ANALYSIS OF SOLAR PHOTOVOLTAIC ARRAY UNDER PARTIAL SHADING CONDITIONS FOR DIFFERENT ARRAY CONFIGRATIONS

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Abstract **-This Paper Presents an improved analysis of solar photovoltaic module under partial shaded condition, when a solar photovoltaic array is under partial shading (non-uniform insolation) conditions than there will be large power losses in the array. Cells/modules under shade absorbs significant amount of electric power generated by cells/modules at higher illumination and convert it into heat across the shaded Cells/modules. Under partial shading conditions in the array there exist multiple peaks in power-voltage characteristics. In this paper we have used MATLAB/SIMULINK software, firstly modeling is done for PV module which is further modified to get PV array model. The array current-voltage and power-voltage characteristic is verified from experimentally available characteristics. Analysis has been done for modules connected in series and parallel under partial shading condition. Demerits of series connections under partial shading condition are inferred. The comparison has been made for series and parallel connected solar photovoltaic modules**.

Index Terms—Array configuration, maximum power point tracking (MPPT),partial shading, photovoltaic (PV) characteristics.

I. INTRODUCTION

With the increase in demand of energy it desired to switch to the renewable energy sources and solar photovoltaic is ideal green energy. A great amount of research has been conducted in this field over last few decades. To extract maximum power from module recognition of optimal operating point is important as solar photovoltaic module is non-linear power source and output power of modules varies with temperature and insolation.[4,10] The extraction of maximum energy becomes more complex under non uniform insolation as there exist multiple peak in P-V characteristics and conventional maximum power point tracking (MPPT) algorithms are not able discriminate between local and global peak so it is very important to understand characteristics of solar photovoltaic array under partial shading condition to maximize its output and to effectively use solar photovoltaic installations under all conditions.

II. PHOTOVOLTAIC CELL

Simple equivalent circuit and single diode model of solar cell is shown in figure 1.

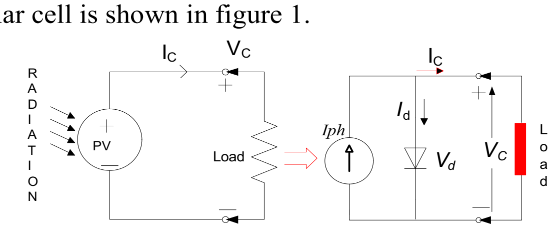

Fig.1. A PV cell and its simple equivalent circuit

Parameters of solar photovoltaic module [3] are shown in Table 1.

The simulation results of the solar photovoltaic module are shown in Figures 2 & 3. Figure 2 & 3 shows I-V & P-V characteristics respectively of solar photovoltaic module at variable solar insolation,25°C.

TABLE . Parameters of the adjusted model of the KC200GT solar array at nominal operating conditions.

S.no	Paramters	Value
1	Voc	32.9 V
2	Isc	8.21A
3	Kv	.0032A/K
4	Ki	- 0.1230V/K
5	Ns	54
6	Rs	.221□

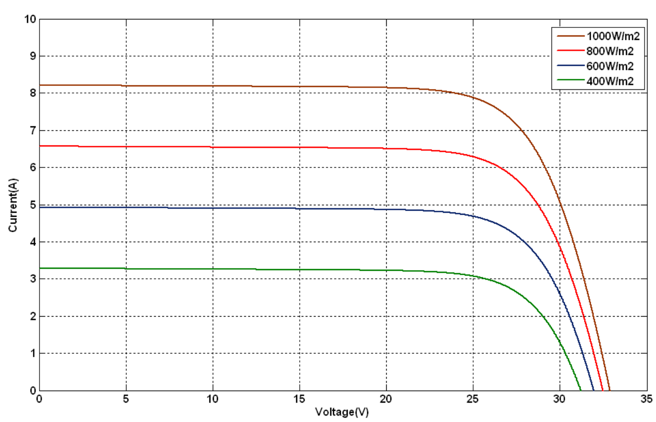

Figure 2. I- V characteristics of solar photovoltaic module at variable solar insolation,25°C.

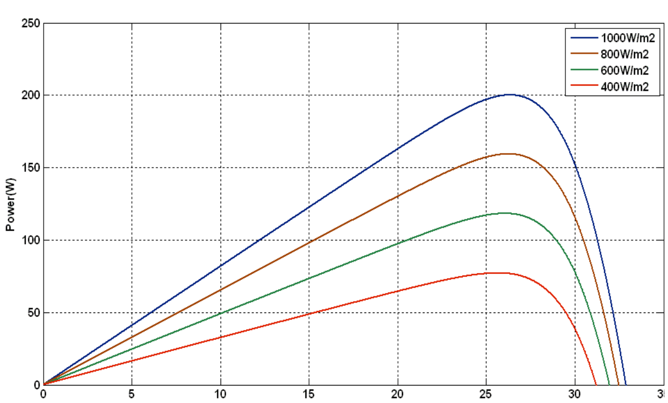

Figure 3. P- V characteristics of solar photovoltaic module at variable solar insolation,25°C.

III. SOLAR PHOTOVOLTAIC ARRAY UNDER PARTIAL SHADING CONDITIONS

In a solar photovoltaic array spread over large area, it is probable that shadow may fall over some of its cells or modules due to shade of a neighboring construction, clouds passing through, shadow of trees etc. In a series connected string of cells/modules, all the cells/ modules carry the same current. Under non-uniform insolation some of cells/modules are shaded they will have less photon generated current but these cells/module are bound to carry same current as other cells/modules are carrying which are at higher insolation.it will results in damage of the system.[5,10] Solar energy is acquiring much acclaim due to the decreasing cost of photovoltaic cells and recent advancements in power conversion technology, now a days there is an increasing trend to integrate the SPV arrays at the design level in the building itself. In building integrated SPV array it is difficult to avoid partial shading of array due to neighboring constructions throughout the day in all the seasons. In conventional SPV systems, the shadow drastically lowers overall power generated.[4]

IV. PARTIAL SHADING CONDITIONS IN PARALLEL CONNECTED SPV MODULES

For checking up the performance of parallel connections under partial shading condition we have taken an array having three modules connected in parallel, Figure 4 shows simulation of three parallel connected modules and each module consist of 54 cells in series. Figure 5 and 6 shows I-V and P-V characteristics of solar photovoltaic array respectively, where each module receives different illumination. module-1 receives 100% illumination, module-2 receives 75% illumination and module-3 receives 25% illumination. The characteristics reveal that both the shaded and non-shaded modules can operate in the area. I-V characteristics reveals that I_{sc} of modules are in proportion with level of radiation falling on it. Module 1 is receiving full illumination so it has I_{sc} of 8.21 amp, module 2 is receiving 75 % of full illumination so it has I_{sc} of 6.15 amp, module 3 is receiving 25 % of full illumination so it has I_{sc} of 2.0525 amp.

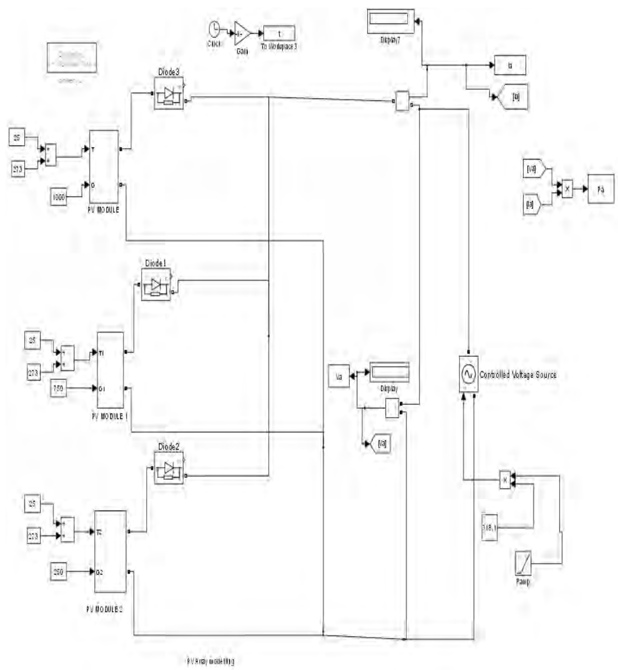

Figure 4. Parallel connected solar photovoltaic Modules under partial shading.

I-V characteristics of Parallel array shows that I_{sc} of parallel array is sum of short circuit current of all modules connected in parallel. P-V characteristics reveals that P_{max} of parallel array is sum of P_{mas}'s of module1, module 2 and module 3. P-V characteristics of parallel connected array under partial shading condition did not have multiple peak, so conventional maximum power point tracking algorithm can be applied.

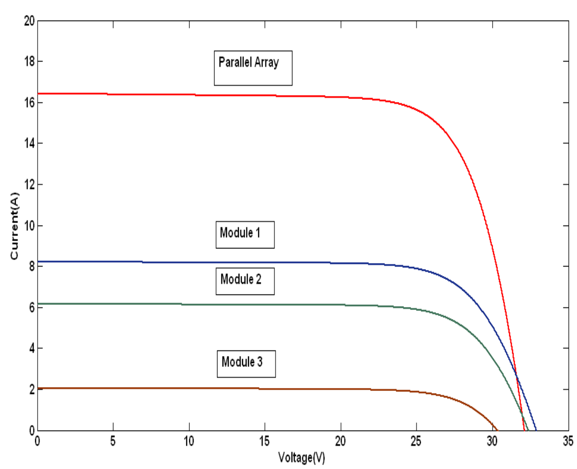

Figure5. I-V Characteristics of three parallel connected modules under partial shading.

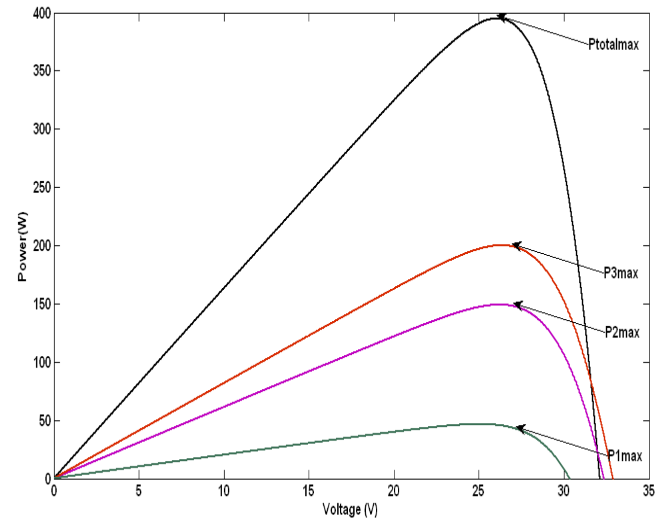

Figure6. P -V Characteristics of three parallel connected modules under partial shading.

V. PARTIAL SHADING CONDITIONS IN SERIES CONNECTED SPV MODULES

The simulation model of three modules connected in series is as shown in Figure7.The I-V and P-V characteristics of SPVA consisting of three series connected modules are shown in Figures 8 and 9 respectively, where each module receives different illumination. The shading condition (100%, 75%, 25%) on three series connected modules.

I-V characteristics of shaded series connected array are in step wave shape and number of steps in I-V characteristics is equal to number of illumination levels on the array. As there are three illumination levels so there are three steps in I-V characteristics, as module 1 is fully illuminated so, step 1 shows I_{sc} of 8.21 amp , module 2 is receiving 75% of full illumination so step 2 shows a current level of 6.15 amp and module 3 is receiving 25% of full illumination so, step 3 shows a current level of 2.0525 amp. There exist multiple peaks in P-V characteristics of series connected solar photovoltaic array under partial shading condition and number of peaks in P-V characteristics is the equal to number of shades on the array, as there are three different shading level, so there are three peaks in P-V characteristics out of which two peaks corresponds to local maxima and other to global maxima.

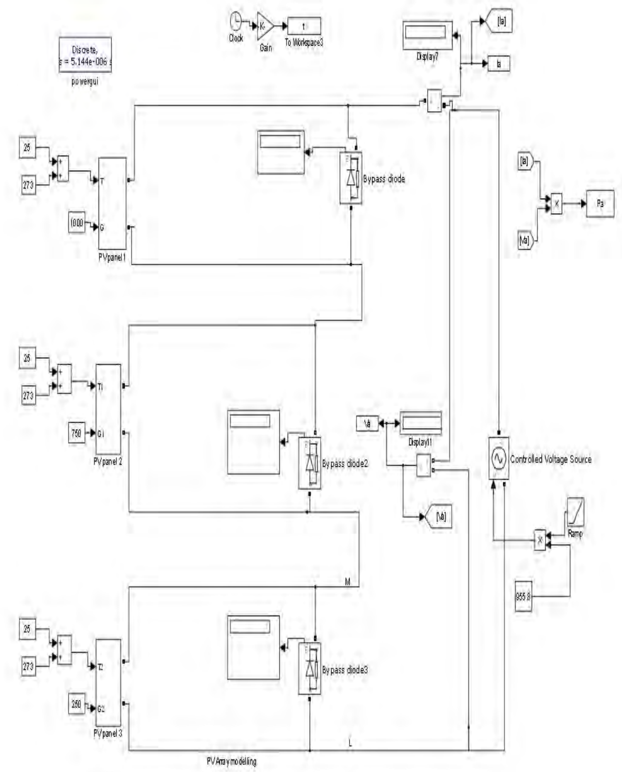

Figure7. Series connected SPV Modules under partial shading with bypass diodes.

VI. PERFORMANCE WITHOUT BYPASS DIODES

We have first taken the case when the bypass diodes are not present. Let the first module is receiving full illumination, modules second is receiving 75 % of full illumination and module three receiving 25% of full illumination. It means that photon generated current of module 1 is greatest and lowest for module 3(I_{sc1} > I_{sc2}>I_{sc3}). Now if load current (I_{pv}) is lower than current generated by lowest illuminated module (I_{sc3}) then current through cell diodes will be difference of generated current and load current. Now let us take case when load current is greater than current generated by lowest illuminated module (I_{sc3}) but load current is less than current generated by module 1 and module 2 (I_{sc1} ,I_{sc2}). Then current through cell diodes 3 will tend to become $I_{pv} – I_{sc3}$ in reverse direction. Reverse biased diode D_3 will offer a high resistance. The point M will go positive with respect to the point L and this voltage will become high, if difference in illumination levels is high, the diode D_3 may get damaged due to excessive heating.[3]

VII. PERFORMANCE WITH BYPASS DIODES

When bypass diodes are connected across module then the reverse current $I_{pv} – I_{sc3}$ will pass through the bypass diodes D_{b3} and there will no damage to the module. A part of power generated by highly illuminated modules is not getting wasted in low illuminated modules but now it will be available to the load. The power generated by low illuminated module is getting wasted as it is short circuited by bypass diode and low illuminated modules have no contribution to the load power. Power-voltage and current-voltage characteristics of solar photovoltaic array having three modules connected in series with different irradiance with bypass diodes are shown in figures 8 and 9.

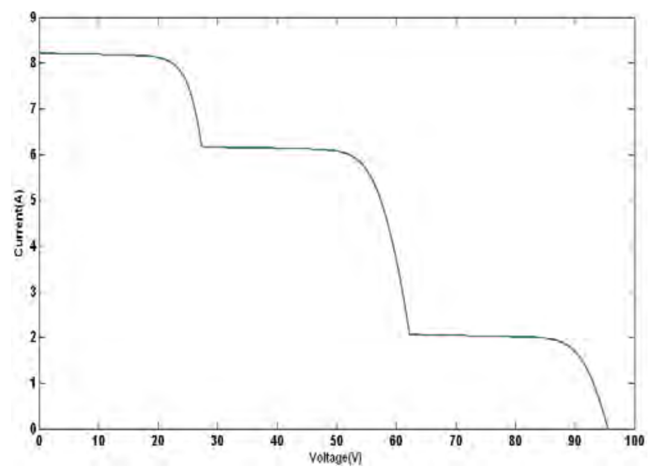

Figure8. I-V curve of three series connected SPV Module at 1000, 750 and 250 W/m^2 respectively.

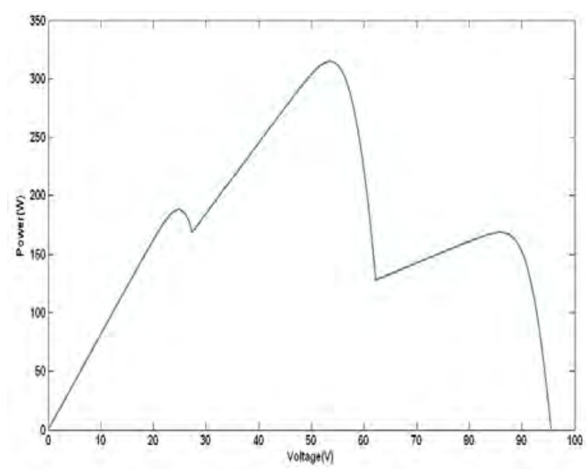

Figure9. P-V curve of three series connected SPV Module at 1000, 750 and 250 W/m^2 respectively.

VIII. CONCLUSION

In a solar photovoltaic array, modules are connected in series to have desirable voltage. From electrical characteristics it is concluded that there are significant power losses due non uniform insolation in the series connected modules. The power generated by modules receiving higher insolation is wasted as heat in modules receiving lower insolation.so it must be ensured that all series connected module must have same illumination. If mismatch of illumination are avoided than it will results in increased power output. Partial shading condition does not have adverse effect under on parallel connected module in an array, so parallel connections must be increased under partial shaded condition. The mismatch loss caused by partial shading is not proportional to the shading area but depends on the shading pattern.

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