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Reconfiguration of Solar Array under Partial Shaded Condition for Maximum Energy Harvesting

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ABSTRACT: This paper proposes a simple adaptive technique to reduce the partial shading losses of a PV array. A sorting is done according to the solar insolation on each module and the distributive algorithm will try to equalize the total irradiation on each row of a TCT array by reconfiguring modules. So that the problems created by shading is reduced and output power is increased. As the algorithm taken is simple, real time implementation is easy and less costly than other techniques. Simulation results show that the proposed algorithm is efficient.

KEYWORDS:MPPT (Maximum Power Point Tracker), partial shading, Reconfigurable PV array

I.INTRODUCTION

Interest in green energy is increasing day by day. As solar energy is free of cost and it can be converted in to electricity the use of photovoltaic cells is increasing rapidly. Even though it is 0.1 % of the total electricity production as of now but according to the International Energy Agency's vision it will be 16% of the world's electricity production. To get the maximum power from the PV array we use MPPT techniques which will track the maximum power point. All the MPPT techniques work on the assumption that the insolation on every module is same. But in real conditions it is not like that. Partial shading is the phenomenon where different modules in the same PV array have different irradiance levels and it reduces the output power from the array. The shading will also cause local hotspots which will damage the shaded cells.

The main methods which are used to reduce the undesired effect of partial shading are

- Use of bypass diodes. Bypass diode are connected in antiparallel with the PV modules. During non-uniform shading the current excess from the short circuit current will be bypassed by the diodes.
- Use of separate MPPT for each PV module is another method. This method is very efficient but it is very costly as the number of converters will be equal to that of number of PV modules.
- Reconfiguration techniques. The whole PV array or a part of it is reconfigured in order to reduce the effect of partial shading.

In this paper, a new way of reconfiguring the solar panels is proposed such that the output power is increased at the time of partial shading. The reconfiguration is based on trying to equalize the total irradiation of each row. Even though many other configuration techniques have been proposed by many authors it all needs complex and time consuming calculations.

II.PARTIAL SHADING LOSSES

The MPP of the PV array will not match with the MPP of each module and it will cause a loss of power at the time of partial shading. Under shaded condition the array cannot produce the power produced at the unshaded condition, this loss is unavoidable. The maximum power that can be produced at the time of shading is the sum of individual maximum powers of each modules at the time of PS. But mismatch losses which is the difference between the global MPP at the shaded condition and the maximum power that can be produced at the shaded condition can be reduced by different techniques. Another loss is also occurred if the converter does not operate at the global MPP. In practical case if conventional MPPT algorithms are used then the converter will be working at the first local maximum point than the global MPP point. In fig.1 the converter will be working at the first local MPP which will cause approximately 25% of loss in output power.

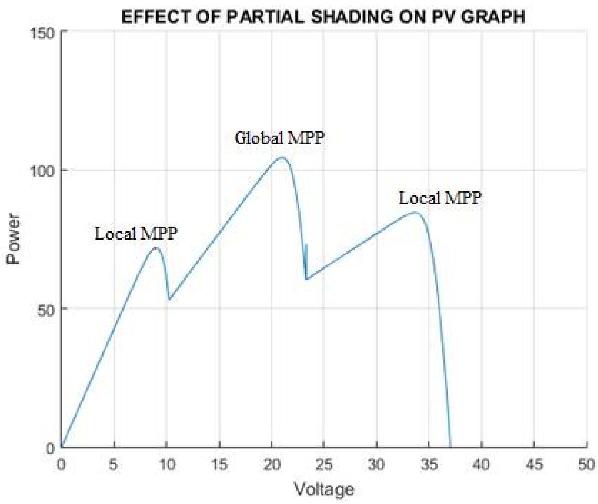

Fig.1 PV graph showing multiple MPP at PS condition.

III.RECONFIGURATION STRATEGY

This section proposes a reconfiguration strategy which helps to switch the PV panels in such a manner that the power is increased at the time of reconfiguration. In this method the voltage of each PV panel is measured first. If the illumination is same for all the panels the output voltage of all the PV panels will be same. If any of the voltage is found to be different than that of the other panel's voltages then it means shading has been occurred. Then the reconfiguration starts. The steps of the algorithm are explained below.

Step 1. The solar panel is connected in its original configuration. The voltage of first row of the array is monitored and if there are i rows then output voltage $V_{out} = i \times V_1$ if there is no shading. Whenever$V_{out} > i \times V_1$ or $V_{out} < i \times V_1$it indicates that shading is occurred. First case shows shading in the first row and second case shows shading in other rows. If shading has been occurred then go for reconfiguration.

Step 2. Open all the connections. Irradiance of each PV panel is estimated. Even though irradiance can be estimated using irradiance sensors, we estimate it using the measurements from the panel's voltage and currents. The advantage of irradiance estimation than measurement is that the cost can be reduced to a great extend as irradiance sensors are costly. If G_{ij} is denoted as the estimated irradiance,I_{ij}, V_{ij} are the voltages and currents of the PV module corresponding to the 3rd row and 5th column, all the other parameters will be available in the data sheet of the PV module given by the manufacturer. Irradiance can be estimated by the equation given below.

$$G_{ij} = \alpha\left[I_{ij} + I_0 \times \left(e^{V_{ij}/nV_T} - 1\right)\right]$$

Step 3. After finding out the irradiation of every module sort them in descending order of the irradiation. Initially the largest i (no.of rows) irradiations are stored as i rows. These PV modules are to be connected in series. Then the greedy algorithm is applied to find the connection of other modules. By taking each irradiance value find the suitable row which will reduce the sum of irradiation in the rows when that particular module is added. Connect that module in parallel to the row which produced minimum sum.Similarly find the position of every other PV modules.

Step 4. Control for the switching matrix is given as per the connection found out in the former step.

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Step 5. The voltages are continuously measured and when the shadows changes and if the output voltage is below the threshold value then repeat from step 2.

The flow chart is shown in figure 2 below.

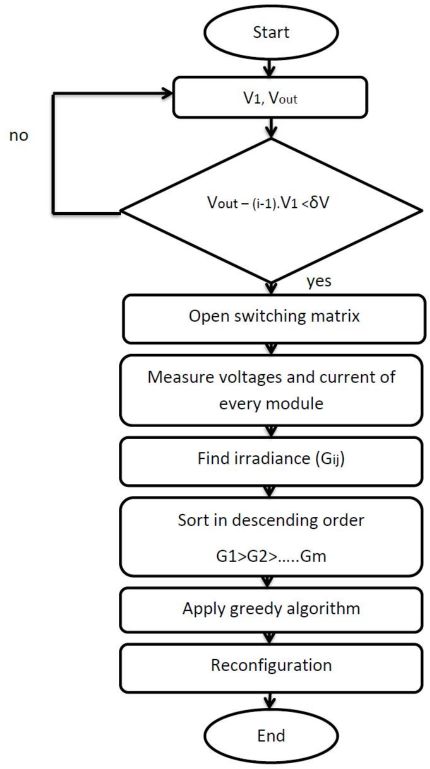

Fig.2 Flow chart of the proposed method

IV. RESULT AND DISCUSSION

The PV array shading is shown below, an initial configuration as shown in fig.3 and thestrategy relocates the panels as in fig.5 The PV Graph before and after the relocation is also shown in fig.4 and fig.6 respectively. From fig.6 it is clear that the power output is increased after reconfiguring the PV panels. Before reconfiguration the sum of row irradiances are 3700, 4200 and 2600w/m^2 respectively and the PV graph shows two different local peaks. Here the global peak is at 750 watts but the MPPT algorithm will take 625 watts as the peak.

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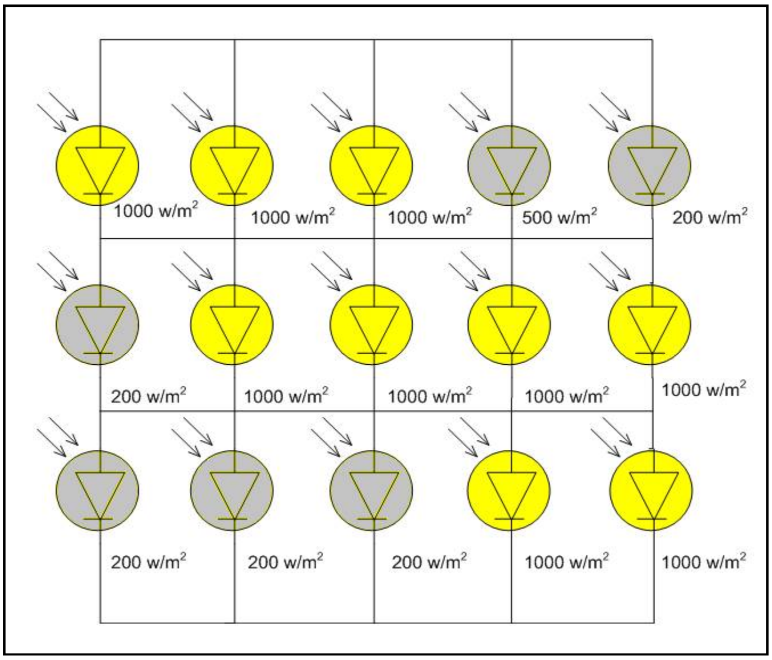

Fig.3Shading distribution before relocation.

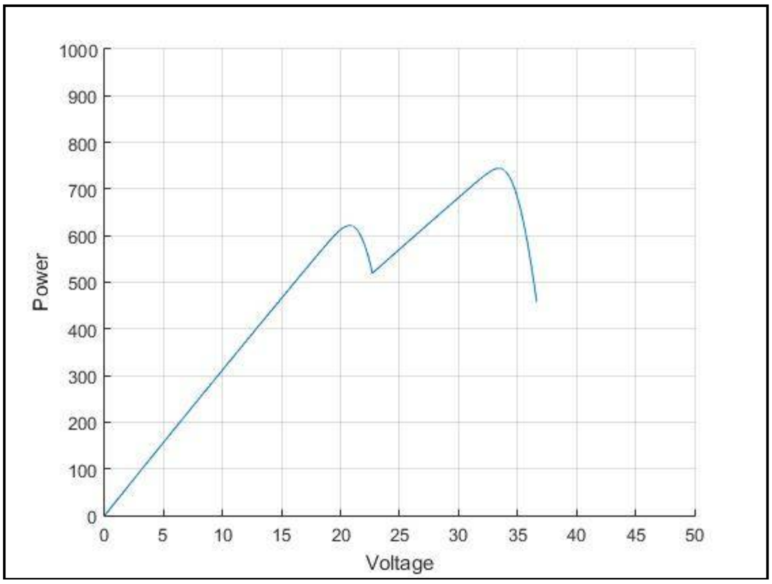

Fig.4 PV graph before relocation

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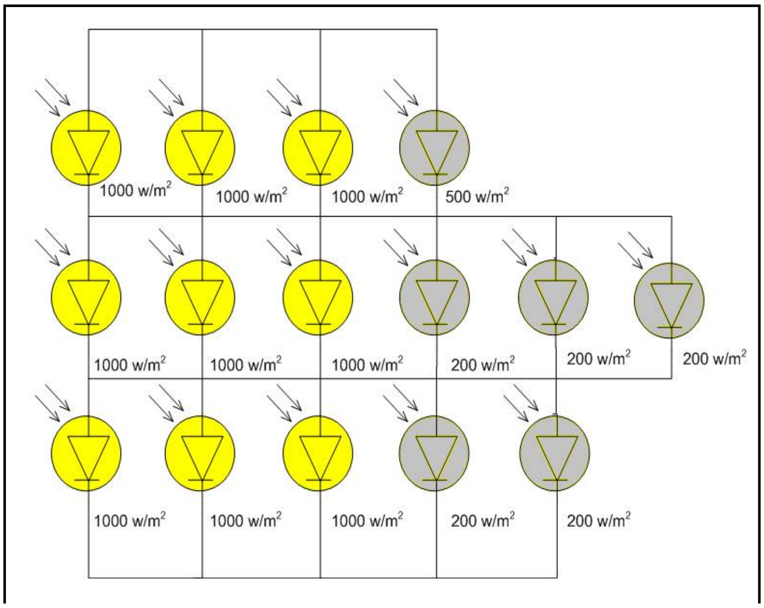

Fig.5Shading distribution after relocation.

From Fig.5 it is clear that after reconfiguration sum of irradiations of rows changes to 3500, 3600 and 3400 w/m^2 respectively. Thus the row irradiances are made almost equal using the algorithm and the PV graph become smooth showing only one peak point which is a global peak. The power output is increased to 880 watts.

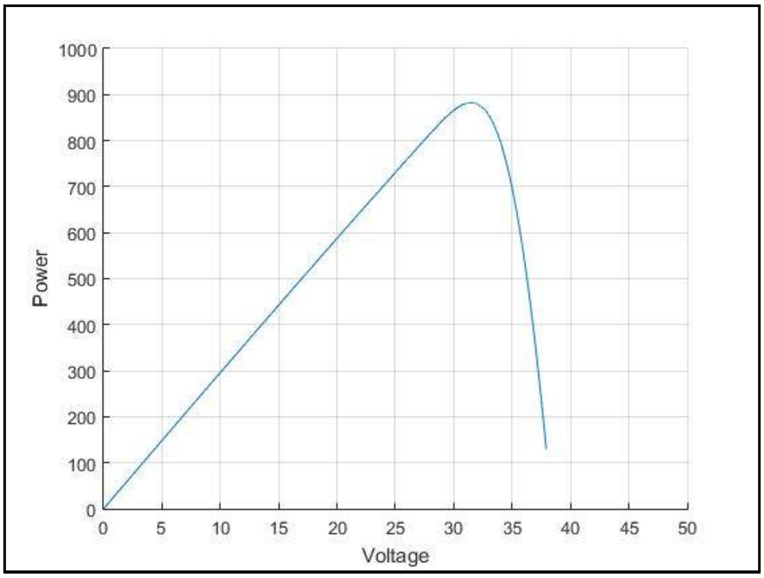

Fig.6 PV graph after relocation.

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Fig.7 shows some other cases which have been taken in to study. From the figure it is clear that after reconfiguration the power output is increased in every case.

Before Reconfiguration Irradiation on each module (w/m²)	O/P (w)	After Reconfiguration Irradiation on each module (w/m²)	O/P (w)
800 200 1000 500 200 300 1000 1000 900 1000 200 200 200 1000 1000	514.87	1000 1000 900 200 1000 1000 800 200 200 1000 1000 500 300 200 200	666.608
300 200 200 500 1000 300 1000 500 300 200 500 500 200 700 1000	492.88	1000 1000 500 500 200 1000 1000 500 300 200 1000 900 700 300 200	664.18
1000 600 700 1000 200 250 650 700 500 525 800 950 1000 925 800	524.12	1000 950 700 525 500 1000 925 700 600 250 1000 800 800 650 200	861.13

Fig.7Different cases taken for study and their results

V.CONCLUSION

This paper proposes a new reconfiguration strategy for PV array to produce enhanced power at the time of partial shading. The proposed scheme is validated using matlab simulation and the result shows that the output is increased and the PV curve became smooth so a single central inverter driven by a conventional MPPT algorithm can be used.

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