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Analysis of PV Array Under Partial Shading

Shivangi Mittal[1&2], Dhiraj Nitnawre[3]
[1]Department of E & I, IET DAVV, Indore
[2]Department of Electrical Engineering, Government Polytechnic College, Dewas
[3]Department of E & TC, IET DAVV, Indore
[1,2]shivangisinghal@yahoo.co.in; [3] dhiirajnitnawwre@gmail.com

Abstract: *This paper presents the effect of shading on a photo voltaic (PV) array. The PV and VI characteristics of the array observed in different shading cases and give some observations we make some statements and based on these statements one hypothesis is presented: 'One peak occurs at N× Voc and the next peak occurs at (N-j) Voc where j is the number of rows that have the same current which occurs at N× Voc. The third peak occurs at (N-j-k) Voc where k is the number of rows that have the same current occurring at (N-j) Voc'. After that, we validated and verified this hypothesis with MATLAB Simulink. With this study we can provide the correct information on shading in the PV array. In this study, the TCT configuration of the PV array was analyzed for a complete analysis of partial shading. This study empowers the researcher with partial shading without any advanced techniques or software.*

Keywords: Partial Shading, PV array, TCT, Mismatch Loss, MPPT

I. INTRODUCTION

The world is going towards technological advancement day by day. Every advancement needs electrical energy. To reach this energy demand it is mandatory to go for an alternative clean, green and sustainable energy source [1]. Solar energy is one most prominent way of generating clean electrical energy. The sun energy is changed into DC electricity using semiconductor materials called photovoltaic (PV) cells [2]. Multiple cells make panels and multiple panels make a PV array to increase the power output. The main cause of concern of solar power systems is partial shading (PS) because it reduces the output power of PV array. Partial shading can cause hot spots in the array so to mitigate the effect of shading, bypass diodes (BD) are connected to the array. Multiple peaks are created due to bypass diodes. MPPT converters are failed to find the global peak [3]. Up to 70% of power loss occurs if the MPPT technique is caught in one of the local peaks instead of a global peak [4] [5]. Power minimization due to PS is dependent on the pattern of shading and shaded modules' location in an array but independent of the shading area [6]. To minimize the effect of partial shading various configurations like Series-Parallel (SP), Bridge Linked (BL), Honey Comb (HC), and Total Cross Tied (TCT) are introduced in literature from which TCT gives the best performance [7]. TCT gives less mismatch loss and the highest fill factor. To mitigate the PS effect we need to disperse the shadow over the entire array uniformly [8]. In the case of high-shaded areas efficiency of TCT could be highest as compared to SP [9]. TCT is perfect for reducing operation loss under partial shading. A power loss could also occur in TCT configuration in some shading patterns [10]. Some other techniques to handle the partial shading issues are static and dynamic reconfiguration. Dynamic reconfiguration techniques alter the electrical connection of the PV array to mitigate the effect of shading electrical array reconfiguration (EAR) and adaptive array reconfiguration (AAR) but a lot of switches and sensors requirement increases the cost of the array. Static array reconfiguration physically relocates the panel to diffuse the shading effect. Electrical connections remain the same so cost, size, and system complexity are not increased [7] [11]. Many physical reconfiguration techniques have been introduced in literature like Competency square (CS) [12], Dominance square (DS) [13], Latin Square (LS) [14], Magic Square (MS) [15], SuDoKu [16], etc. Some researchers have analyzed and compared different reconfiguration techniques under partial shading conditions [17]. An investigation of the shade effect with a random shade pattern on a 10 X 90 size PV array is done by Patel and Agrawal [18]. To study and analyze the different aspects of a PV array user needs to do experimentation or simulation so that he can get an accurate result. Elementary software knowledge and software skills are mandatory for researchers. Limited conceptual awareness of partial shading effects on PV array is because the I-V curve only gives information on the number of local maxima and

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does not give information of the responsible string or module for local maxima. A study is presented to analyze the effects of partial shading on PV arrays connected in series-parallel configuration [19]. As TCT performs better than other topologies so in this paper a study is presented on TCT configuration of PV array to analyze the PS effects.

II. HYPOTHESIS

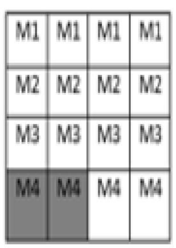
As TCT configuration gives best result under partial shading it becomes essential to analyse the partial shaded model and make a hypothesis. First we need to take some observation of P-V curve of partially shaded PV arrays. some statements have made. Based on these statement one hypothesis is presented.

- Statement 1-It is mandatory to determine current obtained from all rows of the PV array.
- Statement 2-To minimize the number of active bypass diode global peak occurs at NVoc.
- *Statement 3*- Irrespective of any partial shading pattern, the number of peaks (maxima) in PV curve is equal to the number of current variations in rows of PV array.
- *Statement 4*- Uniform shade distribution in all rows will minimize the number of peaks.
- *Statement 5*- In any N×N PV array if number of i×N panels (i= 1,2,3,....N) are shaded with the same irradiation in any pattern, and when these shaded panels are physically placed in all N rows then no multiple peaks will occur.

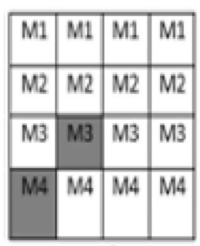
By analysing these statements one hypothesis is presented according to which, "One peak occurs at N× Voc and the next peak occurs at (N-j) Voc where j is the number of rows that have the same current which occurs at N× Voc. The third peak occurs at (N-j-k) Voc where k is the number of rows that have the same current occurring at (N-j) Voc".

III. VALIDATION OF HYPOTHESIS

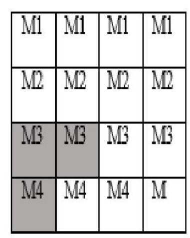
To validate the hypothesis a PV array of size 4X4 connected in TCT topology is taken. In this array 170.05 watt module with a maximum current of 4.75amp and a maximum voltage of 35.8 volts is used. Open circuit voltage V_{oc} is 44.2 volt and short circuit current is I_{sc} 5.2 amp. Three shading cases are given below.



Case I



Case II



CASE III

Fig. 1. Shading patterns of PV array

All modules receives 1000 watt/m^2 and shaded module receives 350 watt/m^2.

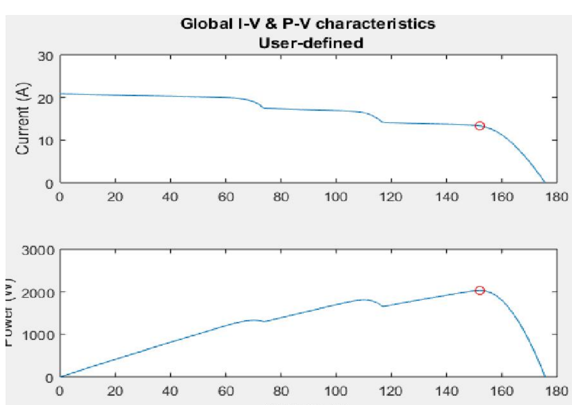


Fig. 2. PV, VI characteristic of the array Case I

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As shown in figure 2 there are two multiple peaks for case I. one peak is at near 4 V_{oc} i.e. N× V_{oc} and the other is at 3 V_{oc} i.e. (N-j) V_{oc}. Here j is one because only one row is shaded and the other three are non-shaded.

As shown in figure 3 there are two multiple peaks for case II. One peak is at near 4 V_{oc} i.e. N× V_{oc} and the other is at 2 V_{oc} i.e. (N-j) V_{oc}. Here j is two because two rows are same shaded and the other two are non-shaded.

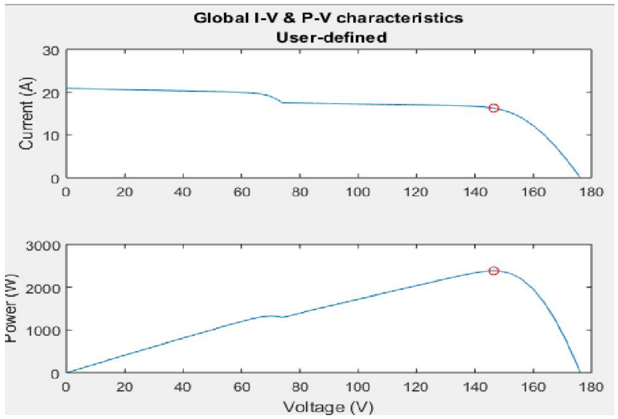

Fig. 3. PV, VI characteristic of the array Case II

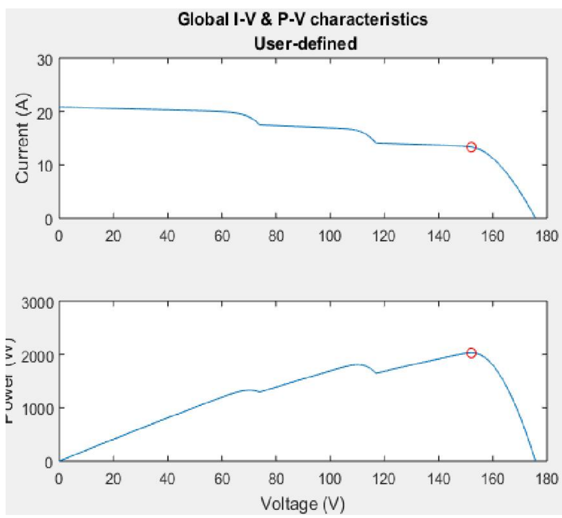

Fig. 4. PV, VI characteristic of the array Case III

As shown in figure 4 there are three multiple peaks for case III. One peak is at near 4 V_{oc} i.e. N× V_{oc} and the second peak is at 3 V_{oc} i.e. (N-j) V_{oc}. Here j is one because row three is more shaded which carries least current. Row four carries more current. Here k is one. The third peak is at 2 V_{oc} i.e. (N-j-k) V_{oc}. and the other two rows are non-shaded. Here are three times row current variations occur.

IV. CONCLUCIONS

In this Paper we presented an analysis for studying effect of PV array under partial shading for which we have chosen five statements. On basis of these statements we took a hypothesis.

"One peak occurs at N× Voc and the next peak occurs at (N-j) Voc where j is the number of rows that have the same current which occurs at N× Voc. The third peak occurs at (N-j-k) Voc where k is the number of rows that have the same current occurring at (N-j) Voc".

This hypothesis is validated by MATLAB Simulink. This will be helpful for those researcher who are designing MPPT controllers. Without use any software researcher can find wide information of location of local and global maxima and no of maxima also. For future study we can study the effect of temperature also.

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