Analysis of Partially Shaded PSPICE - PV Modules for Series- Parallel and TCT Configuration

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Abstract

The present work is a study of effects of partial shading on the performance of a PV module spatially on the maximum power point position. This paper clarifies the mechanism of partial PV shading on a number of PV module connected in series parallel and total cross tide. In series parallel connection the shading effects will be studied for deferent number of module. Also this search was mainly devoted to investigate the performance comparison between series parallel and total cross tide with bypass diode and without. A PSPICE simulation model that represents 36 cells PV module has been used to test this study and results are presented.

Keyword: PV module, shading, PSPICE and bypass diode.

Introduction

Partial shading is a commonly encountered mismatch problem in a PV system. It is caused by snow, tree shadow or bird dung covering PV module surface. In a large PV system occupying a wide area of land, moving clouds can also lead to this phenomenon.[1] all this reasons creates non uniform illumination. If part of photovoltaic cells was shaded, the current which a shaded cell generates will be less than the current which a non-shaded cell does. According to Kirchhoff's voltage law, the shaded PV cells will carry negative voltage and become loads of the circuit. It also consumes the power produced by other non-shaded PV cells in the form of heat, (with the continual) over a long period of time of heat accumulation, the high temperature may damage the packaging material of the modules, or even destroy the internal physical structure of photovoltaic cells, and cause permanent damage, known as "hot spot" phenomenon.[2] There have been several studies on the effect of shadowing on the performance of the PV module. Yaw-Juen Wang and Po- Chun Hsu, 2009[1] presents an equivalent circuit model based on piecewise linear parallel branches to study solar cell modules which are partially shaded. Xu Qingshan etal. [3] described the configuration of bypass and blocking diode to the PV cell and mainly investigated the performance comparison between diverse series / parallel PV array patterns when mismatch exited. Dezso Sera and Yahia Baghzouz, [4] clarifies the mechanism of partial PV shading on a number of PV cells connected in series and/or parallel with and without bypass diodes the analysis is presented in simper terms and can be useful to someone who wishes to determine the impact of some shading geometry on a PV system.

Different PV array models have been developed to suit different simulation programs. This paper starts with the PV panel module part that is built into Simulation Program for Integrated Circuits Emphasis (PSPICE) from previous work[5]. The series and parallel connection have been studied previously.[6] This is followed by the application of the proposed model of the analysis of partial shading of a PV module.

The effects of partial shading on PV module I-V and power curves with different module connection configuration series–parallel (SP) and total cross tied (TCT), will be studied. Also this paper described the effect of bypass diode to the performance of PV module.

PV Module Mismatch

When PV panels are connected in series to achieve the desired system operating voltage, and the series strings are paralleled to achieve higher system currents, the resulting system voltage is usually an "average" of the individual voltage maximum point (V_{mp}) of the individual panels. The difference between the new system voltage that is created when the panels and sub-arrays are connected and

the voltage maximum point of the individual panels is the "mismatch". As the operating point is moved away from the voltage maximum point, the power is reduced by some value. The sharper the" knee" of the I-V curve of the panel, the greater the effect of moving the V_{mp}. For example, if the operating voltage is lower than V_{mp}, and the current does not change proportionately, the actual power output of the panel will be lower than its rated power. If the I-V curve has a soft knee, where the current is increased more significantly as the operating voltage is decreased, there will be less impact on the PV panel power output [7]. Bypass diode are often used to prevent PV cells from detrimental effects of partial shading.

The PSPICE model for SP75 module which consists of 36 cell connected in series shown in Fig.(1a) is used to satisfy this study. This model is very large so to minimize it an integrated part (hierarchical block) has been built into special library as shown in Fig.(1b)[5].

(a)

(b)
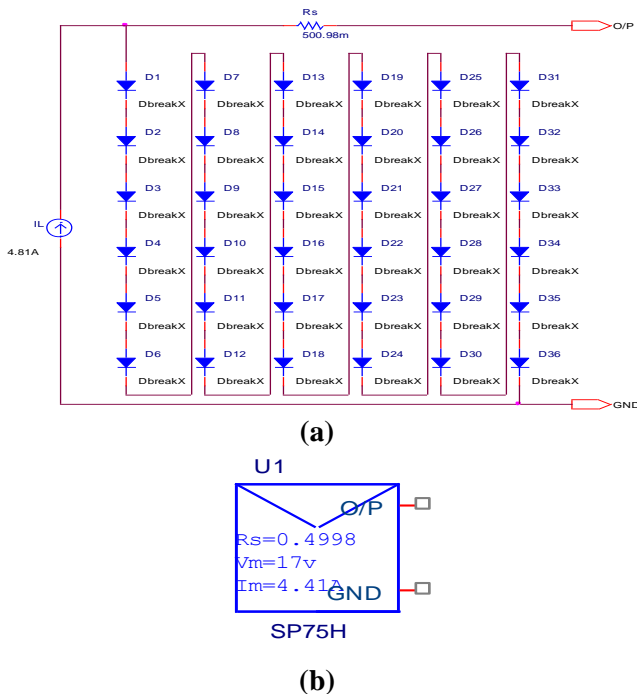
Fig.(1) (a) The electrical circuit of the PV model
(b) The hierarchical block.

This part will be called from that library to simulate the I-V and P-V characteristic of the PV model shown in Fig.(2), as well as this part is used as a source of energy to the power circuits.

(a)

(b)
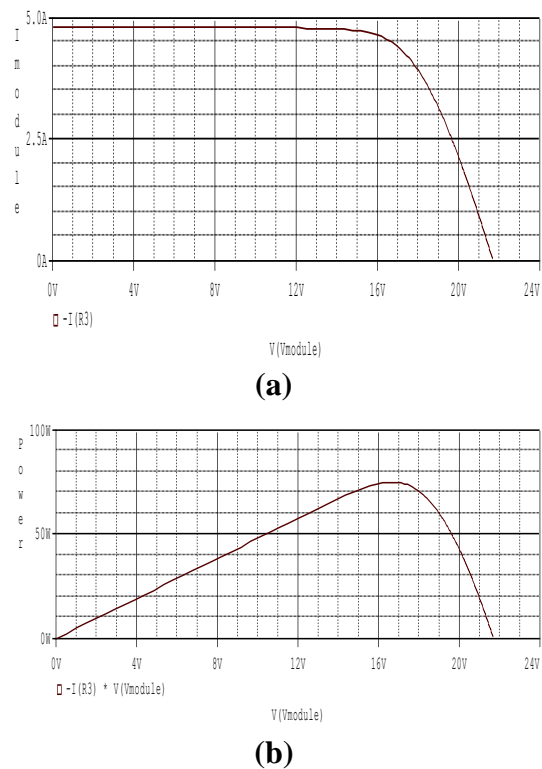
Fig.(2) The PSPICE PV module model
(a) The I-V characteristics.
(b) The P-V characteristics.

Six from this module are connected as series parallel three in each string. The analysis is executed both in equally and unequally radiated conditions. The configurations are taken into account are related to the following connection with six modules:

a) One of the three modules of one PV strings are shaded.

One of six module where represented as electrical (in order to test mismatch effect) and the others as hierarchical block as shown in Fig.(3).
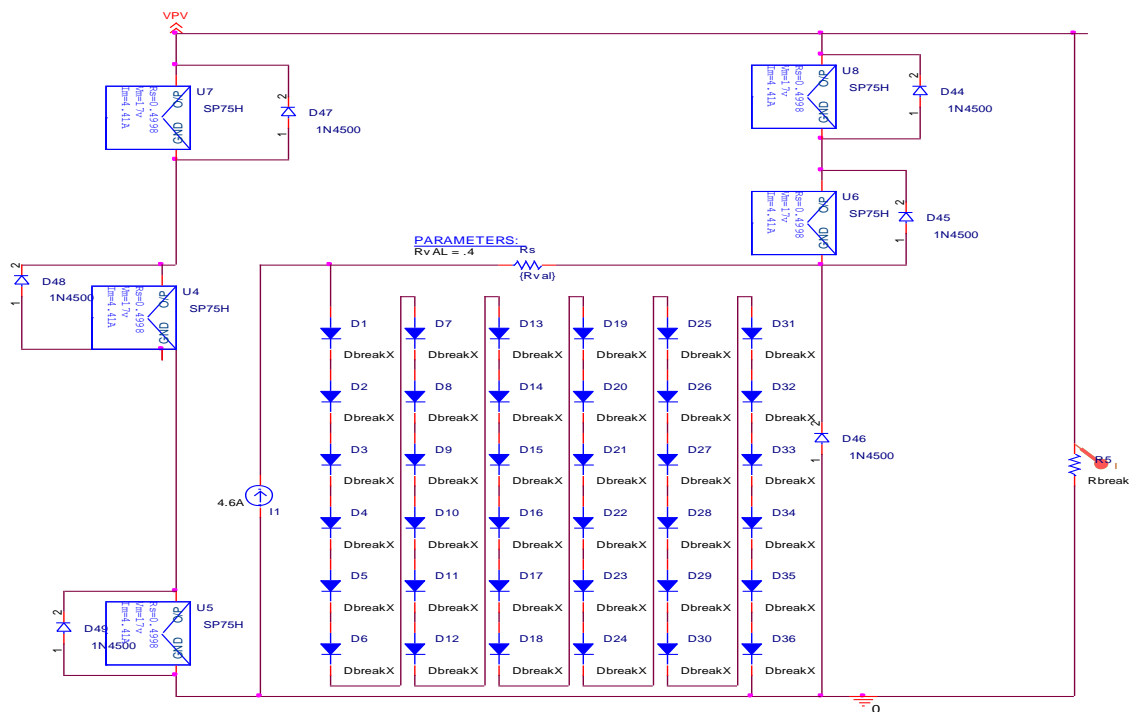
Fig.(3) One of six module as electrical and the others as hierarchical block.

Mismatch was introduced in the simulation by varying the value of single cell current in the module. This causes the single cell to operate at lower current. To extract mismatch from PSPICE PV module, the current source i1 in Fig.(3) will be varies from 4.0A to 4.8A with an increment of 0.4. Simulation with this technique will change the amount of cell mismatch from 0% to 16.6%. Fig.(4) shows the I-V and P-V characteristics for this configuration with bypass diode and Fig.(5) shows the I-V and P-V for the same configuration but without bypass diode where, the MPP reduced from 450W at 52V to 320W at 36 V. These curves obtained from DC analysis (secondary sweep) where the load is defined as R_{break} to cover all the values of the current. R_{break} changes from 10^{-8} to 2Ω with an increment of 10^{-3} in primary sweep.
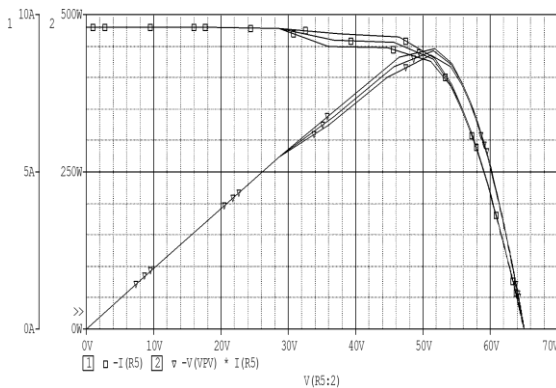

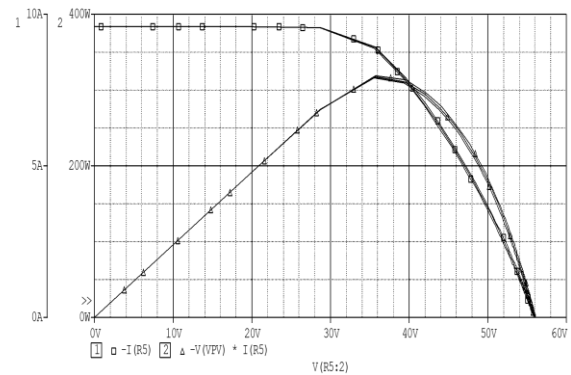*Fig.(4) The I-V &P-V characteristics with bypass diode.*

Fig.(5) The I-V &P-V characteristics without bypass diode.

b) Two of the three modules of one PV strings are shaded

Mismatch was introduced into the simulation by varying the value of a single cell current in two PV module that is represented as electrical circuit in Fig.(6).
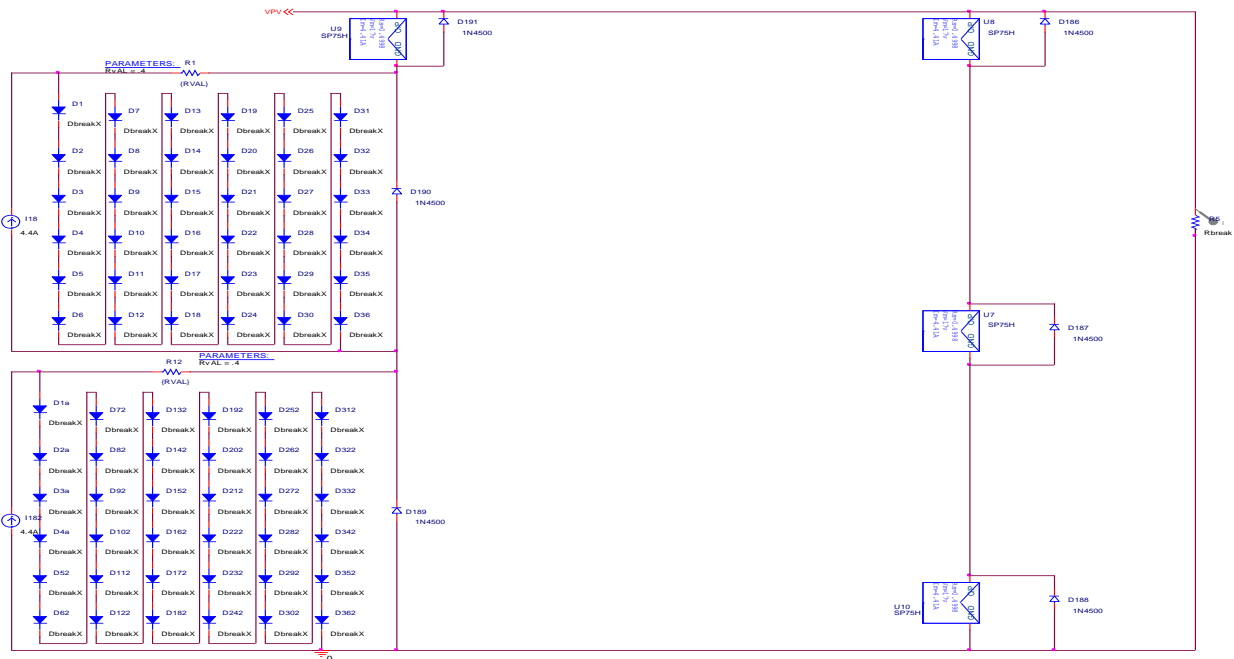
Fig.(6) Two of the three modules of one PV strings are shaded.

Curves that are shown in Figs. (7 and 8) give the behavior of the I-V and P-V for this configuration with bypass diode. These curves illustrated the simulation results with the same arrangements of part a (DC sweep and secondary sweep) and to study the effect of the second module shading a parametric sweep was added to this arrangement (i.e change i182 from 4A to 4.6A with an increment of 0.2).

Fig.(9) gives effects of removing the bypass diode on the maximum power point where it is reduced from 450W at 52V to about 170W at 23V.
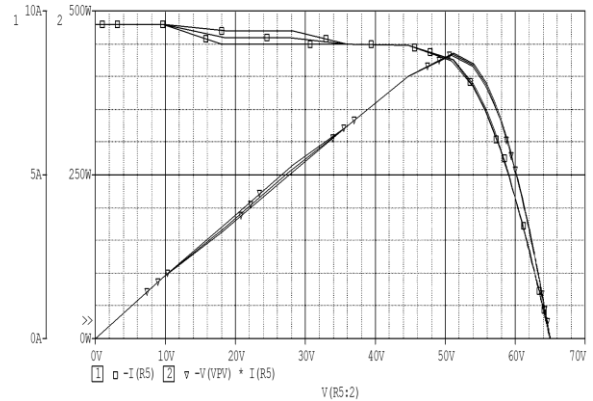
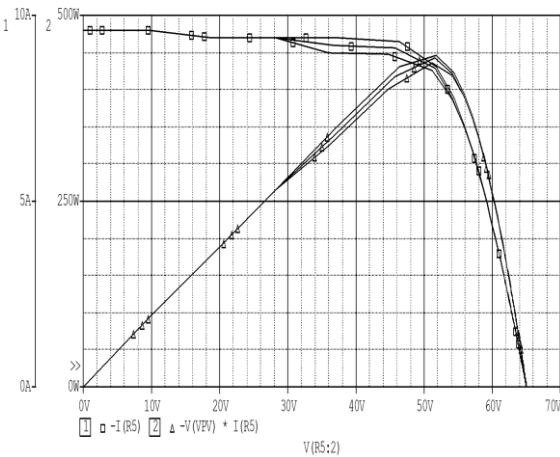*Fig.(8) The I-V &P-V characteristics with bypass diode i18=4.2A, i181= 4.2,4.4 & 4.6.*

Fig.(7) The I-V &P-V characteristics with bypass i18=4.6A, i181= 4.2,4.4 & 4.6.
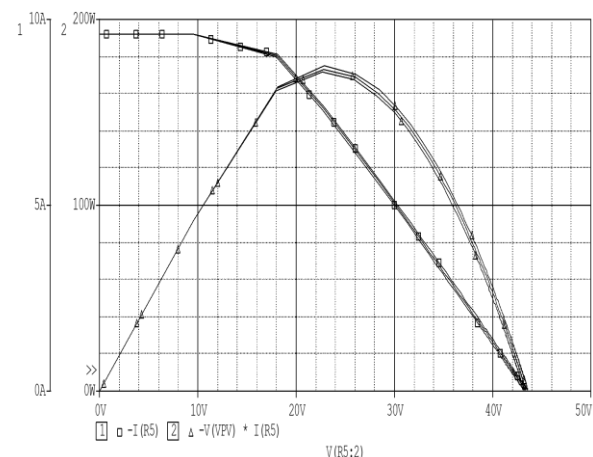

Fig.(9) The I-V & P-V characteristics without bypass diode i18=4.6A, i181= 4.2, 4.4 & 4.6.

c) One of the three modules of each PV strings are shaded

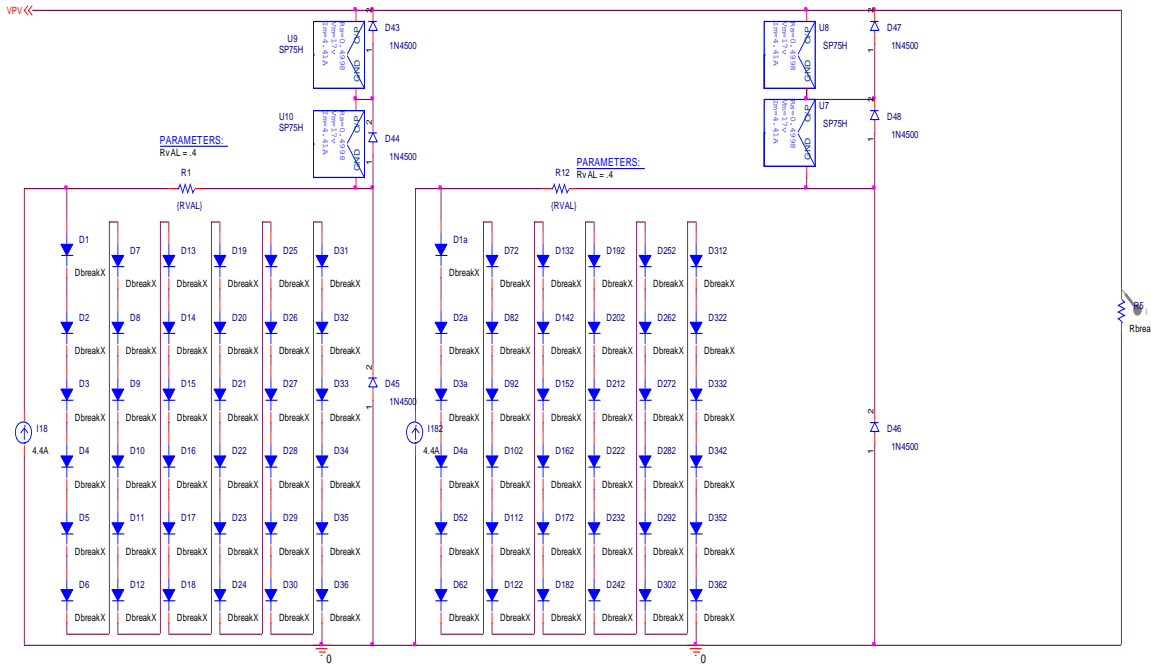As in part b two modules are shaded but each one in separate strings as shown in Fig.(10).

Fig.(10) One of the three modules of each PV strings are shaded.

Fig.(11) and (12) explained the simulation results of I-V and P-V characteristics for different percent shaded with a same arrangement of part b.

Also, Fig.(13) explained the effects of remove bypass diode from this configuration where the max. Power point reduced from 445W at 52V to 300W at 34V.
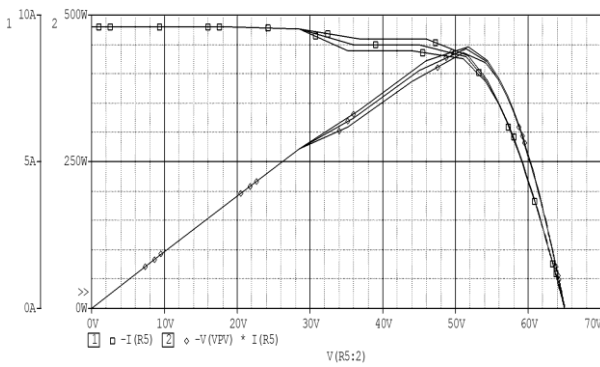

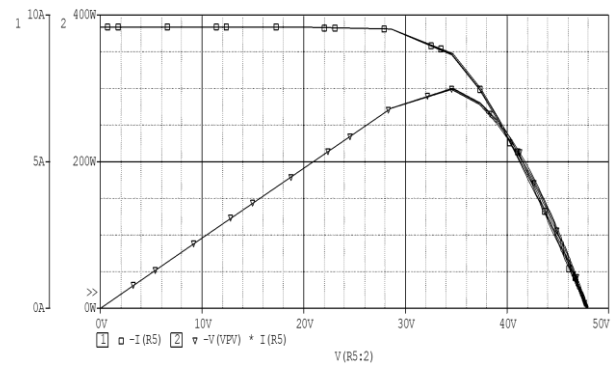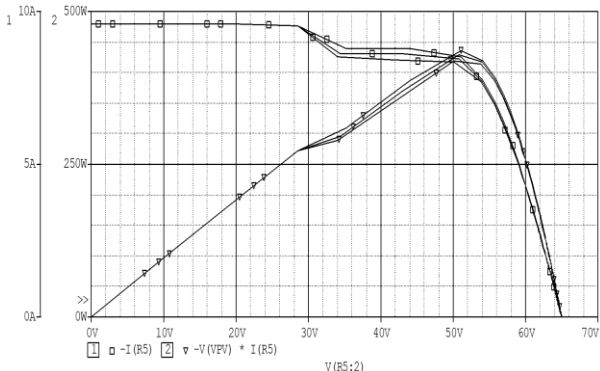***Fig.(11) The I-V &P-V characteristics with bypass diode i18=4.6A, i181= 4.2,4.4 & 4.6.***

Fig.(13) The I-V & P-V characteristics without bypass diode i18=4.6A, i181= 4.2,4.4 & 4.6.

d) The total cross tied (TCT)

This structures shown on Fig.(14) introduce additional connections in between strings of PV modules. The creation of loops in the array increases redundancy in the circuit which enables PV strings to have different currents values flowing through modules of a same string while respecting voltage constraints.
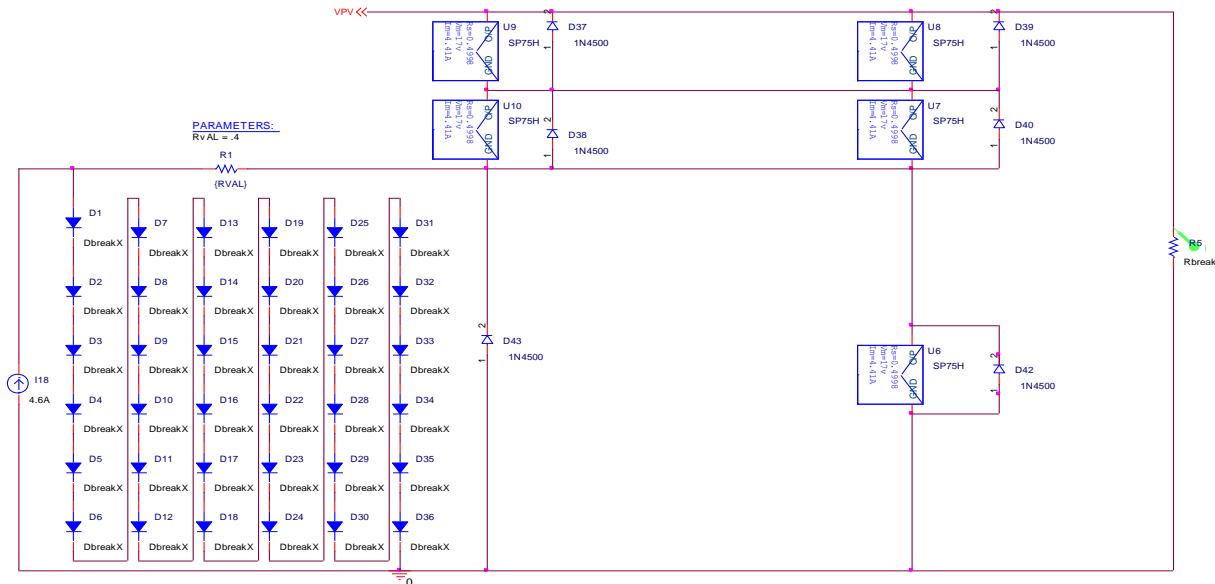

Fig.(12) The I-V &P-V characteristics with bypass diode i18=4.2A, i181= 4.2,4.4 & 4.6.

Fig.(14) The total cross tied electrical circuit as represented in PSPICE.

The complete characteristics for TCT structure with diode and without diode are shown in Fig.(15) and (16) respectively. The maximum power without diode was dropped from 440W at 52V to 300W at 35V.
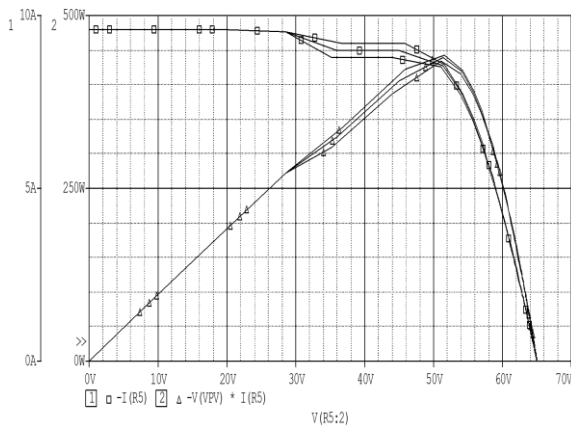

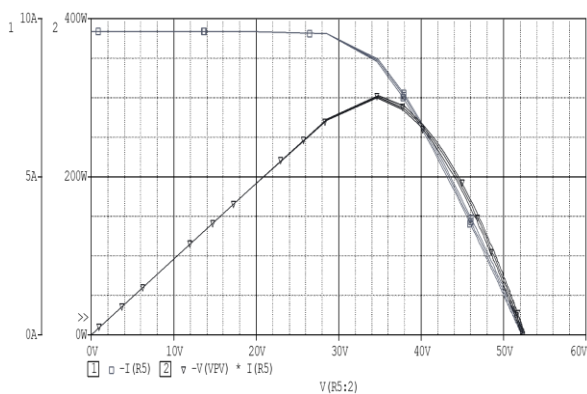*Fig.(15) The I-V &P-V characteristics with bypass diode i18=4.6A, i181= 4.2,4.4 & 4.6.*

Fig.(16) The I-V &P-V characteristics without bypass diode i18=4.2A, i181= 4.2,4.4 & 4.6.

From this four test configuration Table (1) lists the maximum power and percent power losses P_{Losses} that are defined by**:**

$P_{Losses}= ((P_M - P_{Msh}) / P_M) \times 100\%$

Where P_M is the maximum power of the un-shaded module and P_{Msh} is the maximum power of the shaded module

Table (1)
Maximum power and power losses for four cases.

Case	Max. power/W	%Power Losses
1	450	3.3
2	450	2.2
3	445	2.25
4	440	2.27

Fig.(17) compares the percent power losses due to shaded defined by above equation for the four configurations with diode but Fig.(18) illustrates the percent power losses due to the remove of diode.
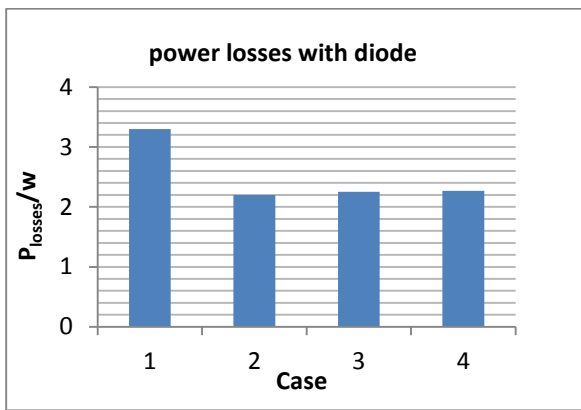
99

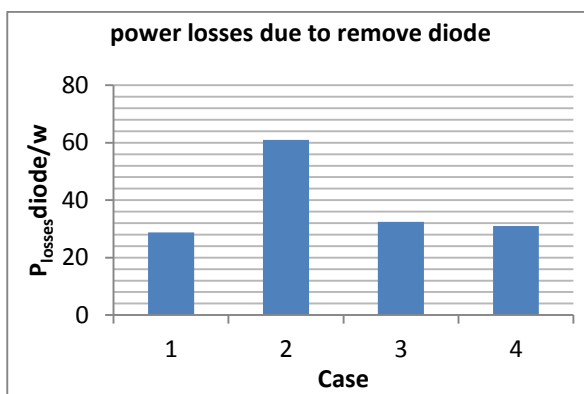*Fig. (17) Comparison of power losses of four cases.*

Fig. (18) Comparison of power losses due to remove diode of four cases.

Conclusion

Several problems associated with partial shading have been simulated in this study. First the effect of adding bypass diode to the module with shading reduced the power losses. All the cases under test gives approximately the same maximum power point but without diode the maximum power dropped to less than its average value especially in the case of shading two module in the same strings. The second effects is the number of modules that is shaded and there location which has no effects on the maximum power for the same connection (S-P) but the maximum power for TCT gives a better results than S-P connection. Finally the PSPICE PV module has a great advantage to the workers in this line.

References

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الخلاصة

العمل المقدم هو دراسة لتأثير التظليل الجزئى على انجاز اللوح الشمسي خاصة على موقع القدرة الاعظم. هذه المقالة توضح آلية التظليل الجزئى على عدد من الالواح الشمسية التي ربطت على التوالي – التوازي s-p وكذلك TCT فى طريقة الربط على توالي – توازي سيتم دراسة تاثير تظليل اعداد ومواقع مختلفة للالواح. كذلك هذا البحث في الدرجة الاولى سيكرس للتحقيق في مقارنة الانجاز بين توالي – توازي و TCT مع وجود الدايود او بدونه. استخدم موديل للوح يتكون من 36 خلية شمسية مربوطة على التوالي والمبني في برنامج PSPICE لفحص هذه الدراسة وتقديم النتائج.