Solution for Partial Shading problem of PV array in Portable Applications

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Abstract: Solar photovoltaic (PV) arrays in portable applications are often subject to the partial shading and rapid fluctuations in shading. In a commonly used series connected wiring connection, the residual energy generated in partially shaded cells affects the energy generated in fully illuminated cells, thus hindering the total power generation in the solar PV array[3]. The existence of local maximum power point tracking (MPP) in the system due to rapid fluctuation of shading pattern results in their rapidly changing values with respect to solar irradiance, which causes much more difficulty in tracking the maximum power point of the system. In this paper we suggest a comparison between series and parallel connection of solar PV cells on the basis of various parameters such as power, voltage and current. The proposed configuration demonstrates the use of series connection in high voltage application and parallel connection in low voltage applications, thus proving that parallel connection is best suited under partial shading conditions for many consumers' applications such as cell phones, music players, calculators etc.

Keywords: Solar PV, Shading, MPP.

INTRODUCTION

Solar PV module is considered as an essential power transformation of Photovoltaic (PV) generation system. The performance of a PV system strongly depends on the operating environmental conditions i.e. solar Photovoltaic PV modules nonlinear output characteristics, which vary with the solar characteristics get more complicated if the insolation, temperature vary with the shaded array configuration [14]. In higher voltage applications, bypass diodes may be placed across groups of cells to prevent mismatched or shaded cells from inhibiting production of power by the rest of the array. PV arrays in portable ormobile applications are often subject to partialshading and rapidly changing shadow conditions [3]. For example, a body-warm PV jacket would be subject to variations of illumination because of continuous movements, both temporally and spatially, due to shading from trees, vehicles, and building and also because of the positions of array with respect to sun. The complex operation conditions for portable PV applications are much different from stationary PV applications where typically no obstructions exist and changing of illumination conditions is slow [6].

Operating Principle of Solar Cell:

A solar cell is mainly a p-n junction which is made up of two different layers of silicon (Si) doped with a small quantity of the impurity atoms in the case of n-layer atoms with one extra valence electron called donors and in the case of p-layer with one lesser valence electron known as the acceptors. When the two layers are joined together, near the interface the free electrons to the n-layer are diffused with p-side, leaving behind an area positively charged by the donors [1] diffused n-side is shown in fig. 1, leaving behind a region negatively charged by the acceptors .The build an electrical field between the two sides that is a potential barrier to further flow. The equilibrium is reach in the junction when the holes an electron cannot surpass that potential barrier and in consequence they cannot move. This electric field pulls the holes and electrons in opposite directions, so the holes can move from the n-side to the p-side and the electrons in the opposite direction.

Types of Solar Cell:On the basis of material, price and efficiency solar cells are of different types: Mono crystalline Solar cell**:** It has efficiency approximately 15-18%. In mono crystalline structure large crystal of silicon (Si) is present. These types of solar panel are the most efficient systems however they are the most expensive. They do somewhat better in lesser light conditions than the other types of solar panels [1].Poly crystalline Solar cell**:** It has efficiency approximately 13-16% Instead of one large crystal this type of solar panel consists of multiple amounts of smaller silicon crystals. In the out of all the types of solar cell, maximum this type of solar cell is available. They are the most common type of solar panel on the market today. They are slightly lesseefficient than the mono crystalline solar panels and less expensive to produce.

Thin film Solar cell: The efficiency of thin film solar cell is approximately 5-7%. Amorphous silicon, copper indium dieseline (CIS) and cadmium telluride (CdTe) are used as semiconductor (SC) materials. If we compare the efficiency of thin fim solar cell with other two panels, it has low efficiency but it is chapest to produce.

MODEL OF A SOLAR CELL:

A photovoltaic cell can be represented by an equivalent circuit, as shown in Fig.1.1. This PV cell characteristic can be obtained using standard equations. For simulation a model of solar cell is selected in Fig. 1.2.

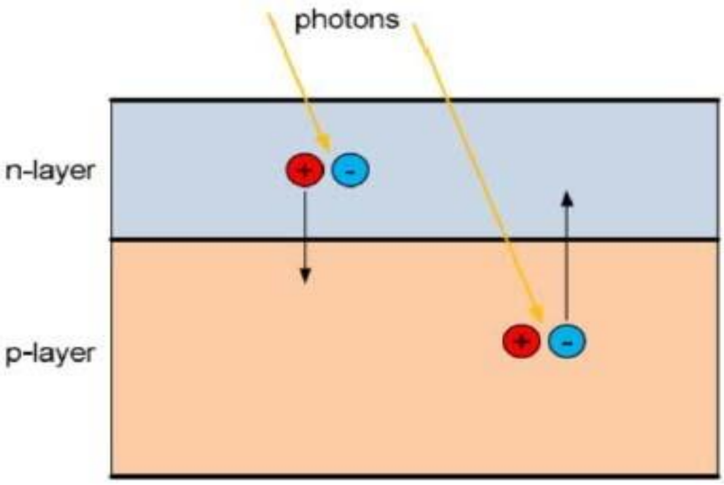

Fig.1.1. Solar PV cell

PV array system the model of a photovoltaic (PV) module is developed first. Each PV module system considered in this paper comprises 4 PV cells connected in series providing an open circuit voltage (VOC) and a short-circuit current (ISC) [8].

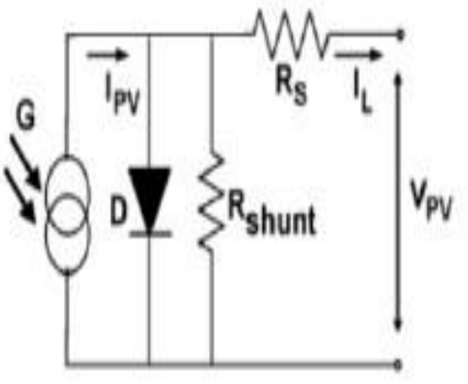

Fig.1.2 Model of solar cell

EXPERIMENTAL RESULTS

Two SIMULINK tests were carried out to validate the performance of the described approach. The first test showed the conventional configuration under constant illumination condition; the other test showed the parallel configuration under constant illumination conditions. For convenience, in the following, the conventional configuration is referred to as the series configuration and any mostly parallel configuration is referred to as the parallel configuration.

PARALLEL CONFIGURATION

SIMULINK model of PV system in parallel connection

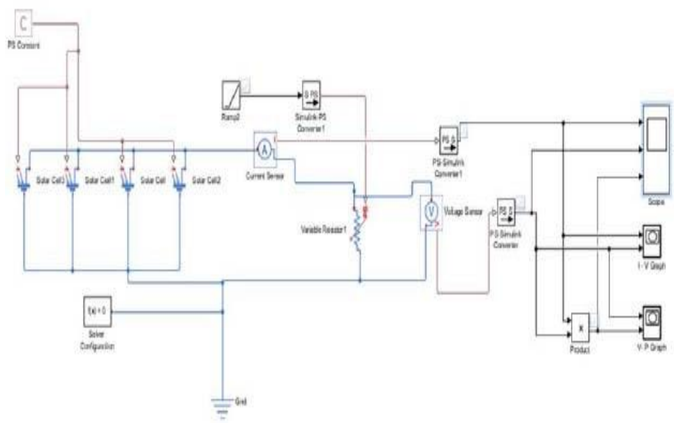

Fig 2.1 Block diagram of parallel configuration

Output of the various characteristics of the parallel operation of PV system is shown below:

(i) V-P Characteristics of Parallel Connection at $1000W/m^2$

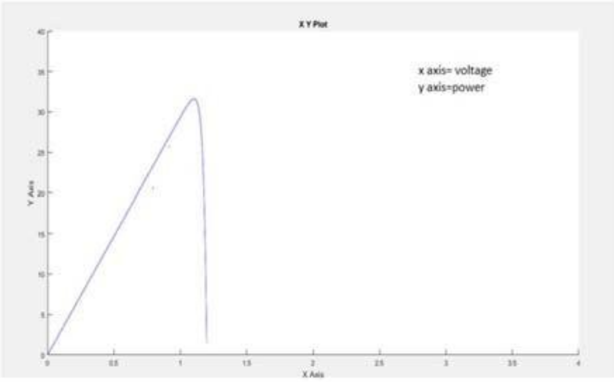

Fig 2.2V-P Characteristics of Parallel Connection at $1000W/m^2$

Output voltage = 1.1 V

Power generated = 3.162e + 01 = 31.62 W

The Above Fig. 2.2 depicts the variation of power with respect to voltage. As the voltage increases power increases and at maximum power point when the voltage equals to 1.1 V maximum power is delivered by the load whose value equals to 31.62 W.

(ii) I-V Characteristics of Parallel connection at $1000W/m^2$

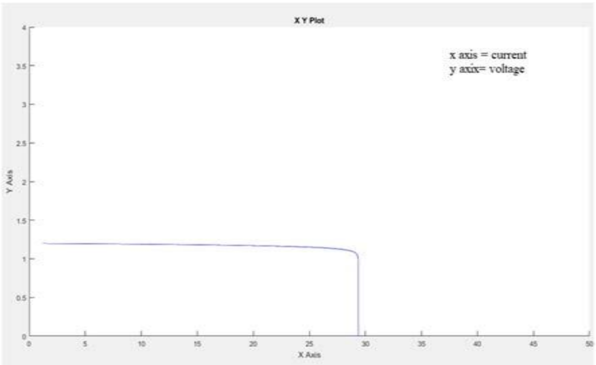

Fig 2.3 I-VCharacteristics of Parallel Connection at $1000W/m^2$

Output voltage = 1.1 V

Output current = 28.8 A

The above Fig. 2.3 depicts the variation of current with respect to voltage. In starting, current is maximum and as the load increases current decreases and the voltage becomes almost constant. At the maximum power point the value of voltage and current are 1.1 V and 28.8A respectively.

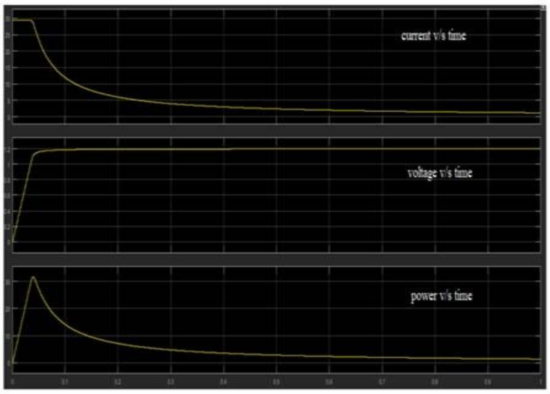

Fig 2.4Current, Voltage & Power Characteristics of Parallel Connection at $1000W/m^2$

Output current = 28.8 A

Output voltage = 1.1 V

Power generated = 3.162e + 01 = 31.62 W

The above Fig. 2.4 depicts the variation of current, voltage and power with respect to time. In starting, when there is no load the value of current is maximum and it decreases gradually as the load resistance increases. The voltage is the product of instantaneous current and load resistance so in starting when there is no load the value of voltage is zero and it increases with increase in resistance. When the current falls to saturation the value of voltage becomes almost constant and it does not increase significantly with further increase in load resistance. The power vs time characteristic is the instantaneous product of voltage vs time and current vs time characteristics. At maximum power point the value of current, voltage and power are 28.8 A, 1.1 V and 31.62 W respectively.

(iii) Current, Voltage & Power characteristics of Parallel Connection at $500W/m^2$, $800W/m^2$ and $1000W/m^2$

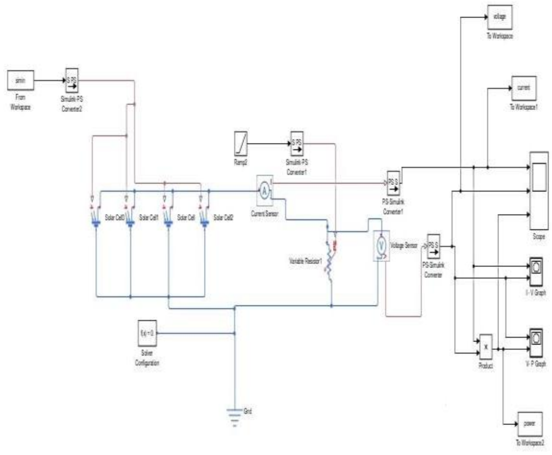

Fig 2.5 Parallel Connection of Solar PV Cell

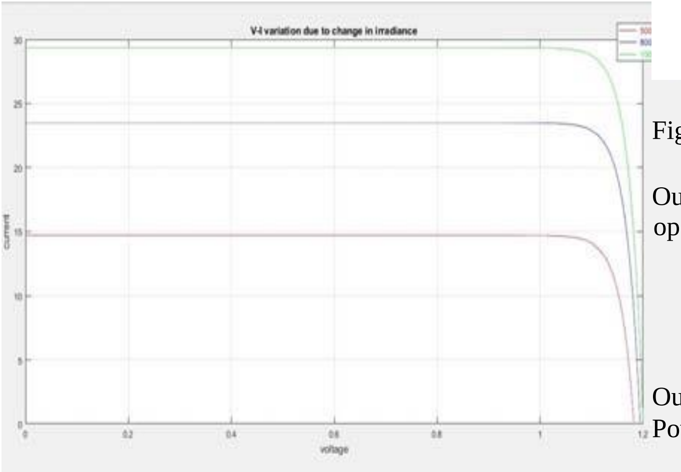

Fig. 2.6 V-Ivariation due to change in irradiance at 500W/m^2, 800W/m^2 and 1000W/m^2

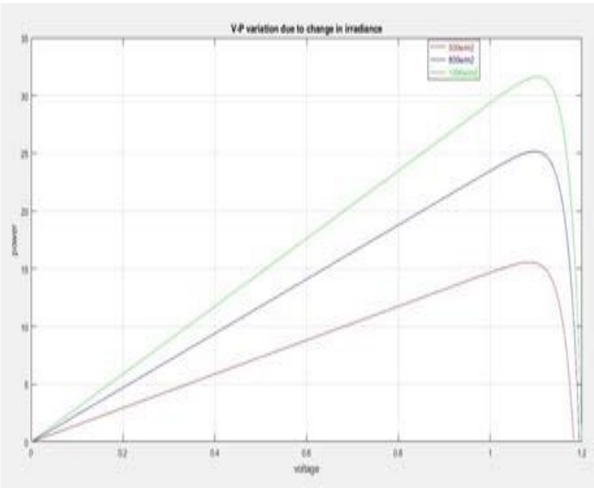

Fig. 2.7 V-Pvariation due to change in irradiance at 500W/m^2,800W/m^2 and 1000W/m^2

SERIES CONFIGURATION:

SIMULINK model of a PV system in series connection:

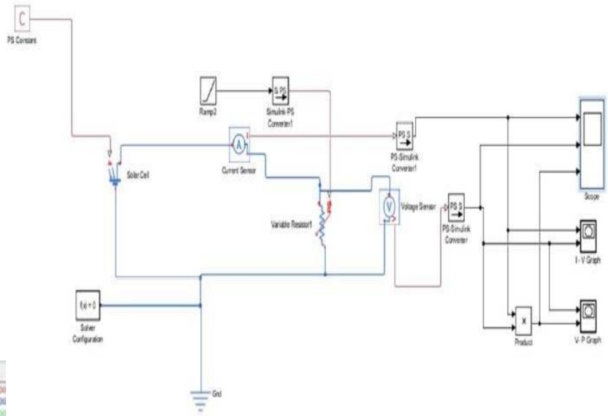

Fig 2.8:Series Connection of Solar PV Cell

Output of the various characteristics of the parallel operation of PV system is shown below: -

(i) V-P Characteristics of Series Connection at 1000W/m^2

Output voltage = 4.41 V
Power generated = 3.164e + 01 = 31.64 W

The Above Fig. 2.9 depicts the variation of power with respect to voltage. As the voltage increases power increases and at maximum power point when the voltage equals to 4.41 V maximum power is delivered by the load whose value equals to 31.64 W.

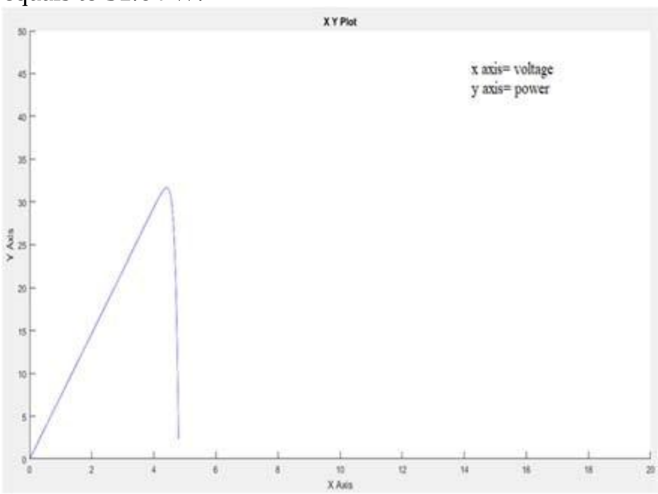

Fig. 2.9 V-P Characteristics of Series Connection at 1000W/m^2

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(i) I-V Characteristic of Series Connection at 1000W/m^2

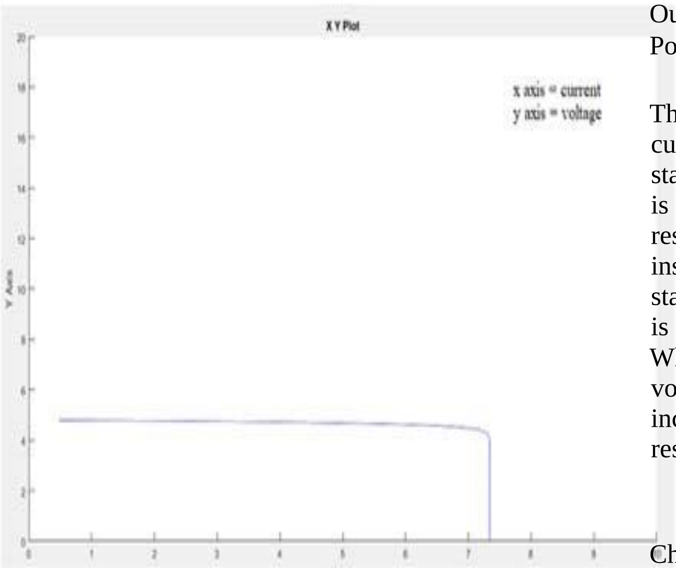

Fig. 2.10I-V Characteristic of Series Connection at 1000W/m^2

Output voltage = 4.41 V

Output current = 7.18 A

The above Fig. 2010 depicts the variation of current with respect to voltage. In starting, current is maximum and as the load increases current decreases and the voltage becomes almost constant. At the maximum power point the value of voltage and current are 4.41 V and 7.18 A respectively.

(i) Current, Voltage & Power Characteristics of Series Connection at 1000W/m^2

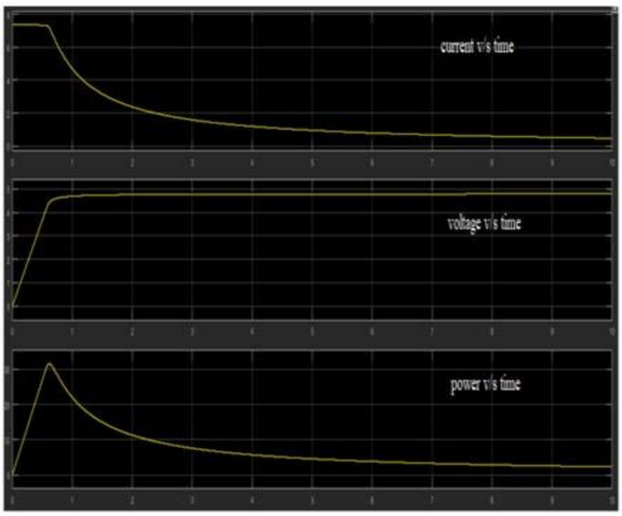

Fig. 2.11Current, Voltage & Power Characteristics of Series Connection at 1000W/m^2

Output voltage = 4.41 V

Output current = 7.18 A

Power generated = 3.164e + 01 = 31.64 W

The above Fig. 2.11 depicts the variation of current, voltage and power with respect to time. In starting, when there is no load the value of current is maximum and it decreases gradually as the load resistance increases. The voltage is the product of instantaneous current and load resistance so in starting when there is no load the value of voltage is zero and it increases with increase in resistance.

When the current falls to saturation the value of voltage becomes almost constant and it does not increase significantly with further increase in load resistance.

(i) Current, Voltage & Power Characteristics of Series Connection at 500W/m2, 800W/m2 and 1000W/m2

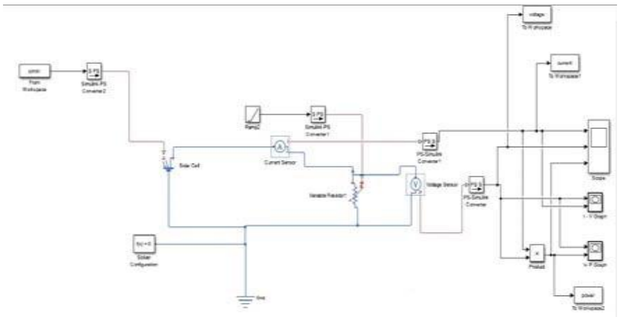

Fig. 2.12 Series Connection at 500W/m2,800W/m2 and 1000W/m2

The power vs time characteristic is the instantaneous product of voltage vs time and current vs time characteristics. At maximum power point the value of current, voltage and power are 7.18 A, 4.41 V and 31.64 W respectively.

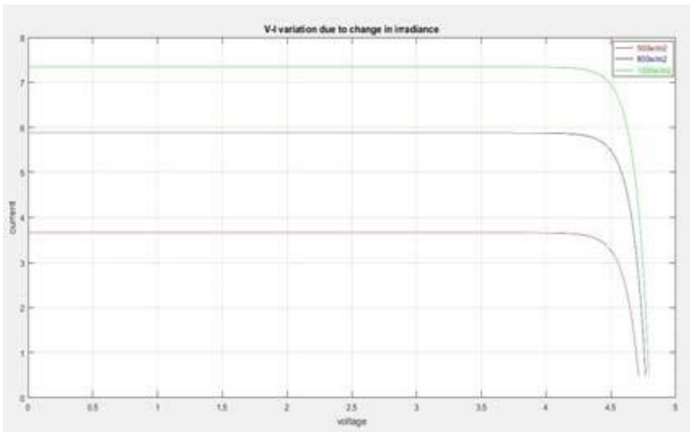

Fig. 2.13 Voltage and Current variation due to change in irradiance

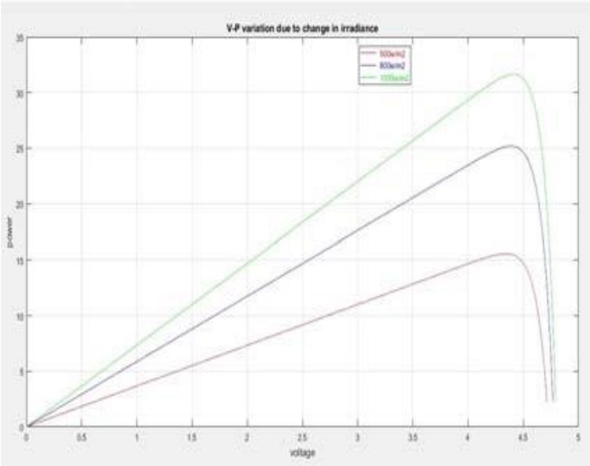

Fig. 2.14 Voltage and Power variation due to irradiance

III. CONCLUSION

PV Cell Characteristics: -
Short Circuit Current - 7.34A
Open Circuit Voltage – 1.2 V
Irradiance Used – 1000 W/m2
Number of Cells used – 4

From the above performed simulations we can conclude that under partial shading conditions,even if one solar panel goes out, then also the system will work in case of parallel PV cell configuration whereas in case of series PV cell configuration if one solar panel goes out or is shaded, then the entire system's production drops drastically.

Table1. Comparison of Series and parallel configuration of PV Cells

Series Configuration		
At MPP	Practical Value	Ideal Value
Power Generated	31.64 W	35.23 W
Output current of Solar Cell	7.18 A	7.34 A
Voltage across the load	4.41 V	4.8 V
Time taken to reach MPP	0.614 sec	
Parallel Configuration		
Power Generated	31.62 W	35.23W
Output current of Solar Cell	28.8 A	29.36 A
Voltage across the load	1.1 V	1.2 V
Time taken to reach MPP	0.039 Sec	

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