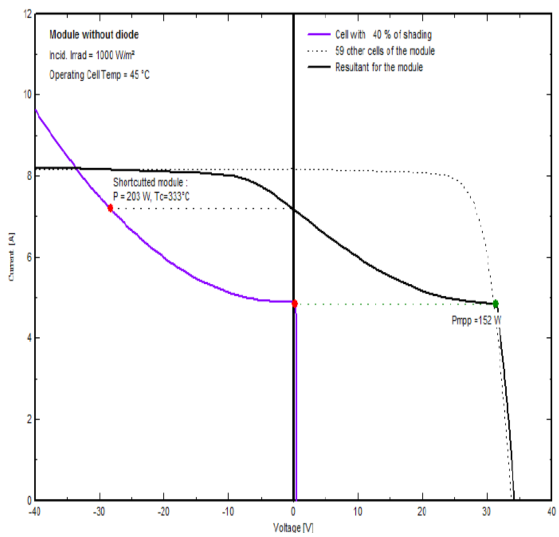


Fig.4 Curves of a PV cell for different solar radiations.

B. Behaviour of a PV cell array

When shadows are casted over a PV module, the behaviour of a PV cell in its reverse zone (negative voltage) must be taken into consideration, since the shaded PV cells can be reverse biased: Fig:4 shows the I-V curve at 40% shading. Here we are considering 300 normal days where as 45 days are cloudy.



C. Behaviour of a PV module

A PV module is made of PV cell arrays, with bypass diodes connected in parallel. The connection setup determines the I-V curve of the PV module when shadows are casted.

In this present paper, we are studying on a PV module consists of 72 PV cells, distributed in 6 rows of 12 PV cells each row, with the configurations

1) Overlapped bypass diodes
2) No-overlapped bypass diodes

1) Overlapped bypass diodes:

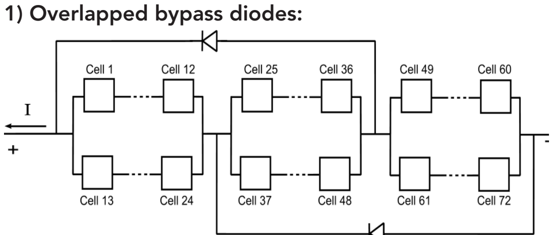


Fig. 5 Electrical scheme with overlapped diodes

In order to study the typical behaviour of the PV module, a simulation of progressive shading will be made from the bottom PV cell row to the top one. This is a practical approach, since at sunrises and sunsets can occur situations where the PV module has the same shading as the simulated ones. There are three possible paths for the most of electrical current (Fig. 7). The path depends on the diodes forward biased, and the diode biased depends on the PV cells shaded. When both diodes are forward biased, the modules of the two central series are the responsible for a notable power draining.

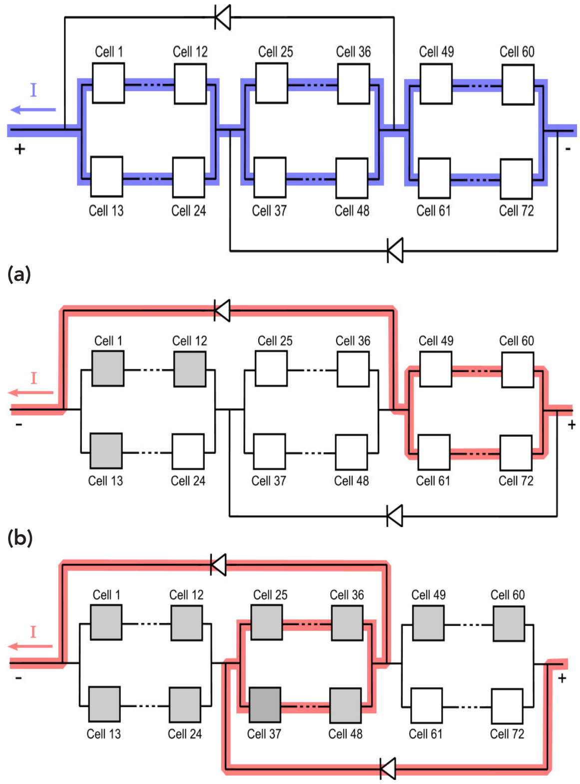


Fig:6 Electrical current in PV modules with overlapped bypass diodes

2) No-overlapped bypass diodes:

In the second analysed configuration, the PV module has no-overlapped bypass diodes, but it has the same physical distribution of the PV cells. In this case, the electrical circuit consists of 3 series, each with 24 PV cells. Every series have a bypass diode (Fig. 9). On account of this configuration, the IV curve of the PV array has double the open-circuit voltage and half short-circuit current of a PV module with overlapped diodes with the same peak power.

In addition, when the PV module is reverse biased, its voltage and its power consumption are less than the previous case. However, when the power generated is low, this consumption may be appreciable due to the power consumption of the forward biased diodes (3.9 watts/diode).

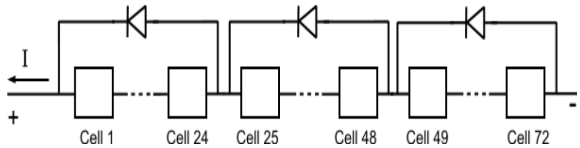


Fig:7 Electrical scheme of PV module with non-overlapped bypass diodes.

D. Behaviour of an PV array

In a not shaded PV array, with no deteriorated PV modules, all the PV modules have the same MPP. But when some PV

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modules are totally or partially shaded, the I-V curve of PV array changes, hence, the MPP of each PV module can be different. This would produce energy losses. The energy loss caused by shadows on the PV modules is not proportional to the area of the shadow, it may be much higher. The losses in a PV array will depend basically on:

• The configuration of the bypass diode.
• The inverter voltage limits in the dc side.
• The layout of the modules.
• The electrical configuration.

The analysis will consider a PV array consisting of 20 PV modules with its 11 inferior rows shaded (Fig. 8). The sunny cells are irradiated by 1000 w/m2 and the shaded ones by 100 w/m2 (Fig. 9).

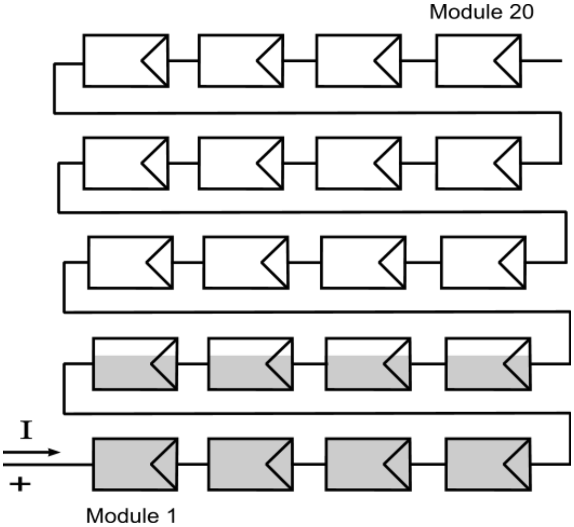

Fig:8 PV array electrical scheme

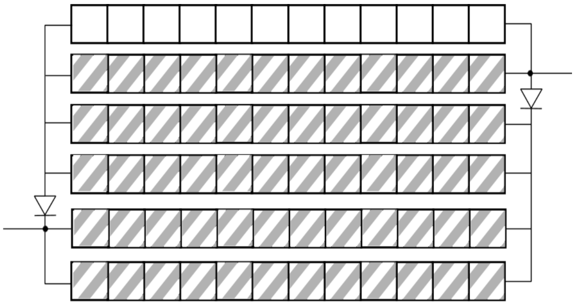

Fig.9 PV module partially shaded

Temperature Of the Module:
The module consisted of 36 cells was placed indoors in the target area of the large area steady-state solar simulator (LASSS). The test was conducted at AM 1.5 spectrum 1000W/m2 with no wind at 25OC ambient. Temperature were then corrected to an ambient of 40°C. The module was operated in short circuit with a central cell half shaded. Points of temperature measurement are:

a) Room ambient.
b) Front glass located on the exposed portion of half-shaded cell.
c) Back face sheet behind centre cell half-shaded.
d) Encapsulant (EVA) behind centre cell.
e) Ambient air within terminal box.
f) Terminal box, inside surface bottom (plastic portion of box which is secured to back of module).
g) Terminal box, inside surface, side of box.
h) Positive terminal (metal portion) of terminal block.
i) Back face sheet under terminal box.
j) Field-wiring, approximate 6mm from positive terminal.
k) Bypass diode.
l) Front glass above centre cell (above exposed portion of half-shaded cell.).

Conclusion:
The modules with bypass diode function are able to show more power output and lower temperature increase than conventional modules when a part of them is shaded. This bypass diode function is also effective for safer operation required for the residential use.

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