I J C T A, 9(37) 2016, pp. 791-802

Design of a MPPT Controller Along with a Reconfiguration Technique for a PV System Under Partially Shaded Condition

P.R. Adityan*, K. Vijayakumar and George Fernandez*****

Abstract: One of the primary factors affecting the operation of Solar Photovoltaic systems is the unfavorable atmospheric conditions. A partially shaded solar panel leads to generation of hotspot or circulating currents among the parallel connected modules. To overcome this, a reconfiguration strategy has been introduced here which takes place within the panel without any external switching arrangement. The above mentioned reconfiguration technique removes the multiple peaks in the P-V curve of the panel. A simple MPPT algorithm like Perturb and Observe can be used, to get maximum efficiency without the need for complex MPPT techniques. A reconfiguration strategy has been introduced here which takes place within the panel without any external Switching arrangements.

Raman Spectroscopy was used to check the nature of synthesised graphene, which help to determine whether the graphene film synthesised is multilayer, bi-layer or single layer.

Keywords: Photovoltaics, array reconfiguration, Maximum power point tracking.

1. INTRODUCTION

The amount of solar energy received by earth is around 174000 Terawatts. So it only behooves one to use such a vast amount of energy in compensating for the ever increasing demand for electrical energy. This can be done by using the Photovoltaic system to convert sun's irradiation into electrical energy [1]. However this technology has its own disadvantages. One of the primary disadvantages is the operation of the solar PV systems in poor atmospheric conditions or partially shaded condition.

The cells in a solar panel are connected in different configuration like series, series-parallel, total cross tied and multi string. Different connections are used for different load conditions. However commercially manufactured panels are connected in series connection. When cells are shaded the connection of the cells in the panel becomes open-circuited. However due to the conduction of other cells, the current flow gets obstructed at the point of shading and this leads to rise in the cell temperature. Thus hot-spots are created which damages the panel permanently. For a series-parallel arrangement, shading of cells in different parallel string leads to unequal voltages among them. This gives rise to circulating current which in addition to reducing the output, may also contribute to hot-spots.

The aim of reconfiguration is to bypass the affected cell and somehow maintain the continuity of the circuit by using adaptive solar cells or reconnect the circuit in such a way that the continuity of the circuit is maintained.

It has been observed that the output of the Solar panel is greatly reduced when a portion or entire surface of the Solar panel receives reduced irradiation. To overcome this great number of researches has been introduced in which the output of such a panel with reduced irradiation is overcome with the help of various MPPT techniques 2. The efficiency of different techniques used depends on the complexity of the

* Student, Dept of Electrical and Electronics Engineering, SRM University, Chennai India. *Email: adityan1991@gmail.com*
** Professor, Dept of Electrical and Electronics Engineering, SRM University, Chennai India. *Email: kvijay_srm@rediffmail.com*
*** Assistant Professor, Dept of Electrical and Electronics Engineering, SRM University, Chennai India. *Email: georgefernandez.s@ktr.srmuniv.ac.in*

process. To achieve higher efficiency researches were done to modify, improve and create hybrid MPPT techniques 3.

Another way to improve the output of the panel could be to modify the cell configuration of the solar panel during such irradiated conditions such that the affected cells can be bypassed out of the circuit. In 4 an EAR (Electronic Array Reconfiguration) technique has been used to reconfigure the modules connection in a solar array. In 5 and 6, the reconfiguration strategy was adapted to reconfigure cells within a solar module rather than entire panel arrangement. However an additional adaptive solar cell bank was used to replace or bypass the affected solar cells. The reconfiguration algorithm is developed according to the kind of design developed in each case.

Another method that is employed to avoid the damage caused due to partial shading or poor atmospheric conditions in a solar panel is to connect bypass diodes across the solar cells so that the entire current can pass through them when the cells are shadowed. This however gives rise to multiple peaks in the Power versus Voltage curve of the solar panel. Due to the presence of multiple peaks, a simple maximum power tracking may get stuck in a lower maxima peak rather than the higher maxima peak. This will lead to reduced output even with a tracking algorithm.

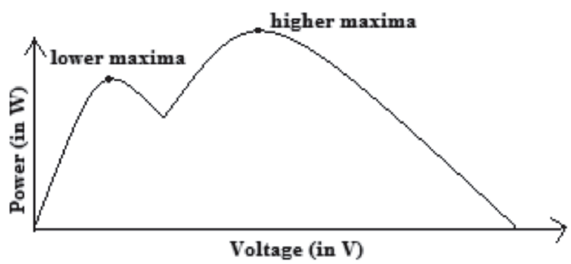

Figure 1: Multiple peaks in a P-V curve

The main components of the system are presented in the form of a Block diagram (Figure 2).

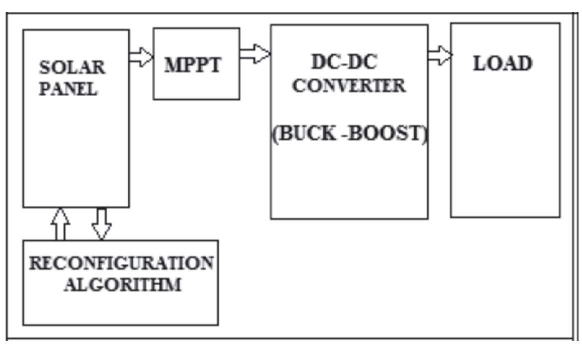

Figure 2: Main Components

In this paper firstly the MPPT based reconfiguration strategy is explained, and then the MPPT algorithm is explained. The MPPT algorithm is applied to the reconfigured solar array and the results are compared with and without the reconfiguration. Also the effect of using bypass diodes is compared. All the algorithms are explained in the form of flowchart and the results are shown in the form of figures and tables.

2. RECONFIGURATION STRATEGY

The process of applying the reconfiguration strategy is explained in the following steps:

- When a portion of the panel is shadowed, the irradiation of the cells falling under that portion is reduced. The switching algorithm detects when the irradiation is reduced below the nominal value and records the respective cells position.

- Every cell in the panel has a pair of series and parallel switches. These switches are labeled as '*a*' and '*b*' respectively. Also bypass diodes
- The algorithm now operated the series and parallel switches of the corresponding cells which are affected and also the neighboring cells. This helps in completing the circuit with the loss of only the affected cells. The rest of the cells in the same series function normally.
- Now the presence of multiple peaks in the P-V curve of the panel is removed.
- The Perturb and Observe (P and O) MPPT algorithm is applied to the output of this reconfigured solar panel.
- This algorithm constantly tracks the slope of P-V curve until it reaches the maximum peak of the curve. Thus a use of simple MPPT algorithm can yield the maximum power value at different irradiation conditions.

The reconfiguration algorithm is shown in the form of a flowchart (Figure 3).

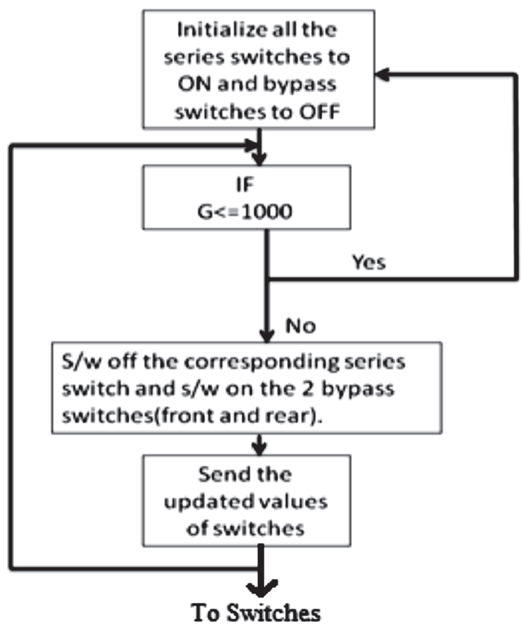

Figure 3: Switching algorithm flowchart

The solar panel (Figure 4) that is designed is a 12 series connected solar cell along with series (a_1, a_2...) and parallel (b_1, b_2...) switches as mentioned earlier. Bypass diodes are connected across the solar cells.

The specification of the designed solar panel is shown below Table 1 for both individual cell and the entire panel. The P-V and I-V characteristics of the panel simulated in MATLAB are plotted below.

Table 1
Solar Panel Specifications

Parameters	*For one cell*	*For the solar panel (12 series connected | solar cell)*
Open circuit Voltage (V_{OC})	0.6 V	7.2 V
Short circuit current (I_{SC})	7.34 A	7.34 A
Voltage at Maximum power point (Ympp)	0.48 V	5.312 V
Current at maximum power point (Impp)	6.95 A	6.681 A
Maximum power (in W)	3.38 W	35.495 W

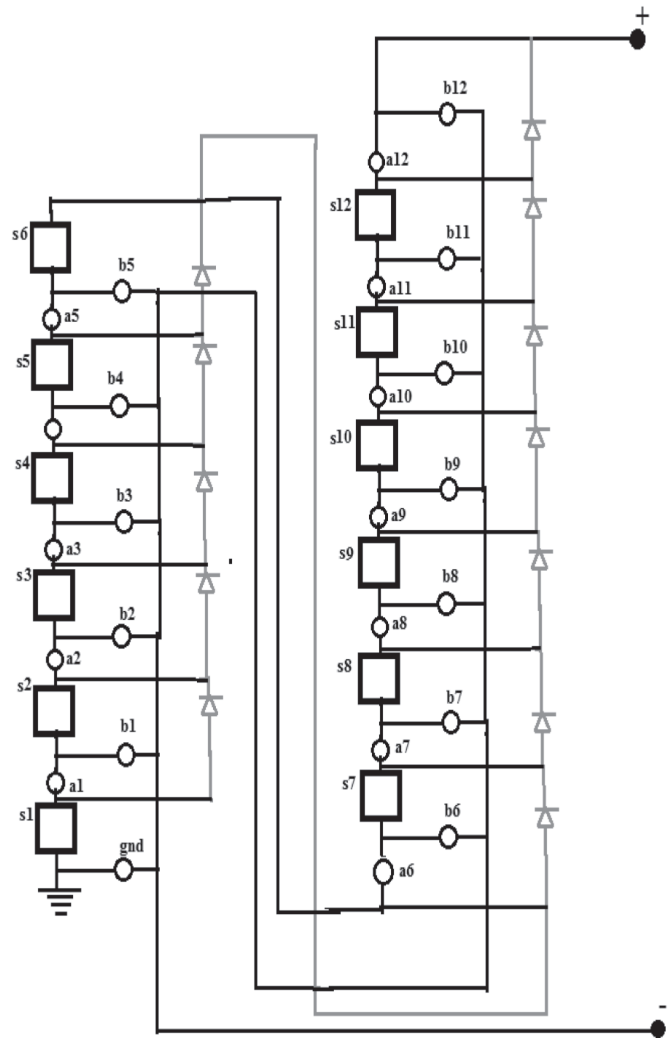

Figure 4: Solar panel

Now to check the reconfiguration working, the shading effect is simulated by reducing the irradiation of one single cell to 100 W/m^2. In the shaded condition the solar panel is connection is shown (Figure 5, Figure 6, Figure 7 and Figure 8).

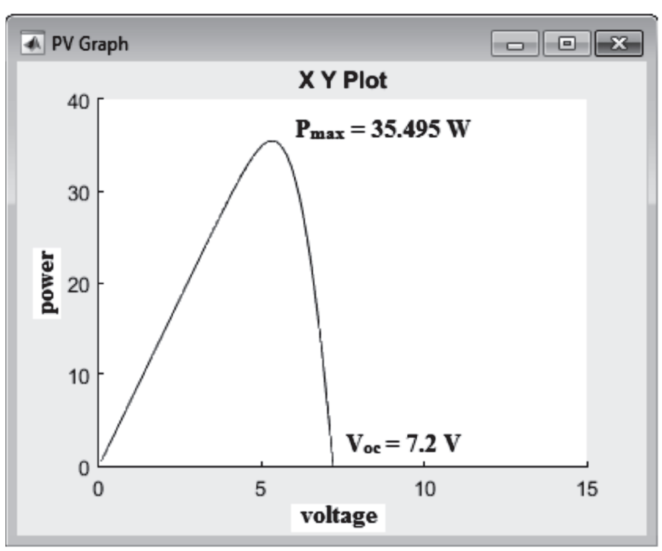

Figure 5: P-V curve

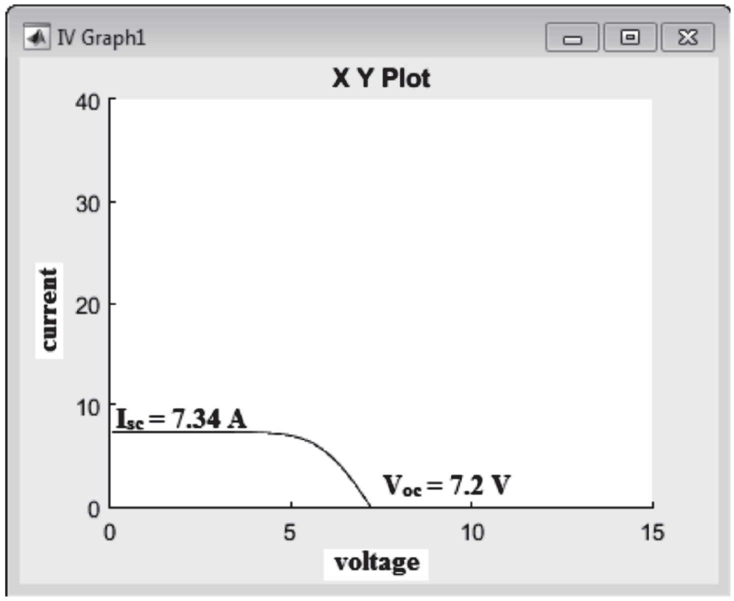

Figure 6: I-V curve

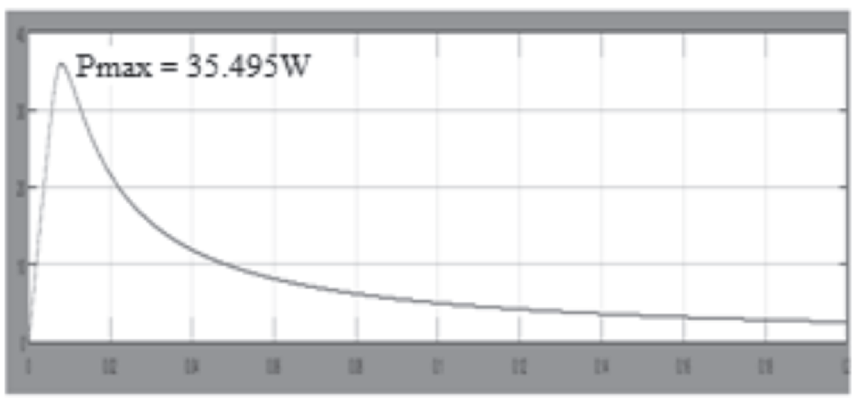

Figure 7: Power curve

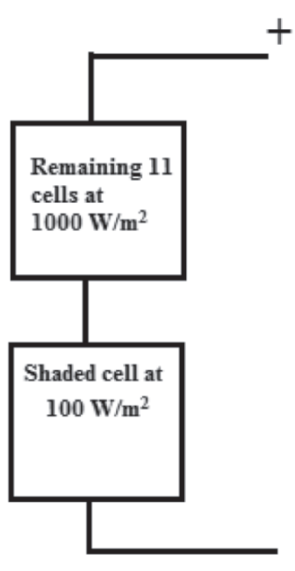

Figure 8: Shaded cell connection

Now the effect of the shading is shown by plotting the P-V and I-V graph (Figure 9, Figure 9.1 & 10).

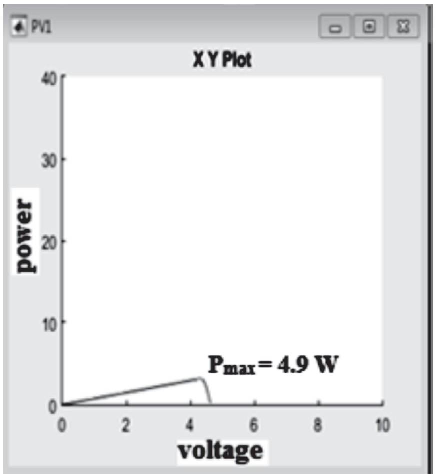

Figure 9: P-V curve for shaded panel

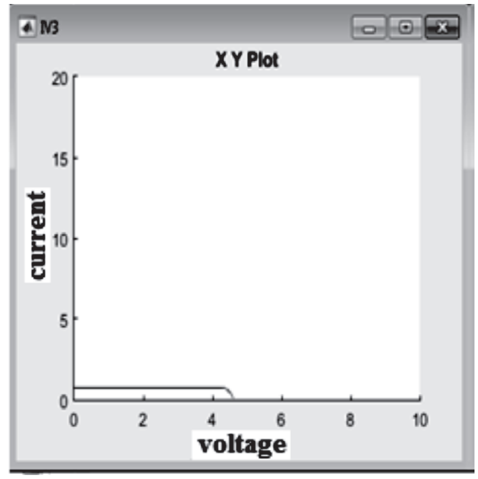

Figure 9.1: I-V curve of shaded panel

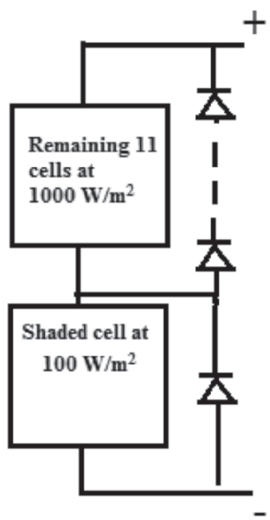

Figure 10: Cell connection with bypass diodes

From the graph it can be seen that the overall power has reduced greatly. This is due to the fact that in a series connected cell configuration, reduced irradiation in even one cell leads to an incomplete circuit. Thus the output of all the other cells which are not irradiated is also affected. Now to overcome the shading effect bypass diodes will be connected across the cells. The connection is shown and the corresponding outputs are plotted below Figure 11, Figure 12 and Figure 13.

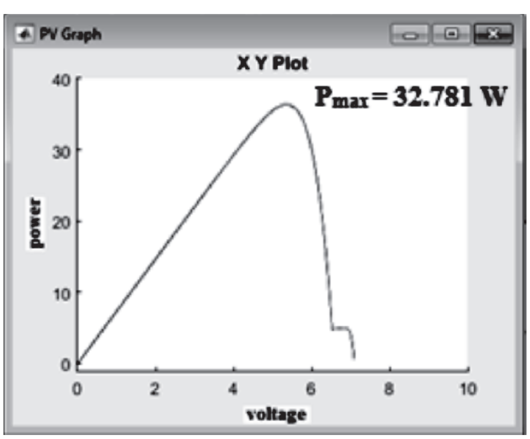

Figure 11: P-V curve with bypass diodes

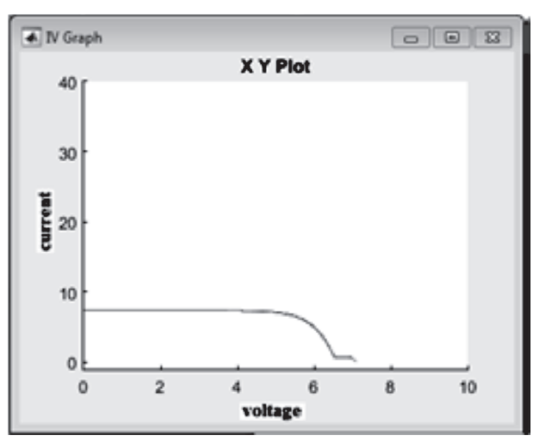

Figure 12: I-V curve with bypass diodes

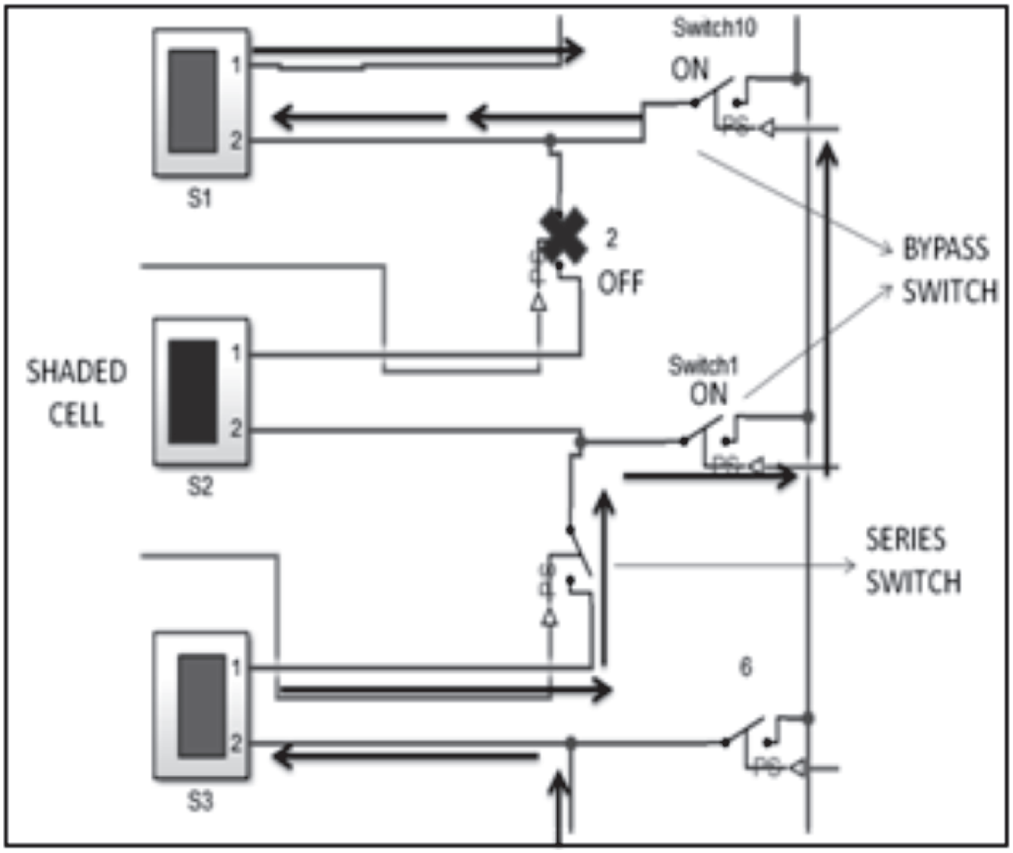

Figure 13: Graphical representation of switching operation

As it was mentioned earlier the use of bypass diodes give rise helps to increase the overall power, nonetheless it shows multiple peaks in the P-V graph of the panel. We now apply the reconfiguration technique to the above panel arrangement and check the output. A graphical representation of the switching operation is presented here for better understanding. Then the corresponding outputs were plotted in Figure 13, 14 and 15.

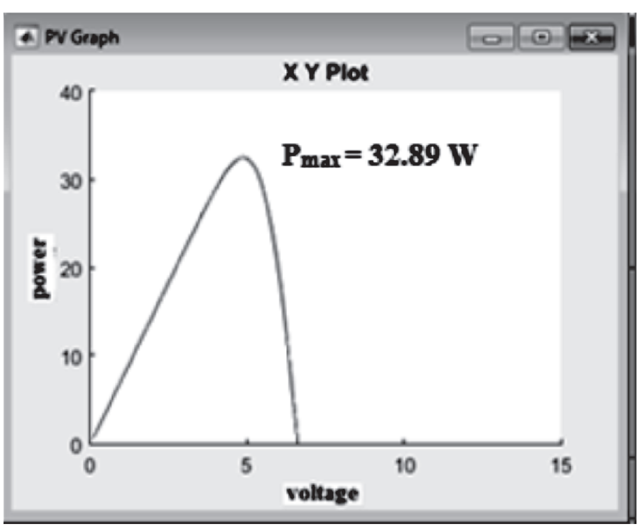

Figure 14: P-V curve for reconfigured panel

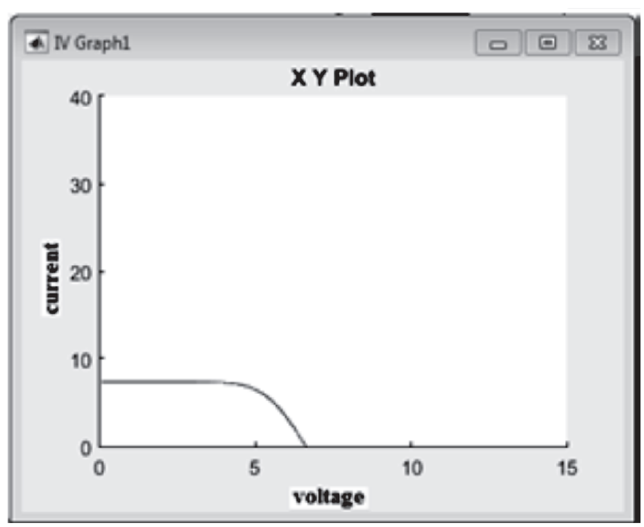

Figure 15: I-V curve for reconfigured panel

Now from the above result, it is evident that the reconfiguration technique has overcome multiple peaks in the P-V curve and also shown little higher output, the above results are compared in the Table 2 below.

Table 2
Comparison of Results

Circuit used (with 1 shaded cell)	*Power output (in W)*
Simple series connected circuit without using any modification	4.9
Series connected circuit with bypass diodes connected	32.781
Series connected circuit with bypass diodes connected and applying reconfiguration	32.89

3. MPPT ALGORITHM

The MPPT technique that is used here is a Perturb and Observe (P & O) algorithm. The P and O algorithm is one of the simplest algorithms and it's widely used. However its efficiency is not very high as compared to other complex algorithms due to its limited speed of tracking. However to overcome this limitation a reconfiguration technique is applied which will allow the tracking to be smooth and give the maximum power output. It is given in Figure 16.

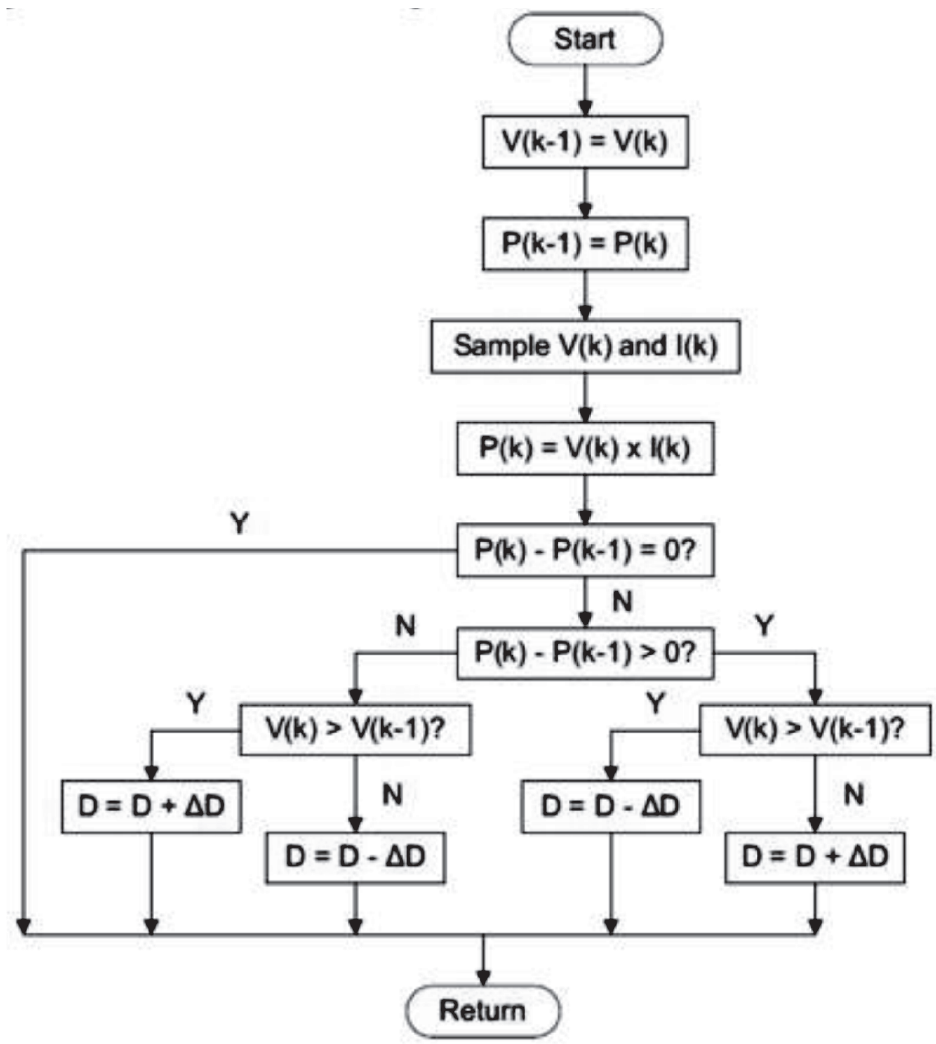

Figure 16: P and O flowchart

The circuit used for simulation in MATLAB SIMULINK is shown below Figure 17.

Firstly the MPPT will be applied for a shaded panel without reconfiguration and its output will be plotted based on the above model in Figure 18 and Figure 19.

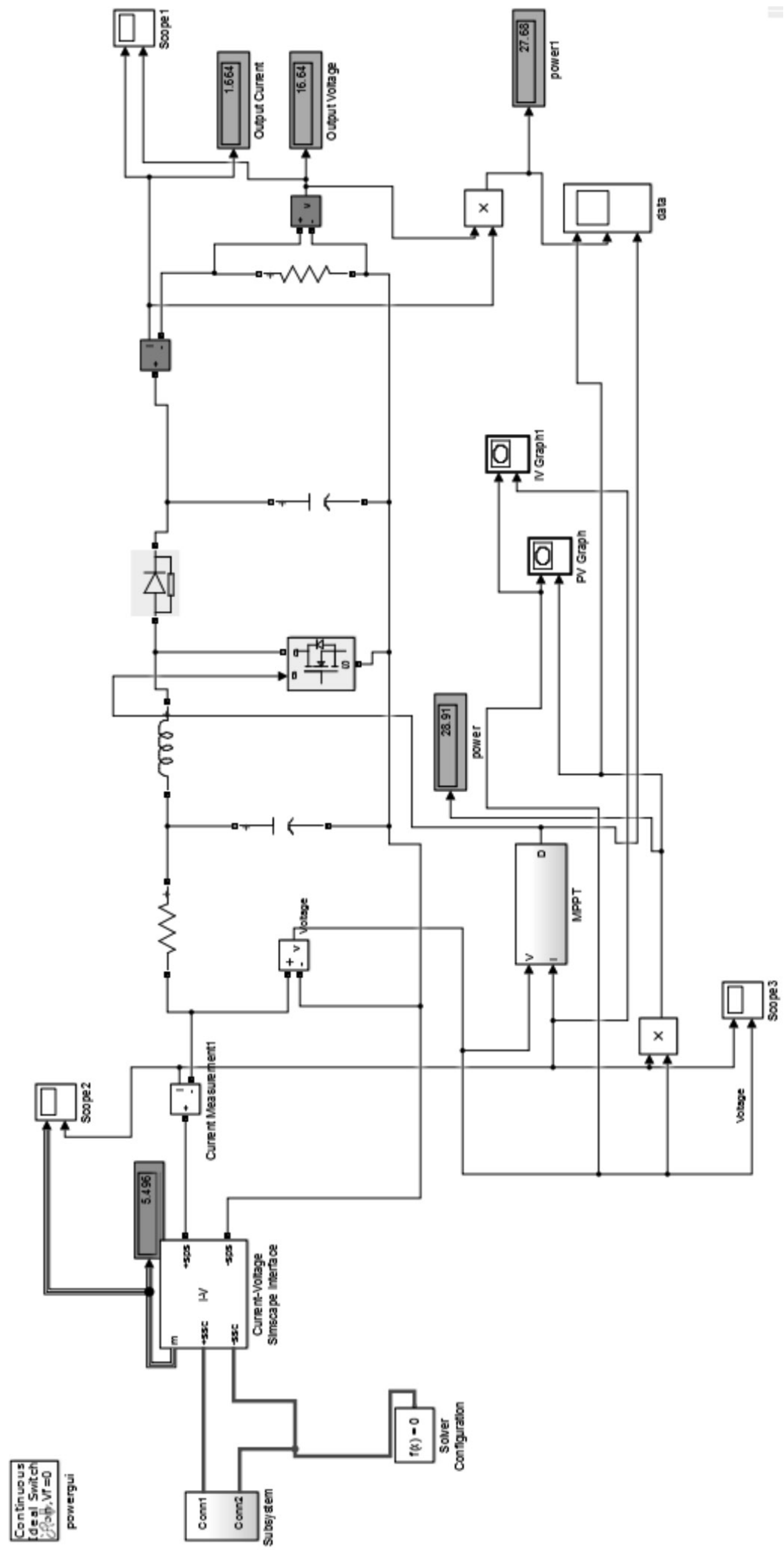

Figure 17: Simulink diagram

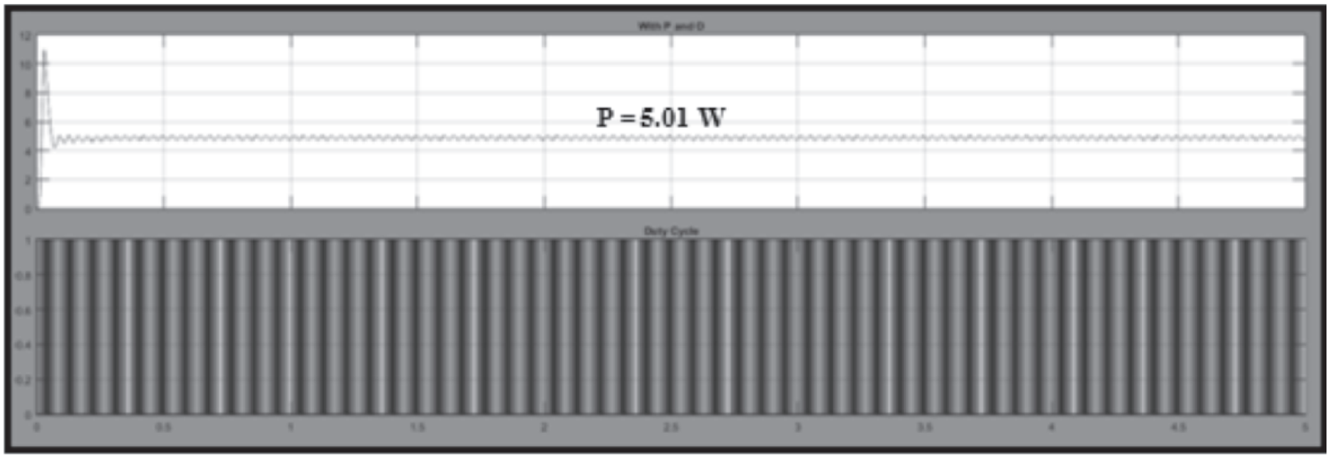

Figure 18: Power output and duty cycle for shaded cell using MPPT

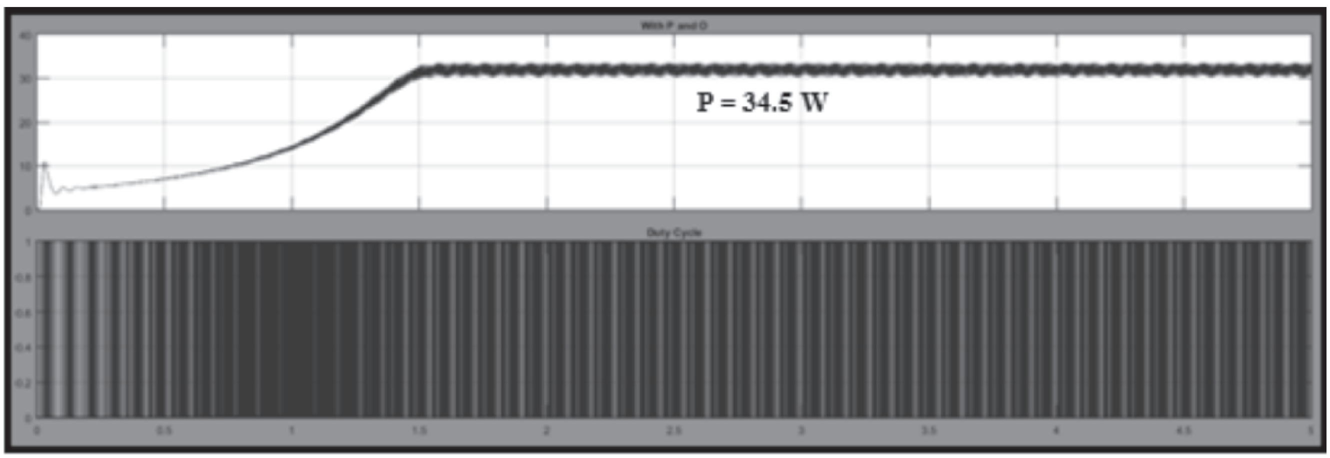

Figure 19: Power output and duty cycle for shaded cell using reconfiguration and MPPT

From the outputs it can be seen that, the MPPT algorithm gives a higher output with reconfiguration. As explained earlier, due to the presence of multiple peaks, the P and O algorithm gets stuck at a local minima (P) value of 5.01W. Once the multiple peaks are removed due to reconfiguration, the MPPT tracks the maximum power output. The plot for multiple peaks (Figure 20) and MPPT tracked voltage (Figure 21) is presented below.

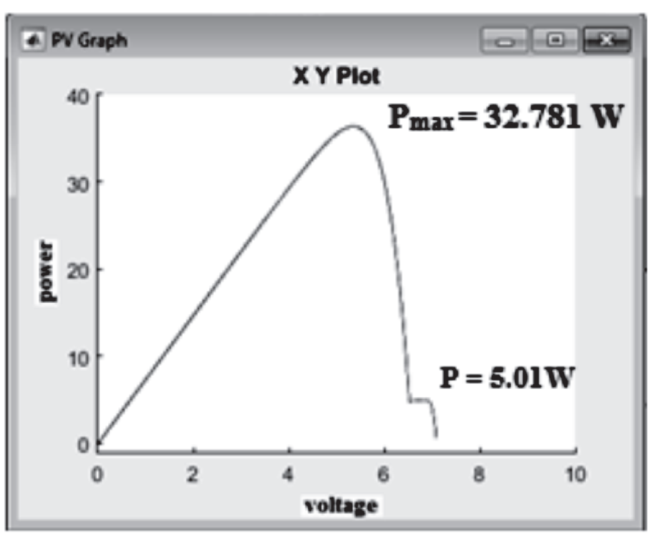

Figure 20: Multiple peaks due to shading

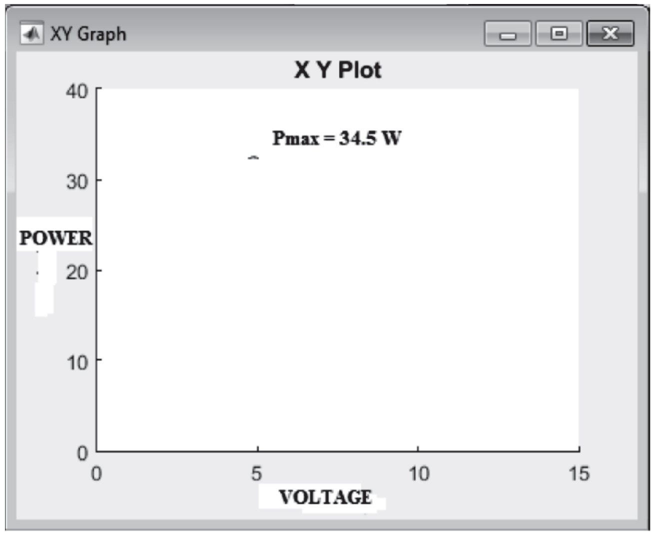

Figure 21: MPPT algorithm power output at maximum power point

From the above results we can see that the power tracked by the algorithm is hovering at the peak of the curve at around 34.95W. The comparison of the above results is compared in Table III.

Table 3
Comparison of Results

Circuit used (with 1 shaded cell)	*Power output (in W)*
Simple series connected circuit without using any modification	4.9
Series connected circuit with bypass diodes connected	32.781
Series connected circuit with bypass diodes connected and applying P and O	5.01
Applying a Reconfiguration strategy to the above circuit	34.5

4. CONCLUSION

It is seen that the shading of a single solar cell in a series connected panel can reduce the power output greatly. Bypass diodes were connected to the circuit and the output was seen to increase. However multiple peaks were seen. When the MPPT algorithm was implemented, the multiple peaks were shown to restrict the output to a lower minima value. Further reconfiguration was applied with and without the MPPT algorithm. The results showed that the Maximum power point tracker was tracking the output to the maximum value under shaded conditions. In future this work can be improvised by adding a more evolved algorithm for optimized switching of the cells. This switching algorithm can be further used to implement switching between the modules in an entire array.

References

1. G.K. Singh, "*Solar power generation by PV (photovoltaic) technology: A review*", Energy, Volume 53, 1 May 2013, Pages 1-13, ISSN 0360-5442.
2. Dominique Bonkoungou, Zacharie Koalaga, Donatien Njomo, "*Modelling and simulation of photovoltaic module considering single-diode equivalent circuit model in MATLAB*," SSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 3, March 2013.
3. Krismadinata, Nasrudin Abd. Rahim, Hew Wooi Ping, Jeyraj Selvaraj, Photovoltaic Module Modeling using Simulink/Matlab, Procedia Environmental Sciences, Volume 17, 2013, Pages 537-546, ISSN 1878-0296.
4. Salameh, Z.M.; Liang, C., "*Optimum switching points for array reconfiguration controller*," in Photovoltaic Specialists Conference, 1990., Conference Record of the Twenty First IEEE, Vol., No., pp. 971-976, Vol. 2, 21-25 May 1990.

5. Ze Cheng; Zhichao Pang; Yanli Liu; Peng Xue, "*An adaptive solar photovoltaic array reconfiguration method based on fuzzy control*," in Intelligent Control and Automation (WCICA), 2010 8th World Congress on , Vol., No., pp.176-181, 7-9 July 2010.

6. El-Dein, M.Z.S.; Kazerani, M.; Salama, M.M.A., "*Optimal Photovoltaic Array Reconfiguration to Reduce Partial Shading Losses*," in Sustainable Energy, IEEE Transactions on, Vol. 4, No.1, pp. 145-153, Jan. 2013.