Power Improvement of Uneven Irradiance Photovoltaic System Using Snake Ladder Pattern Array Reconfiguration

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Abstract

The working of solar photovoltaic (PV) system is disturbed due to changeable event of irradiance. Due to that, occurrence of mismatch losses happens and in turn reduces the power production of good PV panels in it. The aim of this work in this article is to extract the utmost power from each of the solar PV panel in the array by decreasing the losses because of mismatch. An innovative array reconfiguration method is projected in this article, which is the snake ladder pattern in the row/column formation. Each of the PV row/column is formation with different PV panels from the rows/column of the expected array reconfiguration. This developed project allows the PV system to function with lowest number of losses due to mismatch by uneven irradiance in the PV array. The production analysis is been checked and verified in the simulation of a 6 × 6 PV system in MATLAB. The developed array reconfiguration is around 39% more capable than the existing series-parallel connection and as well as superior than the TCT and sudoku puzzle pattern methods.

Keywords. Solar PV, maximum efficiency, reconfiguration, snake and ladder.

1. Introduction

In some years, the reduction of fossil sources directs to the process of non-conventional energy resources. Solar PV systems are the best power source between other non-conventional resources because of its advantages [1]. Various conservation parameters are inducing the drop of PV's organized conversion efficiency. Among those parameters, uneven irradiance is one of the most important one in dropping the PV efficiency. The conservative algorithms are united with soft computing methods like artificial-intelligence (AI), neural network (NN), Fuzzy Logic Control (FLC), and so on along with it. Though, during the uneven irradiance, the PV systems function with many local maximum power points (LMPP) and the

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maximum power point tracking (MPPT) algorithm unable to get the peak MPP (PMPP) amongst numerous LMPPs [2]. The drop in production power is based on the array connection and irradiance that happened in it. The series (Se) array connection method has drawbacks on the uneven irradiance. Altered array reconfiguration techniques had been created such as series-parallel (Se-P), bridge-linked (BL), honey-comb (HC), and sudoku-puzzle pattern (SPP) by the researchers to bound the effects of uneven irradiance [3]. The electrical array reconfiguration (EAR) schemes were proposed for the PV array in [4]. This EAR scheme reshuffles the PV panel's inter-connection by using the switches like IGBTs and MOSFETs to produce more power even with the same uneven irradiance. A controller which will be controlling these switches according to the shading in the PV panels [5]. Except in the big PV power plants, the model of EAR is difficult to implement, because of this requirement of many controllers, switches, and sensors [6]. This article introduces a snake-ladder (SL) reconfiguration method with the enhancement ability of uneven irradiance dispersion. The faction of the dice is the fundamental ideas at the back this EAR scheme. The developed SL EAR is given with all necessary constraints. Many parameters are defined in the constraints, which satisfy the all supposition given in the snake-ladder pattern array reconfiguration. This developed SL EAR scheme has been tested in 6×6 PV arrays in MATLAB. The improved enhancement of the developed snake-ladder pattern array reconfiguration has been validated with different levels of irradiances and compared with various EAR scheme.

This article ordered as given: the mathematical model of PV panel is given in Section 2 and the developed snake-ladder EAR is discussed in Section 3 along with results and validation using 6x6 PV array. Section 4 provides the suggestions and the merits of the developed method are given as conclusion.

2. MATHEMATICAL MODEL OF PV PANEL

A PV cell's equivalent circuit is shown in Figure 2.1 and it is prepared using a current-source (I_{ph}) connected to a shunt-resistance (R_{sh}). Similarly, n numbers of PV cells are connected in Se-P manner to develop a PV panel. The equation of the PV panel is given in the form of current,

$$I_m = I_{ph} - I_{sat}\left[exp\left(\frac{V_m + I_m R_s}{(nKT/q}\right) - 1\right] - \frac{V_m + I_m R_s}{R_{sh}} \quad (2.1)$$

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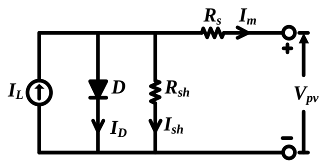

Figure 2.1. Equivalent circuit of solar cell

where, I_m is the extreme producing current, V_m is the extreme producing voltage, I_{ph} is photoelectric-current, saturation-current is given by I_{sat} Boltzmann's constant is K, series resistance (R_s), shunt resistance (R_{sh}), and temperature of PV panel is given by T.

3. DEVELOPED ARRAY CONFIGURATION

The planned electrical array reconfiguration (EAR) is executed with the help of the snake-ladder (SL) arrangement. This method will be selecting the PV panels from the old PV system with the optimized dissimilar PV system. A 6×6 PV array is taken in which all rows should have six number of PV panels. In the existing technique, the initial rows panels are P11, P12, P13, P14, P15, and P16, in the planned reconfiguration, the initial row have panels of all the rows like in the existing technique.

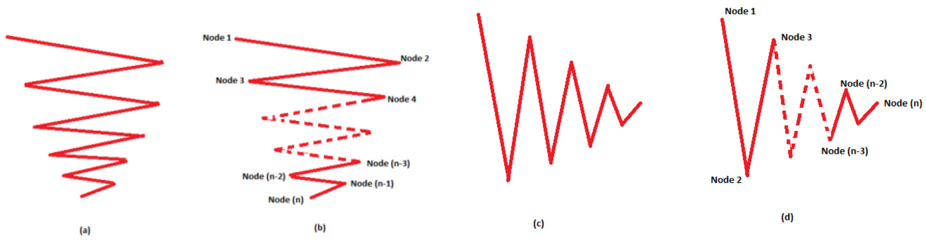

Figure 3.2. (a) horizontal snake ladder formation (b) horizontal node formation (c) vertical snake ladder formation (d) vertical node formation

The normal snake ladder formation and the node establishment from are given in the Figure 3.1. The snake-ladder formation can be developed into two ways like horizontal snake ladder (SL_H) and vertical snake ladder (SL_V) pattern. The horizontal snake ladder formation of array and the node establishment are depicted in Figure 3.1 (a) and (b). Similarly, the vertical array formation of array and the node establishment are depicted in Figure 3.1 (c) and (d).

The formulation of the planned electrical array reconfiguration is shown in Figure 3.2. These are represented for the horizontal SL EAR and vertical SL EAR. In both of those, a classification is created depends on the column count. The PV

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system having the even count in columns as well as an odd count in columns have different equations. Row development for the horizontal snake ladder in an odd count in columns begins with (1)(i) and closes at (n)(i+((n+1)/2). Similarly, in the horizontal snake ladder with an even count in columns, the row development begins with (1)(i) and closes at (n)(i+((n+2)/2). In parallel, row creation to the vertical snake ladder with an odd count in columns begins with (i)(1) and closes at (i+((n+1)/2) (n). Similarly, in the vertical snake ladder with an even count in columns, the row development begins with (i)(1) and closes at (i+((n+2)/2) (n). The planned snake ladder electrical array reconfiguration is applicable to any size of rows and columns of PV system. Every row is developed just by interchanging the values of i and n. The count of i stand for the total count of rows, its formation of the initial row, the count of i is 1, similarly for the 2^{nd} row, the count of i is 2 and so on. To the m × n PV system, the count of i begins with1 to the last count of row m.

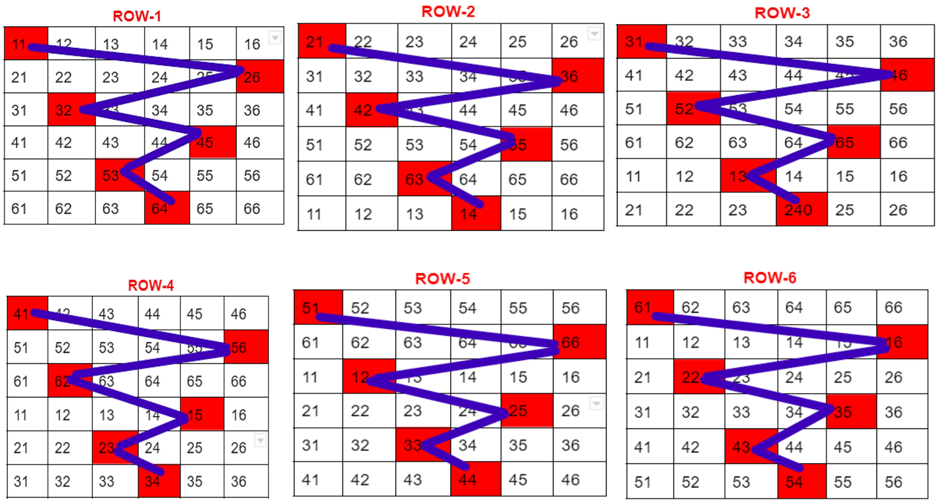

Figure 3.2. Row formation of horizontal snake ladder array formation

Consider this example, in the 6 × 6 PV system, row have 6 counts at the maximum. So, the initial row, i is 1, and 2^{nd} row, the count of i is 2, and it go on till the 6^{th} row. In horizontal SL formation, the row presents the outcome like P_{11}, P_{26}, P_{32}, P_{45}, P_{53}, P_{64}, the formation begins from the initial row and closes in 6^{th} row. Except the 2^{nd} row formation, it begins at second row and closes in first row and similarly in the 3^{rd} row creation, it begins with third and closes in second row. It continues till the sixth-row creation, in that it begins in sixth row and closes in the fifth row.

Table 3.1. Node formation of the initial row for vertical snake ladder

Real Positions of PV panels	**Expression**	**Location of PV panels in developed PV connection**
P11	$= (1)(i)$	P11
P12	$= (2)(i+(n-1))$	P25
P13	$= (3)(i+1)$	P32
P14	$= (4)(i+(n-2))$	P44
P15	$= (5)(i+2)$	P53
P16	$= (6)(i+(n-3))$	P63
To the row development of initial row I =1 and n = 6		

Equally the SL_H and SL_V reconfigurations are created in the 6×6 PV system. The results of developed and existing array reconfigurations were compared and explained. The power production of the developed and existing array reconfigurations is given in the Table 3.3. The power production and, efficiency during uneven irradiation conditions of Se-P, TCT, sudoku based reconfiguration, horizontal snake ladder array reconfiguration (SL_H), and vertical snake ladder array reconfiguration (SL_V) were shown in the output results in Figure 3.3.

Table 3.2. Node formation of the initial row for horizontal snake ladder

Real Positions of PV panels	**Expression**	**Location of PV panels in developed PV connection**
P11	$= (i)(1)$	P11
P12	$= (i+(n-1))(2)$	P62
P13	$= (i+1)(3)$	P23
P14	$= (i+(n-2))(4)$	P54
P15	$= (i+2)(5)$	P35
P16	$= (i+(n-3))(6)$	P46
To the row development of initial row i=1 and n=6		

Table 3.3. Comparison of power outputs

Sl. No	**Topology**	**Efficiency η(%)**
1.	Se-P	26.7%
2.	TCT	54.2%
3.	Sudoku	62.2%
4.	L-Shape [7]	60.7%
5.	Spiral-Pattern [8]	63.1%
6.	SL_H	67.8%
7.	SL_V	68.9%

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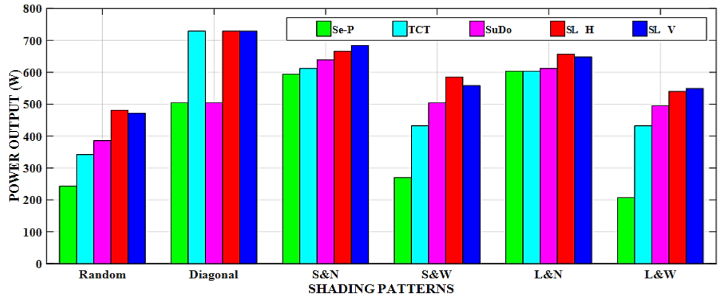

Figure 3.3. Power output comparison chart

For random irradiance, SL_H technique produces 6.70A of Isc and 501W of Pm, similarly SL_V technique produces 6.65A of Isc and 469W of Pm. The developed SL_H and SL_V are improved than existing techniques of Se-P, TCT, and sudoku patterns. During these uneven irradiances, the power productions from existing techniques are 234W, 324W, 368W respectively from Se-P, TCT, and sudoku patterns. The developed SL_H organization produces power with the effectiveness of 58.9% with the 66% of offered irradiance. Likewise, the developed SL_V reconfiguration produces power with the effectiveness of 59.1% with the 66% of offered irradiance. Another pattern such as Se-P, TCT, and sudoku has the effectiveness of 41.1%, 43.0%, and 58.8% respectively. The developed SL_H and SL_V have good P-V and I-V curves than the existing reconfiguration. The effectiveness of the developed scheme is compared to L-shape reconfiguration [7] and spiral-pattern reconfiguration [8] methods. The two articles were about the array reconfigurations for reducing the divergence losses similar to the developed technique. The comparisons of power outcome results are given in Table 3.3. and Figure 3.3.

4. Conclusion

In this article, a new electrical array reconfiguration technique of solar PV system is developed based on the snake-ladder movement. The snake-ladder formation can be developed into two ways like horizontal snake ladder (SL_H) and vertical snake ladder (SL_V) pattern. The developed SL_H and SL_V were validated in the MATLAB software. These SL_H and SL_V reconfigurations were validated with different 6 types of possible variable irradiance. The results of the developed technique are compared with the existing array reconfigurations. The existing techniques are performing fine in few irradiance levels and performing bad in few irradiance levels. But the developed SL_H and SL_V array reconfiguration are performing well in all levels of irradiances. The performance of the PV system

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in different irradiances levels were improved using the developed SL_H and SL_V array reconfigurations.

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