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One Time Relocation Algorithm for Performance Betterment of PV Array under Partial Shading

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Abstract : As the world is shifting towards technological advancement so the energy requirement is increasing exponentially. Carbon emission created by non-renewable energy sources is the main cause of stress of globe for the sustainability. Society need to move towards clean and green renewable energy like solar energy and wind energy. Solar radiations are available abundantly in nature. Irradiance are converted in to electrical energy by PV array system. But the output of PV array influenced by partial shading. MPPT device are failed to track the peak point due to local and global peak because shade is concentrated at one row or column. Researchers introduced many reconfiguration algorithm i.e. electrical or physical to minimize the effect of shading which are applicable on symmetrical PV array. But this paper presents one time relocation (OTR) algorithm to optimize the output power of unsymmetrical PV array system. It change physical position of module at the time of installation. It provide one time arrangement so time and cost is saved. In this work we have simulated the PV array and compared the OTR with TCT configuration. We improved fill factor, performance ratio and maximum power output of PV array system and reduced the mismatch power loss.

Keywords: *Irradiance, MPPT, PV array system, Partial shading, Module, Shading pattern*

1. INTRODUCTION:

The most important components of any infrastructure is Energy sector which have a great impact on economic growth of any country and therefore is also one of the largest industry of the world. Now a day’s energy requirement is increasing day by day. The energy consumption is depends on advancement and living standard of population and industrial revolution of the developing countries. To fulfill this energy requirement we need to shift from fossil fuel to renewable sources. Fossil fuel creates global warming which is great cause of concern of whole world.

The renewable energy sources are solar, wind, tidal, hybrid and many more. In solar power generation the PV cell convert the solar energy in to electrical energy. To compare the performance of solar cells efficiency is the most important parameter. The ratio of energy output from solar cell to the sun energy input in cell is called efficiency. The efficiency of multicrystallian silicon solar cell is (14-19%). The Amorphous silicon based solar cell efficiency is 6% and Multi junction production solar cell is 44%. The characteristics of solar panel depend on radiation and temperature of sun. The series and parallel combination of cell make a module and combination of module make an array. The series connection of modules increase the array voltage and parallel connection of modules increase the array current. So modules are connected according to power requirement.

The solar energy is intermittent in nature. It totally depends on atmosphere. Solar cell produce power when the sun shine. So in day time we get power and in night no power will produced so we need some storage means for night. The PV characteristic of solar cell is nonlinear. According to maximum power theorem when load and source resistance will be equal than output power will be maximum but load is always varied so there is a need to track maximum power point (MPPT). MPPT subsystem automatically very the load to track the peak point of curve. So many MPPT algorithms have introduced in literature. Some commercial algorithm are perturb & observe (PO) [1, 2] and incremental conductance(IC) [3, 4].

When the shadow of bird, tree, cloud, nearby building or any electrical tower fall on PV array than a part of array will not get standard radiation this will affect the performance of array. This condition is called partial shading [5, 6]. During partial shading it will be difficult to track the maximum power point because the PV curve will introduce multiple local peaks and global peaks []. It will become very difficult for an MPPT controller to find the maximum power point. Partial shading will also create a hot-spot in the PV module .so the life of panel will reduce.

To improve the energy output of PV array various interconnection topologies are introduced such as bridge link (BL), series parallel (SP) and total cross tied (TCT) [7, 8]. TCT gives the best power output and reduce the mismatch power loss in case of partial shading. When numbers of shaded PV panels are concentrated in single row than a high row current difference will occur so TCT output will reduce and mismatch loss will increase. The energy output can be increased by making all row currents nearly equal. To reduce the shading effect on one row we need to distribute the shading effect on all rows by electrical array reconfiguration (EAR) [9] or physical array reconfiguration (PAR) [10] In EAR the electrical connection of array changes according to shade. It increases the switching losses and cost of system. In PAR the physical position of modules are changed in such a way so that electrical connection remain same. In this manner switching losses and cost is minimized. In literature review so many algorithm have introduced to solve this problem but many of them are applicable on 3X3 array or 6X6 array or 9X9 array but not applicable on unsymmetrical matrix like 3X4 or 4X6 array. If shaded area is equal but in different pattern the suitable solar radiation for reconfiguring the array are not same [11]. PSO, DE (differential algorithm) and modified incremental conductance methods are complex because of additional component such as environment solar illumination sensors. So the cost of the MPPT control system will increase [12].

The objective of this paper is to optimize the generated power of PV array under partial shading condition using physical array reconfiguration technique without change of electrical connection and to design an algorithm for symmetrical (m x m) and unsymmetrical matrix (m x n) PV array. One Time Relocation (OTR) algorithm has been proposed to minimize the power loss, improve the performance ratio and fill factor.

2. MATHEMATICAL MODELING, DESCRIPTION AND CONFIGURATION

This section is consisting of the modeling description and configuration of Photovoltaic system. PV cell have one diode and two diode models. But in this paper to study the electrical behavior of PV cell one diode model [13] is used which is shown in Figure 1. In ideal equivalent circuit of PV cell one diode is connected with a current source. Practically nothing is ideal so a shunt resistance and a series resistance is connected with diode. It is the five parameter model which are photo current, diode reverse saturation current, diode ideality factor, series resistance and shunt resistance. Diode follows the Shockley diode equation for the current. The output current of PV cell

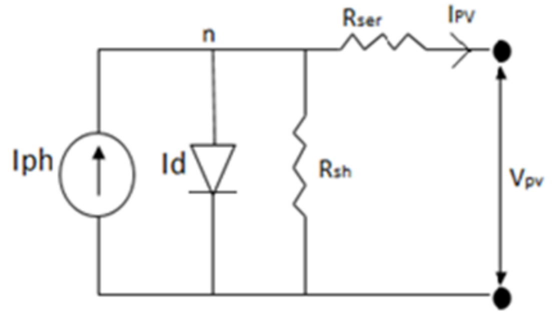

Figure 1 one diode model of PV cell

$$I_{pv} = I_{ph} - I_d - I_{R_{sh}} \quad (1)$$

$$I_d = I_o\left(e^{\frac{V_d}{aV_T}} - 1\right) \quad (2)$$

$$V_T = \frac{KT}{Q} \quad (3)$$

$$I_{R_{sh}} = \frac{V_{PV} + I_{PV}R_{ser}}{R_{sh}} \quad (4)$$

I_{ph} =photo current

I_{pv}= output current of PV cell

I_d=Diode Saturation Current

I_o=Reverse Saturation Current

V_d=Diode Voltage

a=Ideality Factor

V_T=Thermal Voltage

K=Boltzmann constant ($1.3805X10^{-23}$)

T=Temperature of PV module

Q=Electron Charge ($1.6X10^{-19}$ C)

The photo current depends on irradiance and temperature. It is independent to V_{PV} or R_{ser} given by

$$I_{ph} = \mu[I_{sc} + k_i(T - T_r)] \quad (5)$$

Where $\mu = \frac{G}{G_{stc}}$; G is the actual irradiance and G_{stc} is the irradiance at standard test condition I_{sc} is the short circuit current at STC, *ki* is the temperature coefficient of short circuit current (A/K), *T* and T_r are the actual and reference temperature (K). The photo current increases with increase in temperature. The voltage across the output terminal in the condition of open circuit cell is open circuit voltage V_o. The current through the terminal when cell is short circuited is I_{sc}. In open circuit and short circuit conditions solar cell will not produce any power. The PV module is consist of multiple PV cells in series and an array is made up of many PV module connected in series or parallel. To enhance the voltage number of PV modules are arranged in series and to enhance the current number of modules are arranged in parallel. The modules are connected in such a manner so that we will get required power. If N_s is the number of modules arranged in series and N_p is the number of modules arranged in parallel than the PV array eq^n are:-

$$\left.\begin{aligned} V_{pv} &= N_s V_m \\ I_{pv} &= N_p I_m \\ P_{pv} &= V_{pv} I_{pv} \end{aligned}\right\} \quad (6)$$

Reverse saturation current at temperature T

$$I_{OT} = I_{OR}\left(\frac{T}{T_r}\right)^3 e^{\frac{QE_g}{aK}\left(\frac{1}{T_r}-\frac{1}{T}\right)} \quad (7)$$

I_{OR} is the reverse saturation current reference temperature T_r , E_g is energy band gap of cell (J/C)[14].

The open circuit voltage is

$$V_O = V_{OR} + k_v T \quad (8)$$

V_{OR} Is open circuit voltage of cell at STC and k_v is open circuit voltage temperature coefficient.

Current at radiation G other than reference radiation (STC) G_R

$$I = \left(\frac{G}{G_{stc}}\right) \; X \; I_m \quad (9)$$

Fill factor (*ff*) [5] is the ratio of maximum power output to the product of V_{oc} and I_{sc} .

$$ff = \frac{P_{GMPP}}{\text{Voc}*\text{Isc.}} \quad (10)$$

Mismatch power loss (***MPL***) [5] is the difference between maximum power under uniform radiation and maximum power under partial shading condition.

$$MPL = P_{GMPP} - P_{PSC} \quad (11)$$

Efficiency (ξ) is the ratio of maximum power output to the power input

$$\xi \;\% = \frac{P_{GMPP}}{P_{IN}} X100 \quad (12)$$

Performance ratio (PR) [15] is the ratio of maximum power of array under partial shading condition to maximum power under unshaded condition

$$PR = \frac{P_{psc}}{P_{GMPP}} \quad (13)$$

There are various connection topologies named SP-Series Parallel, TCT-Total Cross Tied and BL-Bridge Link in figure 2.

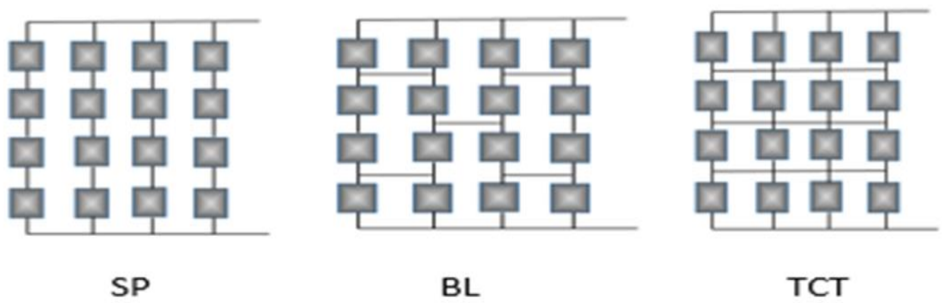

Figure 2-SP, BL, TCT topologies for 4X4 array

3. DIFFERENT PARTIAL SHADING CONDITIONS

In this paper we have included various shading conditions in figure 3. The unshaded panels receive standard radiation i.e. 1000 w/m^2 and shaded panel receive 350w/m^2 at 25^{0}c.

I. *Pattern1*-From low to up shading
II. *Pattern2*-From left to right
III. *Pattern3*-From diagonally

All shading conditions are simulated as TCT and OTR. We analyses the power, efficiency, mismatch loss, fill factor and performance ratio of the array under partial shading. The Table 1 shows specification of PV module at standard test condition (1000W/M^2, 25^{o}C).

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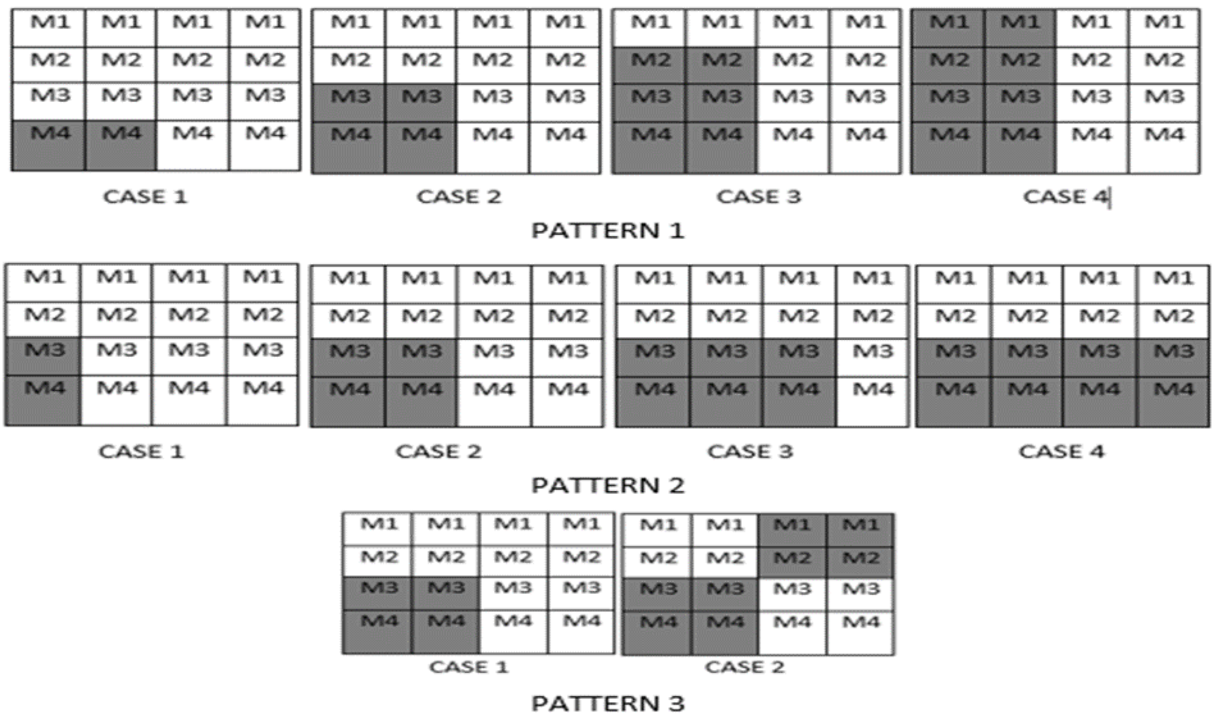

Figure 3-ShadingPattern 1-3

Table 1 : Parameters of PV module (1000w/m^2, 25^{0}c)

Parameters	Values (STC)
P_m	170.05watt
I_m	4.75 amp
V_m	35.8 volt
I_{sc}	5.2 amp
V_{oc}	44.2 volt
No. of series cells	72

4. PROPOSED ONE TIME RELOCATION (OTR) ALGORITHM

In this paper a new physical reconfiguration algorithm named as Proposed One Time Relocation (OTR) Algorithm is presented as shown in Figure 4. The electrical connection will remain unchanged as TCT. According to OTR in m X n array-

The physical position of modules in each odd column is

- Arrange all odd rows module first in increasing order than arrange all even rows module in increasing order.

The physical position of module in each even column is

- Arrange all even rows module first in increasing order than arrange all odd rows module in increasing order.

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M1	M1	M1	M1
M2	M2	M2	M2
M3	M3	M3	M3
M4	M4	M4	M4
M5	M5	M5	M5
M6	M6	M6	M6

6X4 TCT

M1	M2	M1	M2
M3	M4	M3	M4
M5	M6	M5	M6
M2	M1	M2	M1
M4	M3	M4	M3
M6	M5	M6	M5

6X4 OTR

M1	M1	M1	M1
M2	M2	M2	M2
M3	M3	M3	M3
M4	M4	M4	M4

4X4 TCT

M1	M2	M1	M2
M3	M4	M3	M4
M2	M1	M2	M1
M4	M3	M4	M3

4X4 OTR

Figure: 4 Location of modules in TCT & OTR

The benefit of this algorithm is

- It can perform on any number of rows or column.
- It is not necessary condition that $m = n$
- It gives better results than TCT
- It minimize the cost
- It minimize the power loss and improve the performance ratio.

5. ANALYSIS AND SIMULATION

In this paper we selected a 4X4 array for simulation. The pattern1 is presented in fig 5. All the shading case from fig 3 are applied in array. All case have (I) TCT (II) OTR (III) shade dispersion. The shaded module receive 350w/m^2 and other modules receive 1000w/m^2 [16].

5.1 Effect of shading pattern 1 on PV array

In fig 5 case 1, TCT connection all modules in row 1, 2, 3 receives 1000w/m^2 and in row 4 two module receives 350w/m^2 and two module receives 1000w/m^2.

$$I_{R1} = \frac{1000}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M$$

$$I_{R1} = 4I_M = I_{R2} = I_{R3} \tag{14}$$

$$I_{R4} = \frac{350}{1000}I_M + \frac{350}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M$$

$$I_{R4} = 2.7I_M \tag{15}$$

In OTR connection the shade in one row is distributed in two rows so it minimize the shade effect and improve the PV output .All modules in row 1, 2 receives 1000w/m^2 and in row 3, 4 one module receives 350w/m^2 and three module receives 1000w/m^2.

$$I_{R1} = \frac{1000}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M$$

$$I_{R1} = 4I_M = I_{R2} \tag{16}$$

$$I_{R3} = \frac{1000}{1000}I_M + \frac{350}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M$$

$$I_{R4} = \frac{350}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M + \frac{1000}{1000}I_M$$

$$I_{R3} = 3.35I_M = I_{R4} \tag{17}$$

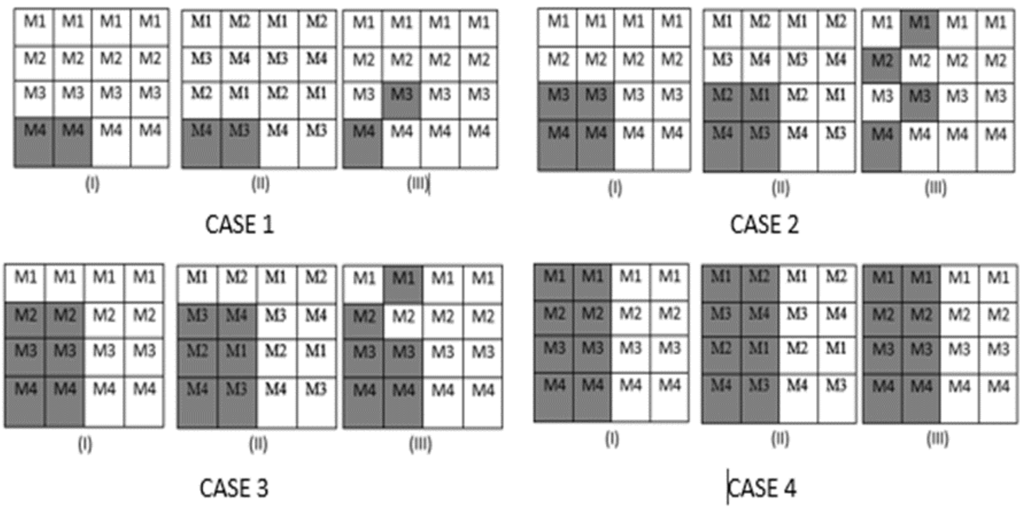

Figure: 5 Pattern 1 (I) TCT (II) OTR (III) Panel Relocation

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Table 2 shows row current, voltage and power of PV array for all the cases in TCT and OTR. In case 1, case 2, case 3 and case 4 the generated power by OTR arrangement are $13.4V_m I_m$ W, $13.4\ V_m I_m$ W, $10.8\ V_m I_m$ W and $10.8\ V_m I_m$ W whereas by TCT arrangement $12.0\ V_m I_m$ W, $10.8\ V_m I_m$ W, $10.8\ V_m I_m$ W and $10.8\ V_m I_m$ W. Figure 6 shows the PV characteristic of shading pattern 1. In case 1, 2 and 3 cases for TCT local and global peak occur and only global peak occur for case 4. No local and global peak occur in case 2 and case 4 for OTR. The voltage at which maximum power occur is $4\ V_m$ for all the cases of OTR and TCT but for TCT in case 1 it is $3\ V_m$.

Table 2 : Pattern 1 P, V, I in TCT and OTR

TCT				***OTR***			
Row current		***V_{pv}***	***P_{pv}***	***Row current***		***V_{pv}***	***P_{pv}***
				CASE 1			
I4	$2.7I_m$	$4V_m$	$10.8\ V_m I_m$	I4	$3.35I_m$	$4V_m$	**$13.4V_m I_m$**
I3	$4I_m$	$3V_m$	**$12.0\ V_m I_m$**	I3	$3.35I_m$	-	-
I2	$4I_m$	-	-	I2	$4I_m$	$2V_m$	$8.0\ V_m I_m$
I1	$4I_m$	-	-	I1	$4I_m$	-	-
				CASE 2			
I4	$2.7I_m$	$4V_m$	**$10.8\ V_m I_m$**	I4	$3.35I_m$	$4V_m$	**$13.4\ V_m I_m$**
I3	$2.7I_m$	-	-	I3	$3.35I_m$	-	-
I2	$4I_m$	$2V_m$	$8.0\ V_m I_m$	I2	$3.35I_m$	-	-
I1	$4I_m$	-	-	I1	$3.35I_m$	-	-
				CASE 3			
I4	$2.7I_m$	$4V_m$	**$10.8\ V_m I_m$**	I4	$2.7I_m$	$4V_m$	**$10.8\ V_m I_m$**
I3	$2.7I_m$	-	-	I3	$2.7I_m$	-	-
I2	$2.7I_m$	-	-	I2	$3.35I_m$	$2V_m$	$6.7V_m I_m$
I1	$4I_m$	V_m	$4.0\ V_m I_m$	***I1***	**$3.35I_m$**	-	-
				CASE 4			
I4	$2.7I_m$	$4V_m$	**$10.8\ V_m I_m$**	I4	$2.7I_m$	$4V_m$	**$10.8\ V_m I_m$**
I3	$2.7I_m$	-	-	I3	$2.7I_m$	-	-
I2	$2.7I_m$	-	-	I2	$2.7I_m$	-	-
I1	$2.7I_m$	-	-	I1	$2.7I_m$	-	-

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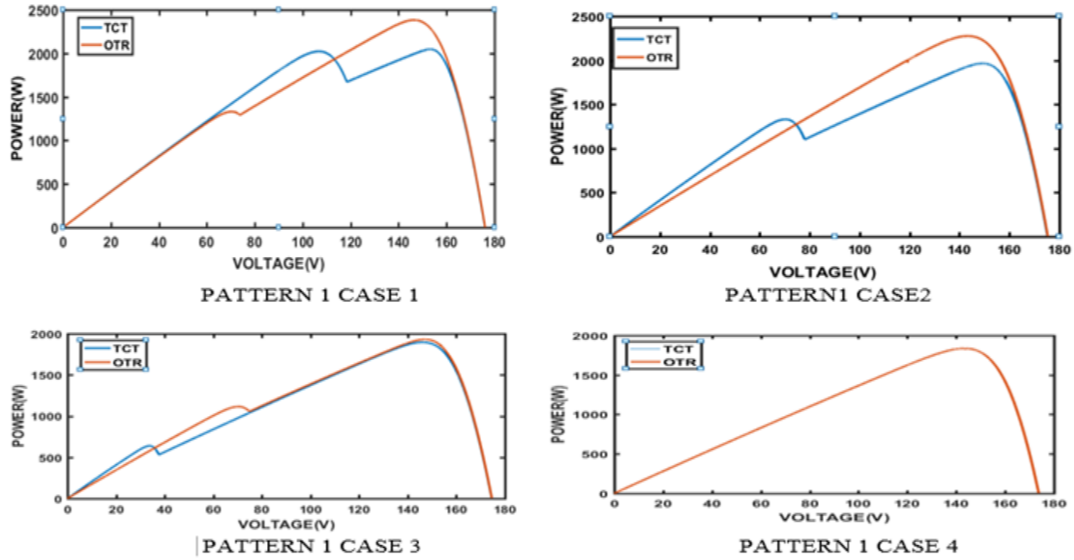

Figure 6: PV Characteristic in case of Shading Pattern 1

5.2 Effect of shading pattern 2 on PV array

In figure7 shading pattern 2 the shade is increasing left to right gradually. Table 3 shows row current, voltage and power of PV array for all the cases in TCT and OTR. In case 1, case 2, case 3 and case 4 the generated maximum power by OTR arrangement are *13.4* V_m I_m W, *13.4* V_m I_m W, *10.8* V_m I_m W and *10.8* V_m I_m W whereas by TCT arrangement *13.4* V_m I_m W, *10.8* V_m I_m W, *8.2*V_m I_m W and *8.0* V_m I_m W. Figure 8 shows the PV characteristic of shading pattern 2. In all cases for TCT local and global peak occur but No local and global peak occur in case 2 and case 4 for OTR. The voltage at which maximum power occur is *4* V_m for all the cases of OTR and TCT but for TCT in case 4 it is *2* V_m.

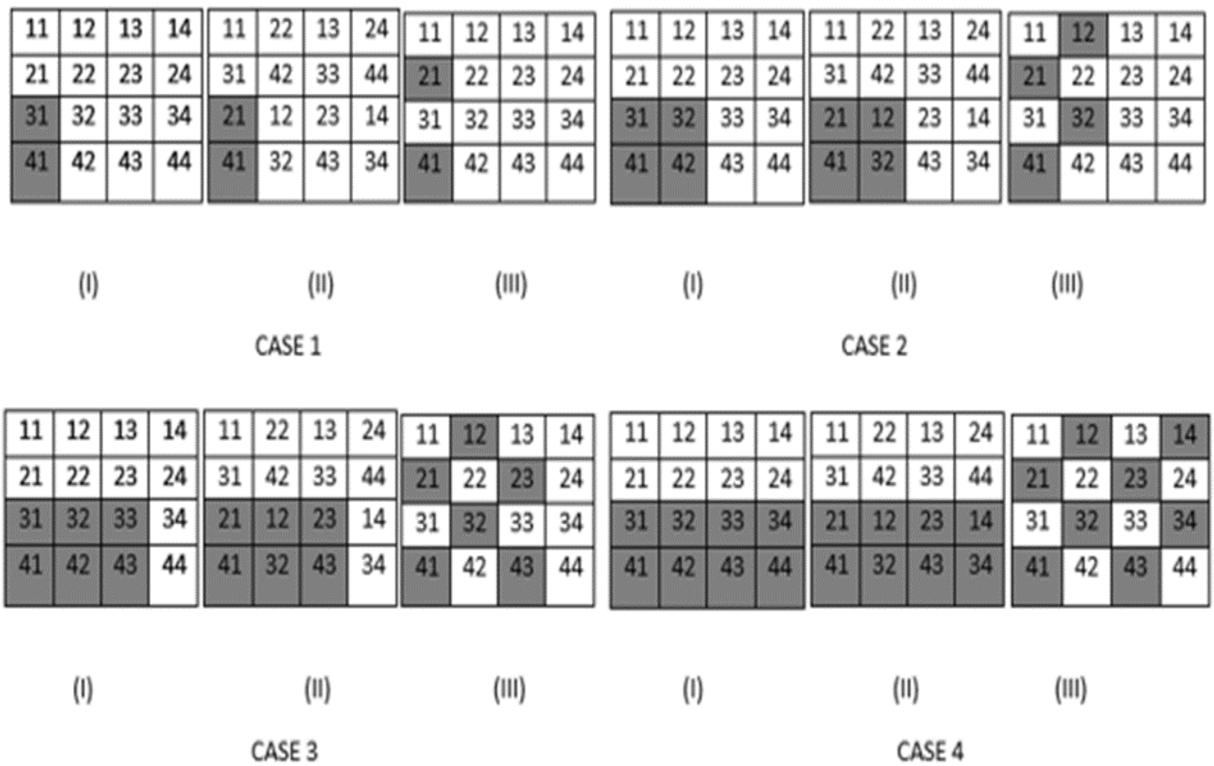

Figure: 7 Pattern 2 (I) TCT (II) OTR (III) Panel Relocation

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Table 3 : Pattern 2 P, V, I in TCT and OTR

TCT				***OTR***			
Row current		***V_{pv}***	***P_{pv}***	***Row current***		***V_{pv}***	***P_{pv}***
CASE 1							
I4	$3.35I_m$	$4V_m$	***13.4 V_m I_m***	I4	$3.35I_m$	$4V_m$	***13.4 V_m I_m***
I3	$3.35I_m$	-	-	I2	$3.35I_m$	-	-
I2	$4I_m$	$2V_m$	8.0 V_m I_m	I3	$4I_m$	$2V_m$	8.0 V_m I_m
I1	$4I_m$	-	-	I1	$4I_m$	-	-
CASE 2							
I4	$2.7I_m$	$4V_m$	***10.8V_m I_m***	I4	$3.35I_m$	$4V_m$	***13.4 V_m I_m***
I3	$2.7I_m$	-	-	I3	$3.35I_m$	-	-
I2	$4I_m$	$2V_m$	8.0 V_m I_m	I2	$3.35I_m$	-	-
I1	$4I_m$	-	-	I1	$3.35I_m$	-	-
CASE 3							
I4	$2.05I_m$	$4V_m$	***8.2V_m I_m***	I4	$2.7I_m$	$4V_m$	***10.8V_m I_m***
I3	$2.05I_m$	-	-	I2	$2.7I_m$	-	-
I2	$4I_m$	$2V_m$	8.0 V_m I_m	I3	$3.35I_m$	$2V_m$	6.70 V_m I_m
I1	$4I_m$	-	-	I1	$3.35I_m$	-	-
CASE 4							
I4	$1.4I_m$	$4V_m$	5.6V_m I_m	***I4***	$2.7I_m$	$4V_m$	***10.8V_m I_m***
I3	$1.4I_m$	-	-	***I3***	$2.7I_m$	-	-
I2	$4I_m$	$2V_m$	***8.0V_m I_m***	***I2***	$2.7I_m$	-	-
I1	$4I_m$	-	-	***I1***	$2.7I_m$	-	-

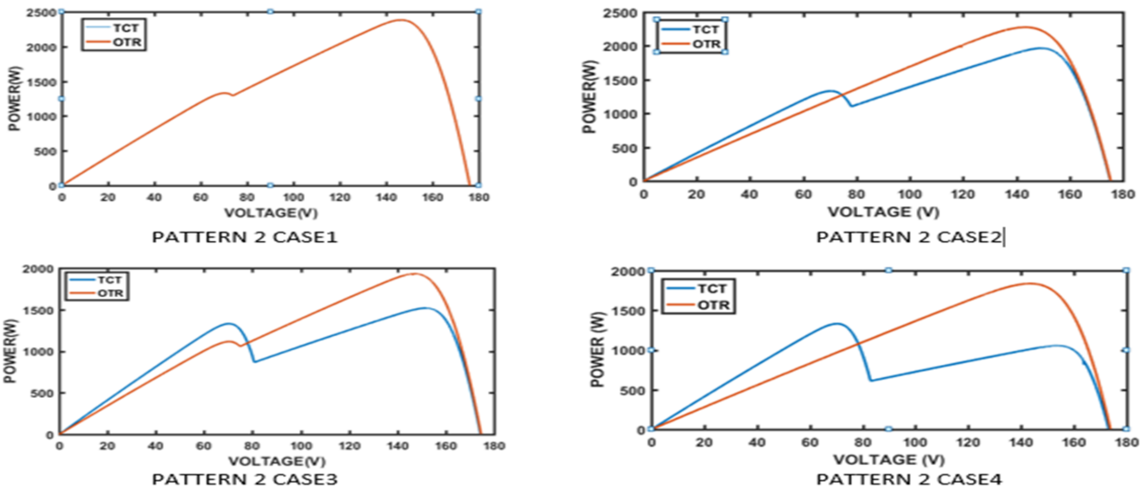

Figure 8: PV Characteristic in case of Shading Pattern 2

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5.3 Effect of shading pattern 3 on PV array

In figure 9 shading pattern 3 the shade is increasing diagonally. Table 4 shows row current, voltage and power of PV array for all the cases in TCT and OTR. In case 1 and case 2 the generated power by OTR arrangement are $13.4V_m\ I_m$ W and $10.8V_m\ I_m$ W whereas by TCT arrangement $10.8V_m\ I_m$ W and $10.8V_m\ I_m$ W. Figure 10 shows the PV characteristic of shading pattern 3. In case 1 TCT configuration gives a local and a global peak and no local peak produced by OTR but in case 2 no local peak present in TCT and OTR. The voltage at which maximum power occur is 4 V_m in both the cases of TCT and OTR.

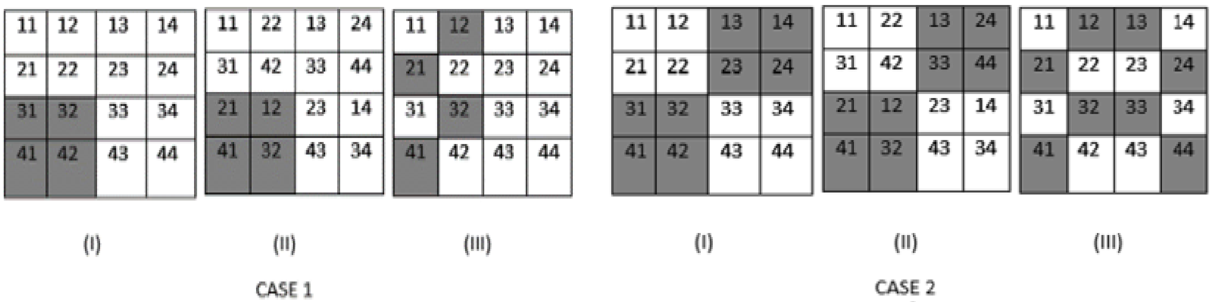

Figure: 9 Pattern 3 (I) TCT (II) OTR (III) Panel Relocation

Table 4: Pattern 3 P, V, I in TCT and OTR

TCT				***OTR***			
Row current		V_{pv}	P_{pv}	***Row current***		V_{pv}	P_{pv}
			CASE1				
I4	$2.7I_m$	$4V_m$	$\mathbf{10.8V_m\ I_m}$	***I4***	$3.35I_m$	$4V_m$	$\mathbf{13.4\ V_m\ I_m}$
I3	$2.7I_m$	-	-	***I3***	$3.35I_m$	-	-
I2	$4I_m$	$2V_m$	$8.0V_m\ I_m$	***I2***	$3.35I_m$	-	-
I1	$4I_m$	-	-	***I1***	$3.35I_m$	-	-
			CASE2				
I4	$2.7I_m$	$4V_m$	$\mathbf{10.8\ V_m\ I_m}$	***I4***	$2.7I_m$	$4V_m$	$\mathbf{10.8\ V_m\ I_m}$
I3	$2.7I_m$	-	-	***I3***	$2.7I_m$	-	-
I2	$2.7I_m$	-	-	***I2***	$2.7I_m$	-	-
I1	$2.7I_m$	-	-	***I1***	$2.7I_m$	-	-

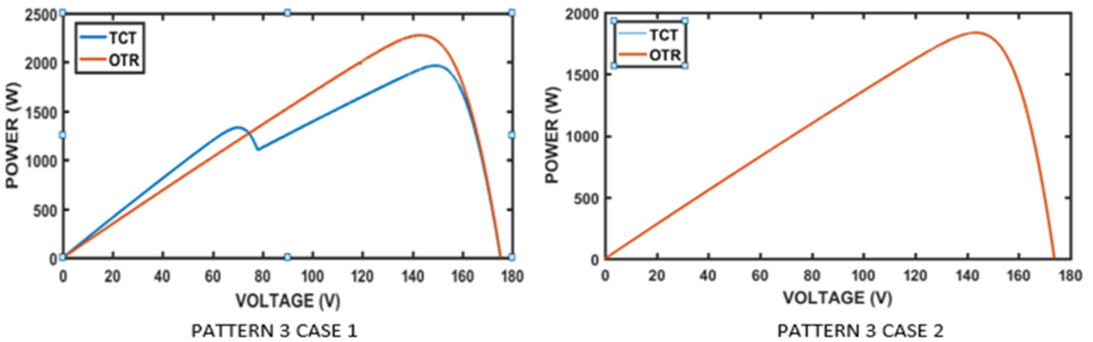

Figure 10: PV Characteristic in case of Shading Pattern 3

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6. RESULTS

The 4X4 PV array performance under shading has been studied in this work for different shading patterns of figure 3. So the results for these patterns are:

6.1 Shading pattern 1

PV characteristic of solar PV array for shading pattern 1 is shown in figure 6 and the values of power and voltage is shown in table 5. The maximum power for OTR configuration in case 1-4 are 2382.6W, 2275.4W, 1931.6W and 1836.5W at voltage 146.43V, 143.25V, 147.05V and 143.34V respectively. For TCT configuration 2046.6W, 1964.8W, 1896.5W and 1836.5W at voltage 153.24V, 149.30V, 146.03V and 143.34V respectively. In case 1, 2, 3 the OTR configuration shows the increased maximum power by 16.4% , 15.8% and 1.85% as compared to TCT configuration and in case 4 the maximum power is same for TCT and OTR configuration. Mismatch power loss for OTR configuration in all cases are 331.8W, 439W, 782.8W and 877.9W similarly for TCT configuration 667.8W, 749.6W, 817.9W and 877.9W. So in case 1, 2 and 3 the mismatch power loss has been reduced 50.3%, 41.4% and 4.3% by OTR configuration. Fill factor for OTR configuration in case 1, 2, 3, 4 are 0.65, 0.62, 0.53 and 0.50 which is higher than fill factor of TCT configuration in case 1, 2 and 3 by 16%, 17% and 1.9% as shown in table 6. According to table 7 Performance ratio which is ratio of maximum power of array under partial shading condition to the maximum power under unshaded condition has been improved by OTR in case 1, 2 and 3.

6.2 Shading pattern 2

PV characteristic of solar PV array for shading pattern 2 is shown in figure 8 and the values of power and voltage is shown in table 5. The maximum power for OTR configuration in case 1-4 are 2383.0 W, 2275.4 W, 1931.7 W, 1836.5 W and for TCT configuration 2383.0W, 1964.8W, 1518.1W, 1330.5W. In case 2, 3, 4 the OTR shows the increased maximum power by 15.8%, 27.2% and 38% as compared to TCT and in case 1 the maximum power is same for TCT and OTR configuration. According to table 6 Mismatch power loss for OTR configuration in all cases are 331W, 439W, 782.7W and 877.9W similarly for TCT configuration 331W, 749.6W, 1196.3 W and 1383.9W. So in case 2, 3 and 4 the mismatch power loss has been reduced 41.4%, 34.5% and 36.5% by OTR configuration. Fill factor for OTR configuration in case 1, 2, 3, 4 are 0.65, 0.62, 0.53 and 0.50 which is higher than fill factor of TCT configuration in case 2,3 and 4 by 17%, 29% and 28.2% as shown in table 6. According to table 7 Performance ratio has been improved by OTR in case 2, 3 and 4.

6.3 Shading pattern 3

PV characteristic of solar PV array for shading pattern 3 is shown in figure 10 and the values of power and voltage is shown in table 5. The maximum power for OTR configuration in case 1-2 are 2275.0 W, 1836.5 W and for TCT configuration 1964.8W, 1836.5W. In case 1 the OTR shows the increased maximum power by 15.8% as compared to TCT and in case 2 the maximum power is same for TCT and OTR. Mismatch power loss for OTR configuration in case 1, 2 are 439.4W and 877.9W similarly for TCT configuration 749.6 W and 877.9W. So in case 1 the mismatch power loss has been reduced 41.3% by OTR configuration. Fill factor for OTR configuration in case 1, 2 are 0.62 and 0.50 which is higher than fill factor of TCT configuration by 17% in case 1 as shown in table 6. According to table 7 Performance ratio has been improved by OTR in case 2.

TABLE 5 **:** Power and voltage of pattern 1-3 for TCT and OTR configuration

PATTERN1		**CASE1**		**CASE2**		**CASE3**		**CASE4**	
		P(W)	**V(V)**	**P(W)**	**V(V)**	**P(W)**	**V(V)**	**P(W)**	**V(V)**
	OTR	**2382**.6	146.43	**2275.4**	143.25	**1931.6**	147.05	1836.5	143.34
	TCT	2046.6	153.24	1964.8	149.30	1896.5	146.03	1836.5	143.34
	P_{inr}	16.4%		15.8%		1.85%		0%	
PATTERN2		**CASE1**		**CASE2**		**CASE3**		**CASE4**	
		P(W)	**V(V)**	**P(W)**	**V(V)**	**P(W)**	**V(V)**	**P(W)**	**V(V)**
	OTR	2383.0	146.30	**2275.4**	143.25	**1931.7**	147.36	**1836.5**	143.34
	TCT	2383.0	146.78	1964.8	149.30	1518.1	157.6	1330.5	70.27
	P_{inr}	0%		15.8%		27.2%		38.0%	

PATTERN3		CASE1		CASE2	
		P(W)	**V(V)**	**P(W)**	**V(V)**
	OTR	**2275.0**	143.25	1836.5	143.34
	TCT	1964.8	149.30	1836.5	143.29
	P_{inr}	15.8%		0%	

TABLE 6 **:** Mismatch power loss and fill factor of various topologies of pattern 1-3

MISMATCH POWER LOSS(W)						FILL FACTOR			
		CASE1	CASE2	CASE3	CASE4	CASE1	CASE2	CASE3	CASE4
PATTERN1	OTR	331.8	439	782.8	877.9	0.65	0.62	0.53	0.50
	TCT	667.8	749.6	817.9	877.9	0.56	0.53	0.52	0.50
		50.3%	*41.4%*	4.3%	0%	16%	17%	1.9%	0%
PATTERN2	OTR	331	439	782.7	877.9	0.65	0.62	0.53	0.50
	TCT	331	749.6	1196.3	1383.9	0.65	0.53	0.41	0.36
		0%	41.4%	34.5%	36.5%	0%	17%	29%	28.2%
PATTERN3	OTR	439.4	877.9	NA	NA	0.62	0.50	NA	NA
	TCT	749.6	877.9	NA	NA	0.53	0.50	NA	NA
		41.3%	0%			17%	0%		

TABLE 7 : Performance ratio of various topologies of pattern 1-3

		PERFORMANCE RATIO			
		CASE1	CASE2	CASE3	CASE4
PATTERN1	OTR	0.88	0.84	0.71	0.68
	TCT	0.75	0.72	0.7	0.68
		17.30%	16.60%	1.40%	0%
PATTERN2	OTR	0.88	0.84	0.71	0.68
	TCT	0.88	0.72	0.56	0.49
		0%	16.60%	26.70%	38.70%
PATTERN3	OTR	0.84	0.68	NA	NA
	TCT	0.72	0.68	NA	NA
		16.60%	0%		

7. CONCLUSION AND FUTURE WORK

In this paper we introduced a modern algorithm named one time relocation (OTR) for minimizing the effect of shading on (m X n) PV array system. This algorithm provides a better configuration to optimize the energy output and minimize the effect of shade. We have taken random shading pattern for the study. The complete simulation work has performed on MATLAB platform. The results of OTR compared with TCT configuration and found that

- Maximum power increased in OTR up to 38% as compared to TCT.
- Mismatch power loss decreased in OTR up to 50.3% as compared to TCT.
- Fill Factor increased in OTR up to 29% as compared to TCT.
- Performance Ratio increased in OTR up to 38.7% as compared to TCT.

OTR is providing us the improved results i.e. optimize the generated power of PV array under partial shading condition without changing electrical connection, minimize the mismatch power loss, improve the performance ratio and fill factor are fulfilled by OTR algorithm. The effect of temperature has neglected and the calculation done by connecting bypass diode in parallel to Module. The future work is to calculate the power by considering effect of temperature and also researchers can study the work without bypass diode to minimize the cost.

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