

Effect of Partial Shading on Characteristics of PV panel using Simscape

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ABSTRACT

In this paper a simulation based study is presented for a PV panel under partial shading condition with bypass diode and without bypass diode. In a solar photovoltaic array, it is possible that shadow may fall over some of its cells. Under partial shading conditions the PV characteristic gets more complex with multiple peaks. The purpose of this paper is to illustrate the effects that partial shading can cause in a PV array. This is done by simulation using Matlab/Simscape. The characteristics of PV array are compared under partial shading and uniform irradiation. PV array system is made up of 18 cells in order to show two conditions, one where there is no partial shading and one containing partial shading. This paper shows the changes in characteristics while it is compared with shaded and un-shaded conditions. All the results are shown in graphical forms to illustrate the results. Simulation is performed on Matlab/Simulink software using Simscape.

Keywords - PV; Partial Shading; Simscape; Simulation

I. INTRODUCTION

Photovoltaic cell harnesses the solar energy which is coming in abundant form from our sun in the form of light, which are actually packets of photons. This energy was actually not utilized until last century. As the sand of time passed and our dependency on electricity had reached to a level of utmost necessity for life and also we had been searching for the options available for non conventional energy resources, our zeal for new, better and abundant was satisfied by means of solar energy. So field of solar energy is very essential and had a lot of future potential.[1]

In a PV array photovoltaic modules are connected in series and parallel to obtain the required power. The total power in such an array is, however lower than the sum of the individual rated power of each module. The paper covers one of the main-reason for this difference in power i.e. partial shading. All the cells in a series array are forced to carry the same current including those which are under shade. The shaded cells may get reverse

biased, acting as loads, draining power from fully illuminated cells. If the system is not appropriately protected, problems like hot spot may arise and the system can be irreversibly damaged in several cases.

PV plants are built today in a fixed series-parallel configuration and the single module is equipped with bypass diodes included indifferent configurations. The purpose of this diode is to bypass the single module when it is slightly radiated in order to avoid that the single module current may reduce the current of the whole photovoltaic array. The purpose of this paper is to illustrate the effects of partial shading on PV array characteristics .This is done by simulation using Matlab/Simscape

II. HOW SIMSCAPE IS DIFFERENT FROM SIMULINK

Simulink is a graphical programming language where input and output blocks are connected together to represent a dynamic system. It is a traditional language which converts the modeling equations into block diagram representation. On the other hand,

Simscape is a physical modeling language used to present mathematical models of physical components. It provides basic blocks from different physical domains such as electrical, mechanical, hydraulic, pneumatic, thermal, etc. The model can be constructed, as in Simulink, by assembling the building blocks together to build a complete system with the ability to have different domains. Connecting Simscape to Simulink blocks and vice versa is an interesting subject where the advantages of these to programming languages will be considered. Based on the fact that both languages have different signal nature, it is not possible to overlap or connect their blocks directly. As a result, transitional structures must be used for this purpose. Infact, there are two types of intermediate blocks depending on the function and use of the signal. The first one is the converters which are basically used to connect Simscape diagrams to Simulink sources and sinks. While the interfaces blocks are used to couple between Sim Power Systems and SimScape Electrical circuits.[2,3]

III. PARTIAL SHADING AND BYPASS DIODE EFFECTS

It is not possible to have uniform illumination of PV panel all the time because of buildings or trees shades, atmosphere fluctuation, existence of clouds and daily sun angle changes as shown in Fig. 1. Power loss occurs from shade, also current mismatch within a PV string and voltage mismatch between parallel strings. Typically, a crystalline silicon module will contain bypass diodes to prevent damage from reverse bias on partially shaded cells.

The operating principle of a solar cell with a Bypass Diode is such that during normal operation without shade, the Bypass Diode is reverse biased and has high impedance, therefore no current flows through it. Connection diagram of solar PV module is shown in Fig. 2. Neighboring cell voltages forward bias its Bypass Diode and the impedance of the diode becomes lower than the shaded cell and module current shunts around the shaded cell through the diode. This prevents the un-shaded cells from forcing a current against the reverse biased state of the shaded cell; therefore hot spot overheating is prevented. Partial shading is the condition when the modules connected in series and parallel doesn't receives same illumination as compared to the other modules and result is the power generation by the different modules is different for the same rating of the panel. But, if same power doesn't flow to all the modules the lower generating modules will act as a sink and absorb the power from the modules which are generation more power, the result would be dense the partial shading more will be power loss. Because of the absorption of the power, the cells would get

heated up and cause hot spot problem, which could result into the cracking of the glass shield.

To overcome this effect, we use bypass diode across the string of particular cells connected in series (ideally we should use one bypass diode across each cell but it is not feasible). Bypass diode allows the current to flow in one direction. If the power flows toward the sink, bypass diode connected in ant parallel offers the power low impedance path. This prevents the power loss in the panel and prevents the problem like hotspot and shield cracking. [1,4].



Fig. 1 Partial shading on the PV Panel

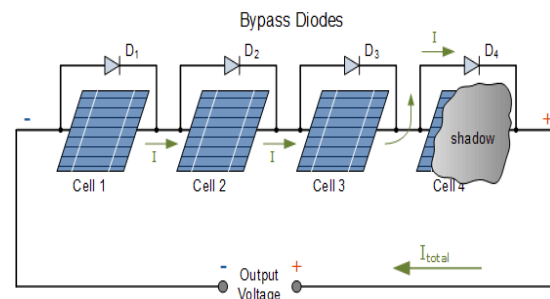


Fig. 2 Connection of Bypass Diode across the module

IV. EQUIVALENT CIRCUIT WITH PV CHARACTERISTICS

Commonly, the equivalent electrical circuit of single PV cell is shown in Fig 3. Current generated by a single cell is expressed by[5]

$$I = I_L - I_o \left(e^{\frac{V+IR_s}{nsV_t}} - 1 \right) - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Where junction thermal voltage V_t is defined as

$$V_t = \frac{AkT}{q} \quad (2)$$

- I_L - photo-generated current,
- I_o - dark saturation current,
- R_s - panel series resistance,
- R_{sh} - panel parallel (or shunt) resistance,
- k - Boltzmann's constant,
- q - electron charge,
- ns - number of cells connected in series,

T - cell temperature (in degree Kelvin),
 A - diode quality (or ideality) factor

We can neglect the term '-1' in equation 1 because the dark saturation current is negligible as compared to the exponential term. Fig. 4 shows the I-V curve for different irradiance 1000wb/m² and 500wb/m²[5]

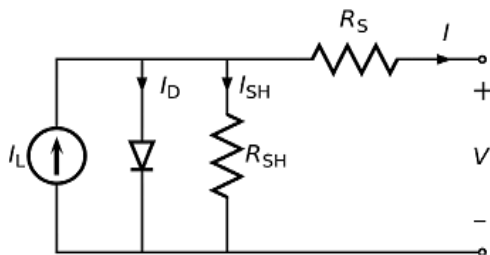


Fig. 3: Equivalent circuit of PV cell using single diode model.

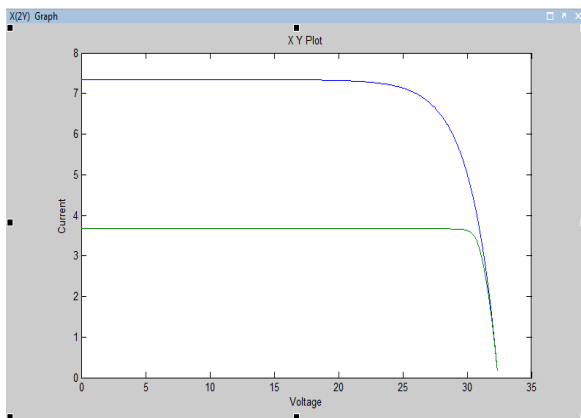


Fig. 4 I-V characteristics for 1000wb/m² and 500wb/m²

V. MODELLING AND SIMULATION OF DIFFERENT SUBSYSTEMS

In order to form an array, cells are connected in series and parallel to meet the power and voltage requirements. The solar cells are taken from the simscape library and are connected together. The solar cell comprises of three terminals, of which one terminal is for irradiance while the other two act as the positive and negative terminals of the cell. The connection is done in Fig. 5. The parameters of solar cell is given in appendix-1.

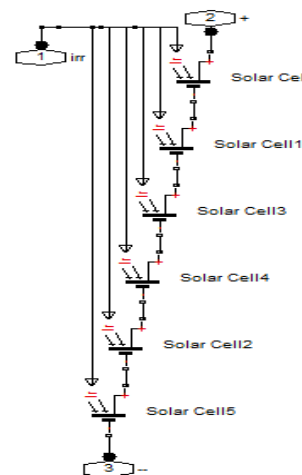


Fig. 5 Subsystem consisting of six PV cells
Module of Solar Array with Uniform Irradiance

54 cells are connected in series (by connecting 3 groups of 18 cells) and are given an irradiance of 1000 W/m². Bypass diode are connected across each group of 18 cells.

The connection is done as shown in Fig. 6 and characteristics are shown in Fig. 7 and 8 as Power-Voltage and Voltage-Current respectively.

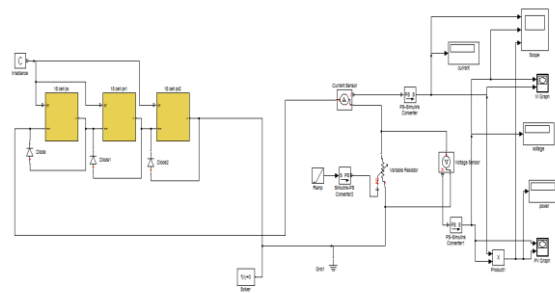


Fig. 6: Solar Array with Uniform Irradiance

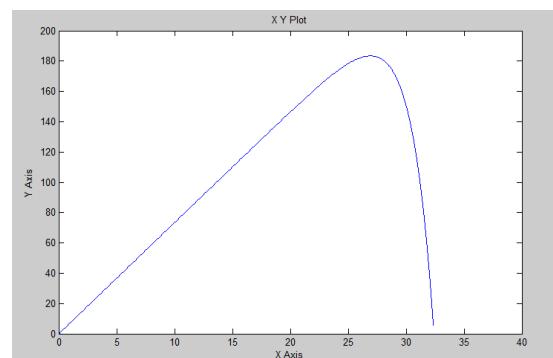


Fig. 7: P-V Characteristic of solar array with uniform irradiance

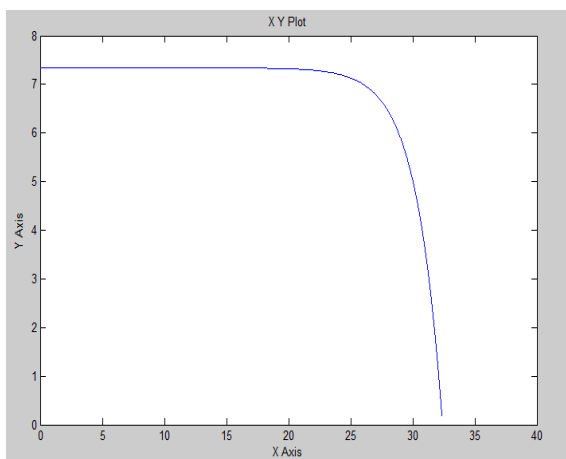


Fig. 8: V-I Characteristic of solar array with uniform Irradiance

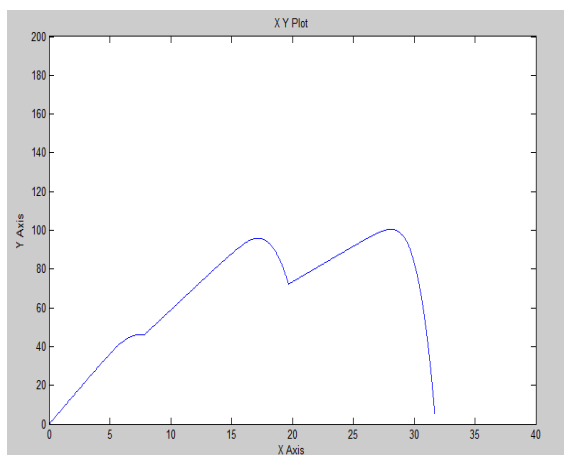


Fig. 11 P-V Characteristic of solar array with non-uniform Irradiance (Shading Effect)

Module of Solar Array with Non-Uniform Irradiance

In this case also, 54 cells are connected in series, but 18 cells receive irradiance of 1000 W/m², the next 18 receive 800 W/m², while the rest receive an irradiance of 500 W/m².

The connection is done as shown below in Fig. 9 and characteristics are shown in Fig. 10 and 11 as I-V and P-V respectively

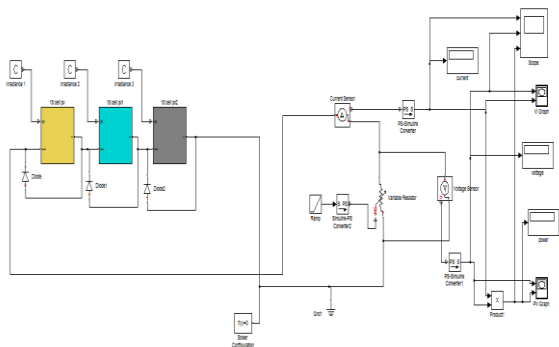


Fig. 9 Solar array with Non-Uniform Irradiation

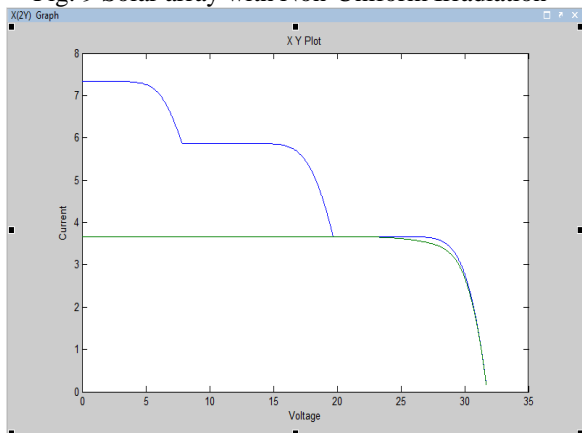


Fig. 10 I-V characteristic of PV panel under partial shading condition (1000, 800, 500 W/m²) with and without diode.

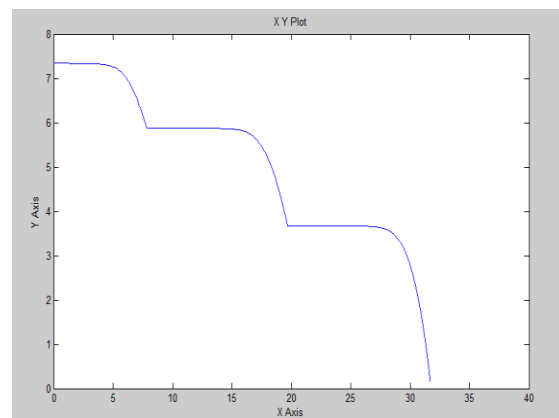


Fig. 12 V-I Characteristic of solar array with non-uniform Irradiance (Shading Effect)

VI. RESULTS AND DISCUSSION

In order to understand the effect of partial shading and bypass diode on PV panel, a comparison of current, voltage and power was made under uniform illumination (of 1000W/m²), partial shading with bypass diode and under partial shading without bypass diode. all the results are shown in graphical forms. Fig. 13 shows the comparative waveforms of current at uniform irradiance and partial shading (with bypass diode and without bypass diode). Same variations are shown in Fig. 14 for voltage profile and power in Fig. 15.

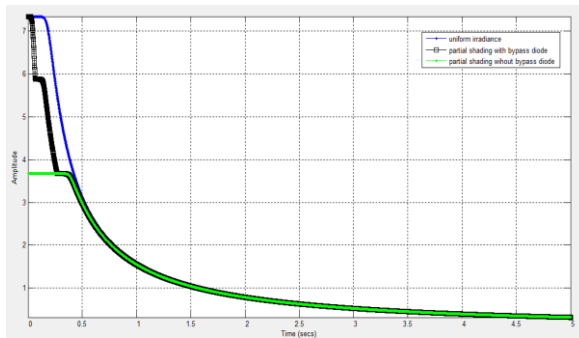


Fig. 13 Comparison of Current in uniform irradiance, partial shading (with bypass diode) and partial shading (without bypass diode)

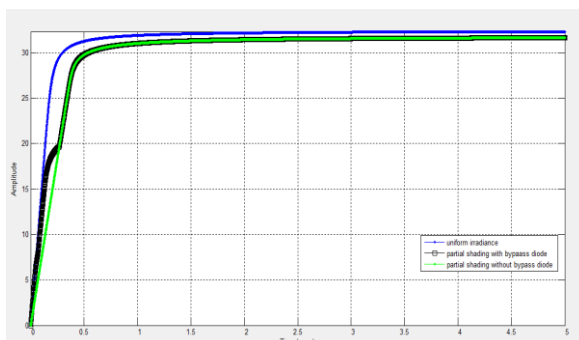


Fig. 14 Comparison of voltage in uniform irradiance, partial shading (with bypass diode) and partial shading (without bypass diode)

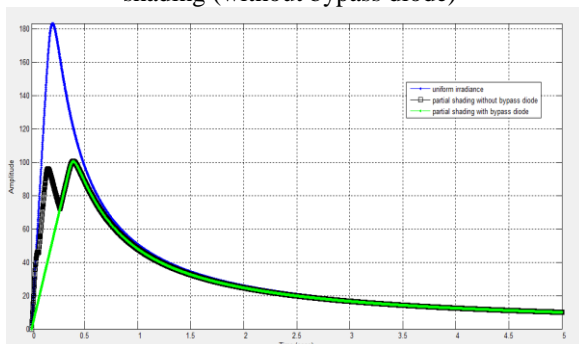


Fig.15 Comparison of power in uniform irradiance, partial shading (with bypass diode) and partial shading (without bypass diode)

VII. CONCLUSION

In this paper, Simulation based study is done for partial shading conditions on PV panel. All the simulation models of PV cell and panel are modelled with the use of Simscape in Matlab/Simulink environment. On simulating the above models and after making the comparisons it is observed that under partial shading, not only the voltage and power output is reduced, but also instead of obtaining a single peak of maximum power, multiple peaks are obtained. The presence of bypass diode also affects the PV array characteristics. Simulation results validates the system performance under partial

shading conditions with bypass diode and without bypass diode.

VIII. ACKNOWLEDGMENT

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