COMPARATIVE STUDY OF DIFFERENT SOLAR PHOTOVOLTAIC ARRAYS CONFIGURATION TO MITIGATE NEGATIVE IMPACT OF PARTIAL SHADING CONDITIONS

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Abstract

Growth of photovoltaic systems that require more and more productive alternatives, not only in micro-fabrication techniques but also in methods of energy extraction. In recent years, a large number of Maximum Power Point Tracking algorithms with various complexities over decades the ability to efficiently locate the global maximum under partial shading was followed by evolved. Partial Shading Conditions (PSC) play a major role in determining the energy and power productivity of a solar photovoltaic (SPV) system. Under PSC, the SPV panels receive varying levels of solar irradiance, resulting in a decrease in the power generation of the SPV system, and these losses in SPV panels can be minimized by adjusting the configuration of the array/module panels. The panels can be designed to increase production energy and power quality in several different configurations, such as Series(S), Parallel (P), Series-Parallel (SP), Complete Cross Tied (TCT), Bridge Linked (BL) and Honeycomb (HC). This work is aimed at presenting all the configurations already presented in the literature and referencing and evaluating the findings of PSC on SPV systems. In this paper, there are four 4-4 array configurations of solar photovoltaic panels to be addressed. Parallel series (SP), complete cross-linked (TCT), the bridge linked (BL) and honeycomb are four configurations (HC). To decide on the effect of shadow with 10 shading patterns, four simulated models were carried out. For the above-mentioned configuration, the simulated results indicate a power against voltage (PV) curve of 4 to 4 SPV array under PSC. This thesis will be a reference point for useful and important knowledge for researchers in the field of solar panels.

Keywords: Photo-voltaic cells, Power Enhancement, Partial Shading, series-parallel (SP), total cross-tied (TCT), bridge link (BL), and honeycomb (HC)

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I. Introduction

The world's ever-increasing energy demand needs to be met by renewable energies to conserve the planet's valuable resources. Solar energy is one of the means of doing it, which has distinct advantages over competitive alternatives: low cost of maintenance, long life, ease of processing and lack of moving parts. Nevertheless, many problems keep PV systems from being the energy of the future. Partial shading [I-VI] is one of the key factors that decreases the output power of the PV array. A barrier through which sunlight does not pass is formed by dust deposited on panels, bird droppings, moving clouds, and other standing objects. It has been noted that the efficiency of the PV system decreases significantly under such circumstances and harvesting power becomes very difficult. Also, shaded cells result in hot spots being generated that deteriorate the panel and reduce its lifetime. To battle this problem, PV panel manufacturers also use bypass diodes. A fully efficient solution, however, is yet to come that minimizes the impact of partial shading. In areas where environmental conditions are suitable for harvesting sunlight, photovoltaic plants for industrial use are situated. Nevertheless, in places where partial shade is inevitable, panels for private use may be positioned. Therefore, one of the main issues in the solar sector is the issue of non-uniform solar irradiance. Optimizing the electrical interconnection of the PV array is one of the tricks to circumvent the damaging impact of partial shading. We propose a technique to create a partial shading robust series-parallel PV array configuration in this paper.

PV system decomposition

The theoretical limit of energy extraction from the PV cell is primarily determined by the property of the material (semiconductor bandgap)[VII]. However, due to non-ideality in power extraction techniques, not all of the energy could be used in the PV system. Under partial shading conditions, the performance of the solar panel is further lowered. PV system orthoganylation into separate modules reveals many options for optimization to improve performance under non-uniform solar irradiance:

1. Development of algorithms for MPPT capable of locating the global limit.
2. Modification of the electric system of the PV series.
3. Alteration in the architecture of the PV system.
4. Reconfiguration of converter topology.

Model of a PV cell

A fundamental building block of the PV system - the PV cell - is the starting point of our research. There are several mathematical models for understanding PV cells' electrical behaviour. We based this paper on the commonly accepted PV model as shown in Figure 1. More complex models [VIII] were also tested, taking into account recombination current and shunt resistance correction variables, as well as a model built by an artificial neural network [IX], which could be used with minor alterations for simulation. However, it would be more important to see potential outcomes of the partial shading of the PV system and choose the algorithm accordingly for the optimization of the electrical interconnect, rather than making efforts to decide the most precise model. The emphasis was therefore kept on a

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simplified model. On MATLAB, the performance of the PV cell was simulated and the effects of single diode solutions from Figure 2 could be seen
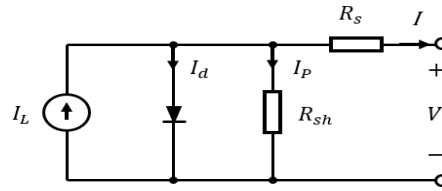

Figure 1: PV Model

The effect of environmental influences on the PV cell could be detected from a single diode numerical computation. Due to the decay of materials, this dependency changes over time, thus, altering the property. In the further study, however, data is crucial as the operating range under various temperatures and solar irradiance are very valuable details about the efficient structure of the array. It can already be seen from figure 2 how non-uniform temperature or irradiance could interfere with the PV array's synchronous functioning. In addition, the importance of bypass diodes becomes evident from Figure 2c, as shaded cells would block all current in the string [XV].
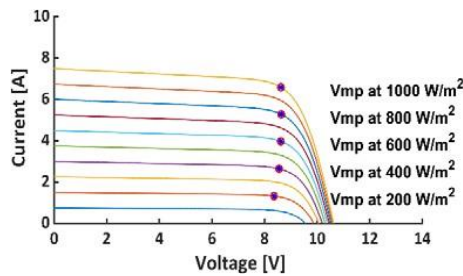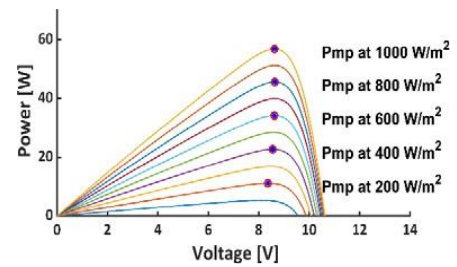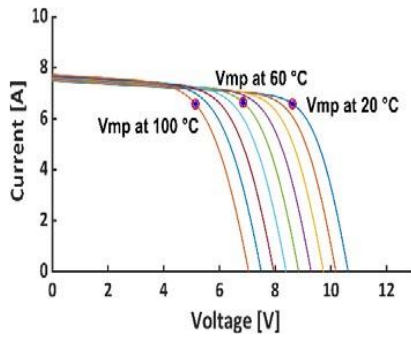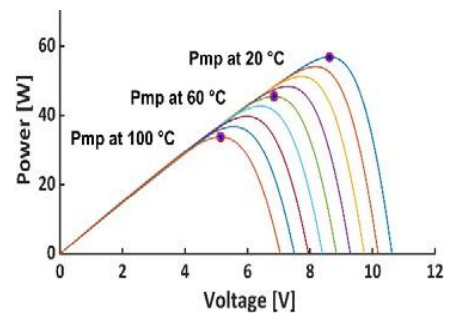

Figure 2 (a)

Figure 2 (b)

Figure 2 (c)

Figure 2 (d)

Figure 3: I-V and P-V properties of PV cells at various temperatures and ranges of irradiation: (a) I-V at different temperatures (1000 W/m2); (b) P-V at different temperatures (1000 W/m2); (c) I-V at different temperatures (20 degC); (d) P-V at different temperatures (20 degC).

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II.   System Configuration

Photovoltaic module

Many models are used to evaluate performance for photovoltaic cell simulation and implementation. Each setup and module with a few additional components and hardware is an improvement over the previous one. Yet module complexity increases as development occurs due to the attachment of additional hardware. One-diode and two-diode models are widely used in all current models[XVI]. The key demerits of other current models are that they are not specific and modeling requires several parameters as well. Between the two-diode model and one diode model, it is generally preferred to implement one diode model [XVII] because the implementation and simulation of solar cells need just five parameters and has adequate accuracy. To estimate changes due to irradiance and temperature changes, the single diode model has the advantage of good stability. Also, the reconfigurable PV array is designed for PV modules to decrease the PSC effect, but the cost of the reconfigurable array is also high, and it is suitable for small PV systems with fewer PV modules [XI] [XII]. Furthermore, the interconnection system of PV modules affects the reduction of mismatch losses as a result of partial shading[XIII]. It is considered that the effect of partial shading conditions can also be minimized by connecting the modules shown in Figure 3 in TCT (total cross-linked), BL (bridge linked)[4], etc (a). Schemes due to the additional parallel relation instead of the traditional SP (series-parallel) scheme. The SP interconnection, on the other hand, has less wiring than TCT and BL links, so the SP price is lower compared to others. In addition, these interconnection networks are studied in literature only for a small part of shaded electrical phenomenon fields (PS-PV) and the generalized association laws for giant PV fields are still being analyzed [XV]. This paper aims to create a standard method for the interconnection of shaded and unshaded modules, as well as to reduce the impact of shadows as a result of improving the generation of energy.
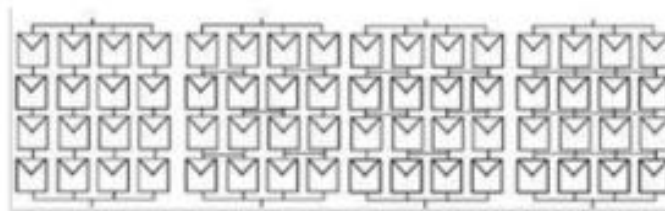

Fig.3: (a)SP   (b)BL   (c)HC   (d)TCT

Simulation

MATLAB/ Simulink is used to perform all simulations in this article. For simulation purposes, PV KC200GT, a standard 200W PV, parameters are taken here. The typical parameters are 1000 W/m2 radiance, 25 LC cell temperature and 1.5 air mass spectrum as shown in Table 1.

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Table 1: Parameters of Solar PV Panel

Parameters	Values
Maximum Power (P_{max})	1. 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}	$1.23 \times 10\text{-}1$ V/LC
Temperature Coefficient of I_{sc}	3.18×10 -3 A/LC
Number per Module	54

Below are four shading patterns used for this research work on SP, TCT, HC and BL configurations in Partial Shading Cases:

Case I Single Row Shading: In this case, we will consider two distinct irradiation levels to know the efficiency and performance of the existing system. Group 1 (top three rows) receives irradiation of 1000W/m2 and group 2 (bottom row) receives irradiation of 200W/m2, as shown in Figure 4 (a).

Case II Double Row Shading: In this case, group 1 (top two rows) receives 1000W/m2 of irradiation and group 2 (bottom two-row) receives 200W/m2 of irradiation as shown in figure 4(b).

Case III Oblique Shading: In this case, group 1 receives 1000W/m2 of irradiation and group 2 receives 200W/m2 of irradiation as shown in figure 4(c).

Case IV Quarter Array Shading: In this case, Group 1 receives 1000W/m2 of irradiation and group 2 receives 200W/m2 of irradiation as shown in figure 4(d).
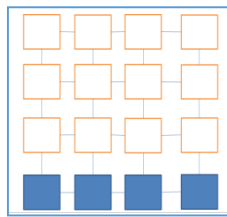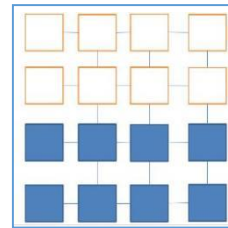
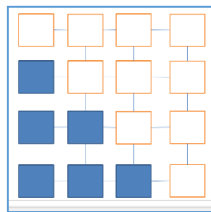Figure 4(a) Single Row   Figure 4(b) Double Row
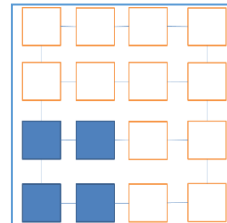
Figure 4(c) Oblique   Figure 4(d) Quarter Array

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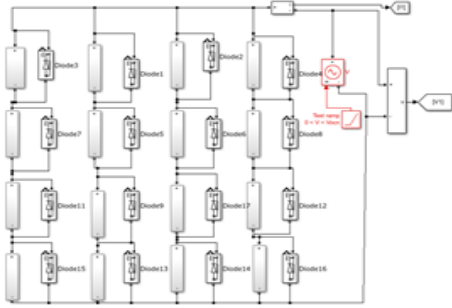**Interconnection Schemes**

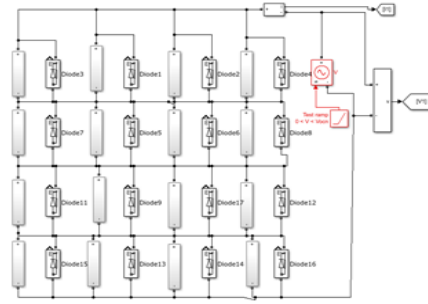
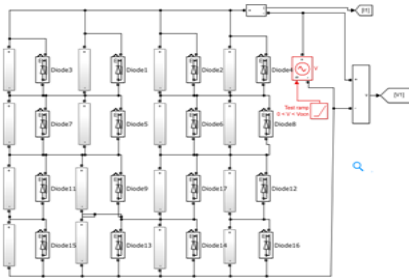Fig 5(a) Series parallel   Fig.5(b) Total Cross Tied
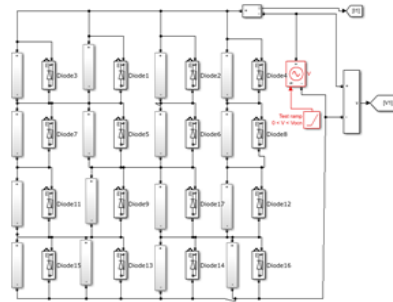

Fig.5(c) Bridge Link   Fig 5(d) Honey Comb

III. Results and discussion

Four simulations were conducted to find out the impact and shadow effects on various configurations such as SP, TCT, HC and BL topologies. The results of various shading scenarios for SP, TCT, BL and HC topologies are shown in Figure 6 as a PV curve.

Table 2 displays SP, TCT, BL and HC configuration electrical parameters (Im, Vm and Pmax) on PSC with different shading scenarios. From the results, it is concluded that a relationship exists between shading patterns and the corresponding power produced. In the case of an increase in corresponding power losses when the number of shaded modules is high, the power output is small.
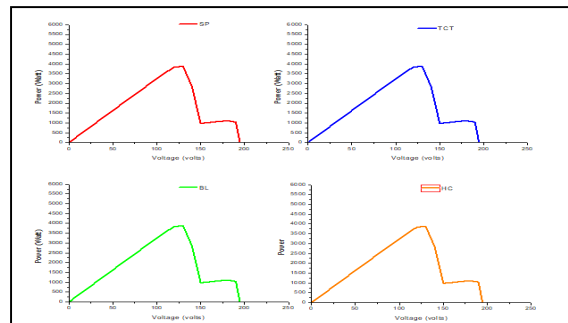

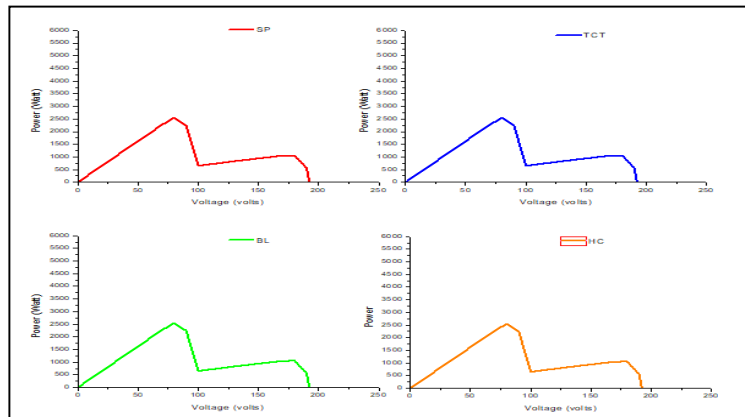**Figure 6(a) PV Characteristics Single Row**

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Figure 6(b) PV Characteristics Double Row

Figure 6(c) PV Characteristics Quarter Array

Figure 6(d) PV Characteristics Oblique

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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	

Observations

With uniform irradiance, all topology generates the same power and is completely shaded when single and double rows are TCT topology provides the best results because when the shadow is oblique, it generates high power and current. SP topology gives best and when the shadow is Quarter Array, it produces high power and present.

IV. Conclusion

In this paper, an overview and study of the configuration of SP, TCT BL and HC under Partial Shading Conditions are presented and evaluated. From the results, it

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is concluded that the generated power depended on the form of partial shading and also on the number of shaded modules within the array. It can be shown based on outcome and study that TCT configuration shows good performance when the shadow is oblique compared to SP configuration. SP interconnection generates high power and current compared to TCT configuration in the case of quarter array shadow, due to high cable connections that provide a more current path to avoid current reduction similarly. The outcomes of Bridge connection and Honeycomb lie between the interconnection systems of SP and TCT. Future research work may include researching the optimum configuration method that may be more suited for large PV fields and with regular shading scenario changes.

V.   Acknowledgment

Conflict of Interest

There was no relevant conflict of interest regarding this paper.

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