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Comparative Study of Different Configuration Techniques to Address the Outcome of Partial Shading Conditions on Solar Photovoltaic System

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Comparative Study of Different Configuration Techniques to Address the Outcome of Partial Shading Conditions on Solar Photovoltaic System

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Abstract:
As per energy and power productivity of a solar photovoltaic (SPV) system is evaluated, Partial Shading Conditions (PSC) play a significant role. Under PSC, the panels of a SPV modules receive various levels of solar irradiance, as a result power generation of a SPV system diminishes, and these losses in SPV panels may be decrease by changing the configuration of the panels in array/module. The panels may be configure in many different configuration such as Series(S), Parallel (P), Series Parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL), and Honeycomb (HC) to improve the output energy and power efficiency. This work is aimed to present all the configuration that already been presented in literature and result of PSC on SPV systems are referenced and analyzed. There are four configuration 4×4 array of solar photovoltaic panels to be discussed in this paper. Four configuration are Series parallel (SP), total cross tied (TCT), bridge linked (BL), and honey comb (HC). Four simulated models were performed to decide to effect of shadow with 10 shading patterns. The simulated results shows as a power against voltage (PV) curves of 4×4 array of SPV under PSC for above mentioned configuration. The PV curve of the proposed configuration is enhanced the power efficiency and the minute and exact finding of global maximum peak is simpler. The test of the simulated modules and its theoretical results ensure the effective implementation of this techniques in hardware setup also. It is confront that this work will be a reference of useful and important information for researchers in Solar panel area. The work presented in this papers envisages to be a source.

Keywords: photovoltaic cells, power enhancement, partial shading, global peaks, series parallel (SP), total cross tied (TCT) bridge link (BL) and honey comb (HC)

1. Introduction

While planning an inexhaustible renewable energy and power production, efficiency and productivity factor must be careful evaluated to confound endeavours and venture. Power production from SPV is one of the dependable and support source of power that utilizations daylight to create electrical energy and power [1, 2]. Sun oriented energy production has been accomplishing well known acknowledgment because of quick falling price of photovoltaic (PV) system and huge mechanical enhancements in the field sunlight of intensity converters. In the present situation, control age by PV clusters confront various difficulties, production intensity and efficiency of PV generators is seen to be incredibly impacted by the working conditions, for example, the natural temperature, sun's light levels, its topographical area and field issues [3]. The decrease of SPV system output is affected by variation in irradiance with respect to partial shading conditions The shading happens because of mists, flying creatures, nearby building, shaft, tree and residue. The deprivation of output power throughout the PSC depends on type and sequence of shade, position of cell/module within the array and aside from the corresponding of the shaded space of array [4-6]. The reduced efficiency of PV arrays because of partial shading is a predominant barrier in the growth of SPV systems. This issue has been widely discussed in the literature and number of schemes has been introduced to mitigate the results of PSC. Various available methods given by several researchers are studied and compared in terms of their advantages and limitations [7]. Bypass Diode: In uniform irradiance condition the PV characteristics of SPV cell produce single peak power, but Superior photocurrent continues to conduct at the condition of non-uniform irradiance, unshaded cells because the current should be equal when solar cells are connected in series. A known solution for this problem is to attach bypass diodes in anti-parallel but in PSC, bypass diode starts conducting if any solar cell/module is reverse biased. This successively permits the total quantity of current to experience them and it prevent damage of solar cells. However, production of solar panel with bypass diodes is expensive and increase overall price of the system. Also in PSC, the small amount of energy may be very less but produced by shaded cells is totally lost. The total loss is remarkable where low-voltage is required. The non-linearity of PV characteristic is significant with condition by the addition of bypass diodes under PSC due the presence of multiple maxima during tracking. Out of many local maxima, there exit only single GMPP. Because of multiple peaks, existing MPPT techniques does not perform well. In literature, various techniques are reported to find out GMPP in between many local MPPs. These techniques differentiate each other by many factors such as their different accuracy, variable tracking speed, price, hardware necessities, range and kinds of device needed, quality etc [8].

Rest approaches to accord with losses due to partial shading are micro-converters, adaptive reconfigurations of solar array connections, AC modules, generation control circuits, multi-level, and battery equalizer energy recovery. Above mentioned approaches supply sensible results, as every module works at its MPP, but high price of those techniques build power production by PV less attractive and useful [9-10].

The reconfigurable PV array is additionally projected for PV modules to reduce the impact PSC however the price of reconfigurable array is additionally high, and it's appropriate for small PV systems having less number of PV modules [11-12]. Interconnections scheme of PV modules additionally influence to reduce mismatch losses as an outcome of partial shading [13-14]. It is given that impact of partial shading condition may also be decreased by connecting the modules in TCT (total cross tied), BL (bridge linked) [4] etc. shown in figure 1(a). Schemes instead of standard SP (series- parallel) scheme because of additional parallel connection. On the other hand, the SP interconnection has less number of wiring compared to TCT and BL connections and so the price of SP is a smaller as compared to others. Additionally these interconnection schemes are investigated just for little part shaded electrical phenomenon fields (PS-PV) in literature and also the generalized affiliation laws for giant PV fields are still under analysis. [15] This paper is aimed to generate a standard method for interconnection of shaded and unshaded modules, and also to reduce the influence of shadow as an outcome to improve power generation.

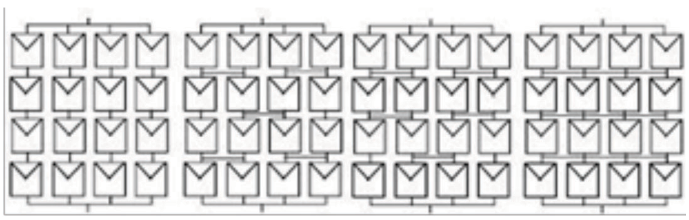

Fig. 1 (a) SP (b) BL (c) HC (d) TCT [18].

This paper is arranged as follows: In Section two, modelling of SPV module are discussed. Section three presents the investigation of 4×4 PV array under different PSC. Section four includes summary and conclusion.

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2. System Configuration

2.1. Photovoltaic module

For simulation and implementation of photo voltaic cell, many models are used analyse performance. Every set up and module is an advancement over the previous one with few additional component and hardware. But complexity of module increases as advancement occurs due to attachment of extra hardware. Among all existed models, one-diode and two-diode models are commonly used [16]. The main demerits of other existing models are that they are not accurate and also require many parameters to model. In between two-diode model and one diode model, commonly one diode model is preferred to implement [17] because it requires only five parameters to implement and model solar cell and has sufficient accuracy. The single diode model has the merit of good flexibility to estimate modifications due to irradiance and temperature changes. This model is shown in figure 2.

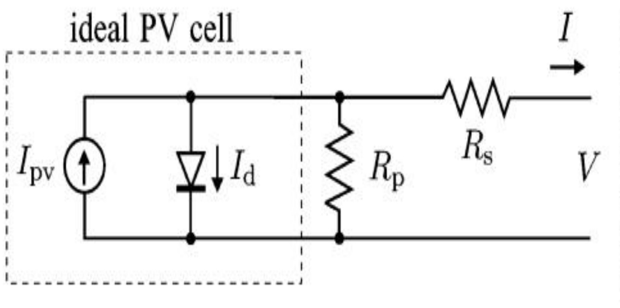

Fig. 2. Equivalent circuit of practical single PV device

I-V characteristic equation of an ideal PV cell is given by:

$$I = Ipv - Io\left[\exp\left(\frac{V + RsI}{Vta}\right) - 1\right] - \frac{V + RsI}{Rp} \quad (1)$$

Where I and Ipv are the total current and photovoltaic (PV) currents, respectivel.

Vt = NskT/q represents thermal voltage of the array where Ns is number of cells in series.

The photovoltaic and saturation current (Ipv & Io) can be given by:

$$Ipv = (Ipv,n + K1\Delta t)\frac{G}{Gn} \quad (2)$$

$$Io = \frac{Isc,n + K1\Delta t}{\exp\left(\frac{Voc,n + Kv\Delta t}{aVt}\right) - 1} \quad (3)$$

Where Δt =T- Tn (T and Tn represent the actual and nominal temperatures [in Kelvin], respectively), G stands for irradiation on the device surface in watts per square meters, Gn stands for nominal irradiation, and K1 and Kv stands current and voltage coefficient respectively.

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2.2 Simulation

All simulations in this paper are done using MATLAB/ Simulink. Here simulation purpose, parameters are taken PV KC200GT, a typical 200W PV. The standard parameters are irradiance of 1000 W/m2, cell temperature of 25 LC and spectrum of 1.5 air mass as shown in table 1.

Table 1 Datasheet of Kyocera PV module.

Parameters	Values
Maximum Power (P_{max})	200 W (+10%/ 5%)
Maximum Power Voltage (V_{mpp})	26.3 V
Maximum Power Current (I_{mpp})	7.61 A
Open Circuit Voltage (V_{oc})	32.9 V
Short Circuit Current (I_{sc})	8.21 A
Max System Voltage	600 V
Temperature Coefficient of V_{oc}	1.23 $\times 10^{-1}$ V/LC
Temperature Coefficient of I_{sc}	3.18 $\times$ 10^{-3} A/LC
Number per Module	54

Four Shading patterns which are used for this research work on SP, TCT, HC and BL configuration in PSC are mentioned below:

Case I Single Row Shading: In this case we consider two different level of irradiations to evaluate the performance of existed system. Group one (top three rows) receive 1000W/m^2 of irradiation and group 2(bottom row) receive 200W/m^2 of irradiation as shown in figure 3(a).

Case II Double Row Shading: In this group one (top two rows) receive 1000W/m^2 of irradiation and group 2 (bottom two row) receive 200W/m^2 of irradiation as shown in figure 3(b).

Case III Oblique Shading: In this group one receive 1000W/m^2 of irradiation and group 2 receive 200W/m^2 of irradiation as shown in figure 3(c).

Case IV Quarter Array Shading: In this case Group one receive 1000W/m^2 of irradiation and group 2 receive 200W/m^2 of irradiation as shown in figure 3(d).

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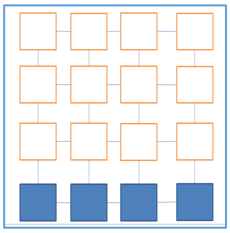
Figure 3(a) Single Row

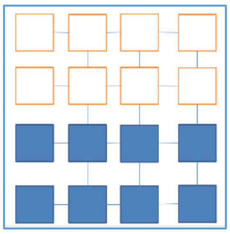
Figure 3(b) Double Row

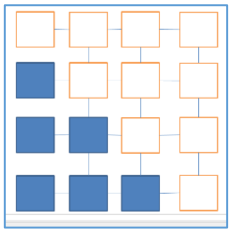
Figure 3(c) Oblique

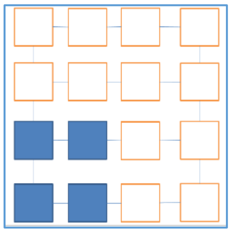
Figure 3(d) Quarter Array

2.3 Interconnection Schemes

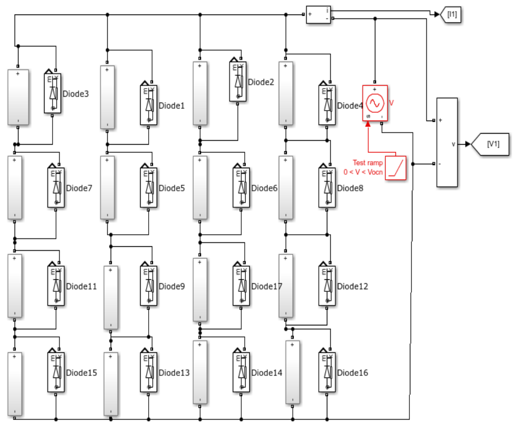

Fig 4(a) Series parallel

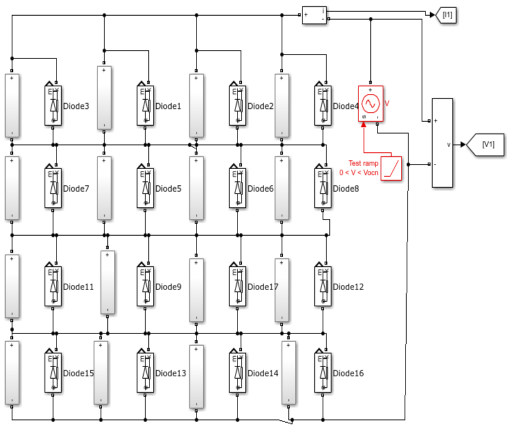

Fig 4(b) Total Cross Tied

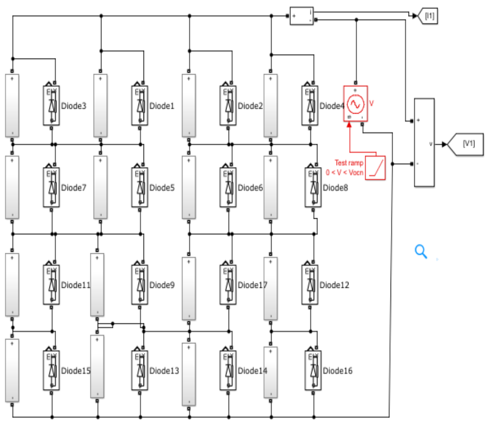

Fig 4(c) Bridge Link

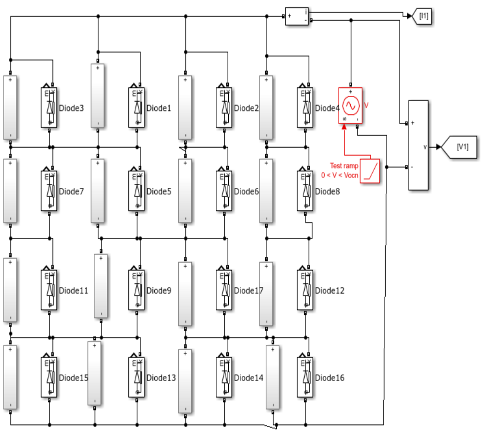

Fig 4(d) Honey Comb

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3. Results and Discussion

To find out the impact and results of shadow on different configuration like SP, TCT, HC and BL topologies, four simulations were performed. Figure 5 shows the results as a PV curve of different shading scenario for SP, TCT, BL and HC topologies

Table 2 shows electrical parameters (Im, Vm and Pmax) of SP, TCT, BL and HC configuration on PSC with various shading scenario. It is concluded from the results that, there exist a relationship between shading patterns and corresponding power generated. In case when number of shaded modules increased corresponding power losses is high as a result the power production is small.

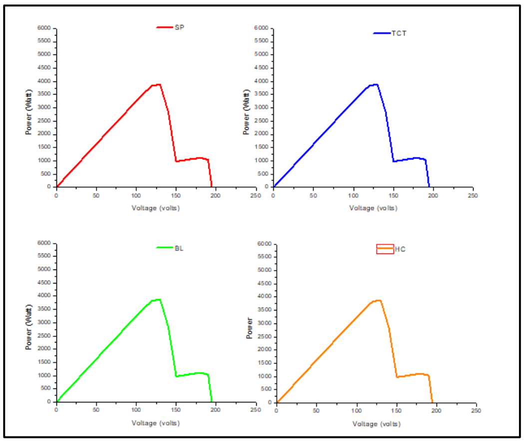

Figure 5(a) PV Characteristics Single Row

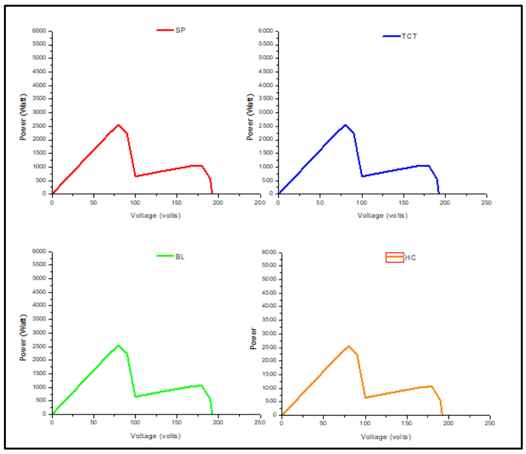

Figure 5(b) PV Characteristics Double Row

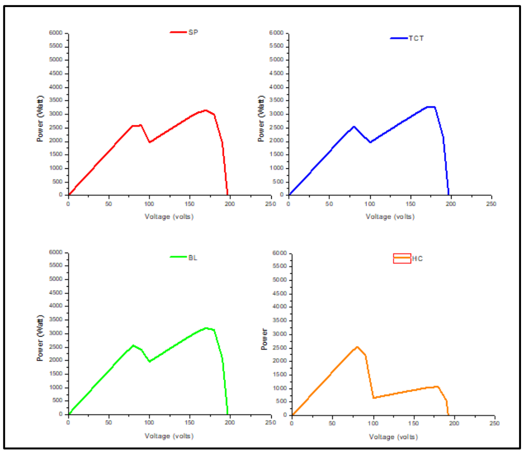

Figure 5(c) PV Characteristics Quarter Array

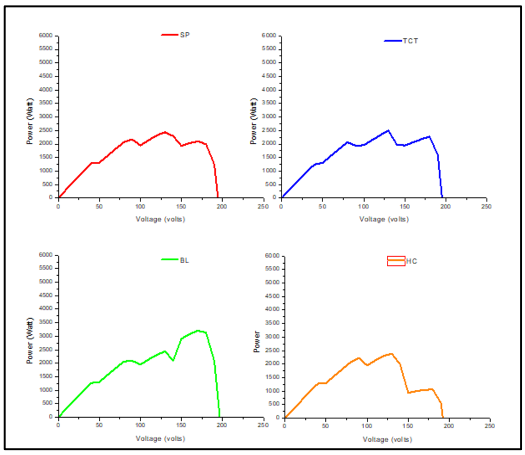

Figure 5(d) PV Characteristics Oblique

Table 2 Electrical parameters of SP,TCT,BL and HC Configuration

Case	Topology	P_m(kW)	V_m(V)	Im	Best
Uniform Irradiance	SP	5.2634	170	30.9	SP, TCT, BL and HC
	TCT	5.2634	170	30.9	
	BL	5.2634	170	30.9	
	HC	5.2634	170	30.9	
Single Row	SP	3.563	110	32.3	SP, TCT, BL and HC
	TCT	3.563	110	32.3	
	BL	3.563	110	32.3	
	HC	3.563	110	32.3	
Double Row	SP	2.5464	80	31.83	SP, TCT, BL and HC
	TCT	2.5464	80	31.83	
	BL	2.5464	80	31.83	
	HC	2.5464	80	31.83	
Oblique	SP	2.225	90	24.12	TCT
	TCT	2.497	130	19.3	
	BL	2.4343	130	19.3	
	HC	2.2255	90	24.72	
Quarter Array	SP	2.599	90	28.77	SP
	TCT	2.546	80	31.83	
	BL	2.5612	80	32.01	
	HC	2.5465	80	31.83	

3.1 Observations

- All topology produces same power with uniform irradiance and when single and double rows are fully shaded
- TCT topology gives best results and it produces high power and current when shadow is oblique.
- SP topology gives best and it produces high power and current when shadow is Quarter Array

4. Summary and Conclusion

An analysis and review of SP, TCT BL and HC configuration under PSC is presented and evaluated in this paper. It is concluded from the results that the power produced depended on type of partial shading and also number of shaded modules within array. Based on result and analysis, it can be seen that TCT configuration is showing good performance as compare to SP configuration when shadow is oblique. This occurs due to high connections of cable which provides more current path to prevent the reduction of current similarly, SP interconnection produces high power and current as compared to TCT configuration in case of quarter array shadow. The results of Bridge link and Honey comb lies between SP and TCT interconnection schemes. Future research work may include study of optimum configuration scheme which can be more appropriate for large PV fields and with frequent change in shading scenario.

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