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Photovoltaic Module Interconnection Modified to Improve Efficiency & Robustness

Ms. Vaishnavi P. Deshpande
Research Scholar, Electrical Engineering Department,
G.H. Raisoni College of Engineering, Nagpur, Maharashtra 440016, India.
Orcid: 0000-0002-0315-4959

Dr. Sanjay B. Bodkhe
Supervisor, Former Professor, Electrical Engineering Department
G.H. Raisoni College of Engineering, Nagpur, Maharashtra 440016, India.
Orcid: 0000-0002-0315-4959

Abstract- Partial shading is the most common mismatch problem in a PV system that affects system performance. The present study investigates the effects of partial shading on different topologies of PV module interconnections such as Total cross tied (TCT),Series-parallel(SP),Honey-comb(HC),Bridge-link(BL) connected solar PV array and compare their performance. A MATLAB simulation model is tested under partial shaded conditions to find the PV module interconnection topology which is less susceptible to partial shading effects. It is found that TCT interconnections are comparatively less sensitive. The effects of unavoidable partial shade can be decreased by using alternative topologies. In the present study, the solar module interconnections topologies are studied to minimize the losses caused by partial shading effect.

Keywords: Energy sources, renewable energy system, partial shading, simulation, solar photovoltaic cell

INTRODUCTION

India situated in the sunny belt of the world map. India is endowed with tremendous amount of solar energy potential. In India, all the parts receives solar radiations approximately 300 days throughout a year [1]. Indian land area receives about 5,000 trillion kWh per year energy and 4-7 kWh per sq. meter per day. In India mainly, the solar energy and Wind energy sectors are more accelerated to increase the contribution of these sectors to the total energy generation in India.

India has an total renewable energy potential of about 900 GW from renewable energy sources such as Wind – 102 GW, Bio-energy – 25 GW, Small Hydro – 20 GW and Solar power – 750 GW. Renewable energy shares 15.90% in total installed capacity in India. As of March 2017, the totalled renewable energy installed capacity is 57,260 MW. Renewable energy has been experiencing over 20% growth in the last five years. From the total renewable power installed capacity of 14,400 MW at the beginning of 2009, it has increased to the capacity of 38,822 MW at the end of December, 2015 to 57,260MW by March, 2017.[2,3]Solar power is amongst the most dominant and well-established second generation renewable technologies. It has numerous ecological benefits such as PV modules do not produce greenhouse gases during manufacturing as well as during operation. The modular PV systems can be built in various ranges of sizes. Modular PV system allows short construction periods reducing technical and financial risks related to testing, and financial utilization. There are no moving parts with the PV power system which reduces the operating and maintenance cost. The approximate lifetime of PV system, which is assumed around 25 years produces more energy than that for their manufacturing [4-5]. PV technology has numerous advantages, but this technology faces various limitations in the path of wide development. The major limitation is the cost. PV has overcome the cost problem with conventional energy only for special cases such as very remote locations where fuel shipping costs are extremely high. The cost of solar energy technologies are rapid decreasing in the recent past years.

The other limitation with PV power generation is its dependence on the weather conditions and insufficient means of storage, resulting in stability and reliability problems for the electrical grid. PV cell convert solar energy to electricity when exposed to sunlight. In order to get required amount of current (Ampere) and voltage (volts) many PV cells are interconnected into a single unit called a PV module. PV modules are connected in series and parallel to form a photovoltaic array. The output of the array is affected by several factors for instance solar irradiance, module rating, operating temperature, soiling, and changing solar spectrum and angle of incidence [6]. The measurement of the array performance is associated with the study of these factors. The efficiency of operation of a solar array depends not only on the weather conditions but also on the module interconnection topology forming an array. The existing literature focusses on adverse effect of partial shading i.e. multiple peak in output power curve and hot spot problem in series connected module. These problems can be partially solved by using different PV module interconnections. Thermal effect on the solar PV interconnections and its influence on the output power and efficiency is studied [7]. The mismatch losses and due to tracking of local MPP instead of the global one for string configurations is studied in [8]. Analysis on the various array configurations under changing illumination conditions is presented in [9]. In [10], a Su Do Ku puzzle pattern in a TCT connected PV array has been proposed to improve the PV power generation under partial shaded conditions. The various partial shading losses due to the false tracking and fill factor under changing illumination conditions is investigated.by using a MATLAB/Simulink model[5] Study of physical Solar PV module is difficult as field testing depends heavily on the varying weather conditions. It is difficult to maintain the same shade throughout the experiment. To avoid this, a simulation study is carried out with the help of a computer model in MATLAB Simulink [11]. This paper is arranged as follows: First section gives modelling of SP, TCT.BL, HC module interconnection topologies. The following sections discuss simulation at varying irradiance and partial shading conditions. Finally, the simulation results are discussed.

In this paper, the performance of a PV array with HC, SP, TCT and BL connection topologies is analysed under different shading conditions by using a MATLAB /Simulink model. In this study a 6x6 PV array is modelled, to observe the effect of shading on output power. The system performance is investigated for different shading condition.

ARRAY INTERCONNECTION SCHEMES

In a PV array, the interconnection scheme refers to the manner in which modules are interconnected in the array. The widely used interconnection schemes reported in the literature [12] are the SP, TCT, HC and BL configuration as shown in fig 1(a),1(b),1(c),1(d).

Series-Parallel (SP)

A combination of series and parallel modules is the most common type of connection used in commercial applications. This consists of a column of solar modules connected in series and a few columns connected in parallel depending upon the voltage and current requirement of the load. The series parallel connection is shown in Fig.1(a)

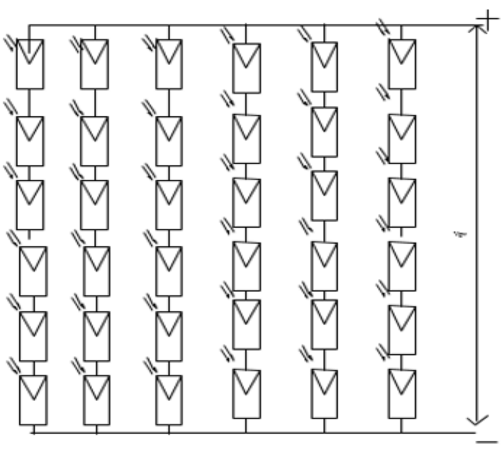


Figure 1(a): Solar modules connected in Series-Parallel (SP)

Total cross tied (TCT)

The total cross tied connection is similar to series parallel connection with the difference that in total cross tied connection first a group of modules are connected in parallel then the combination called tiers are connected in a string as shown in Fig 1(b)

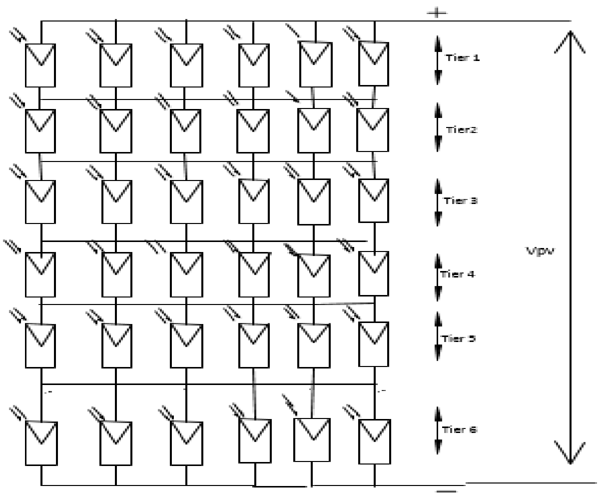


Figure 1(b): Solar modules connected in Total Cross Tied (TCT)

Honey comb (HC)

The Honey comb connections are looked like a linked honey comb structure. The middle layers are connected in parallel and the top layer is in series. The layers in between the hexagons are connected in parallel as shown in Fig.1(c)

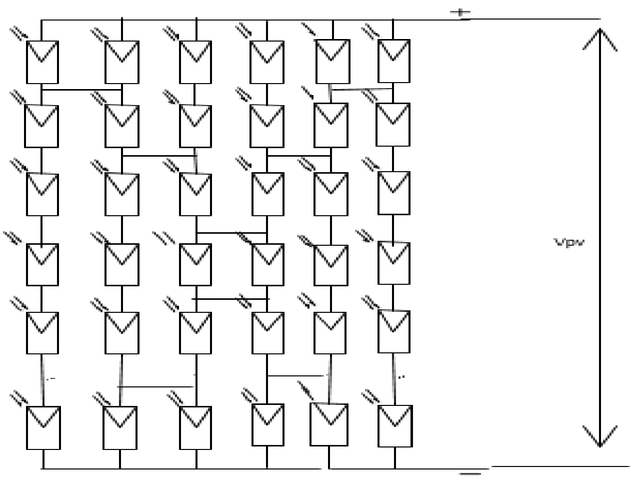


Figure 1(c): Solar modules connected in Honey comb (HC)

Bridge linked (BL)

Bridge linked technique closely follows the total cross tied method. In this connection every two modules are connected in series and the middle one is connected to the column next to it as shown in Fig.1(d)

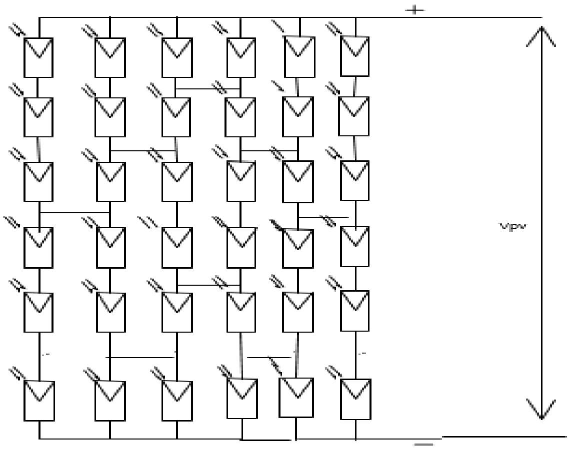


Figure 1(d): Solar module connected in Bridge Link (BL)

TYPES OF SHADE

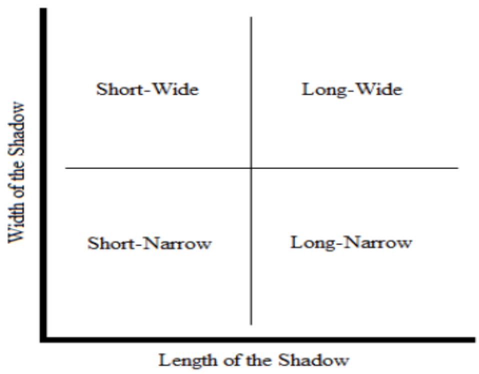
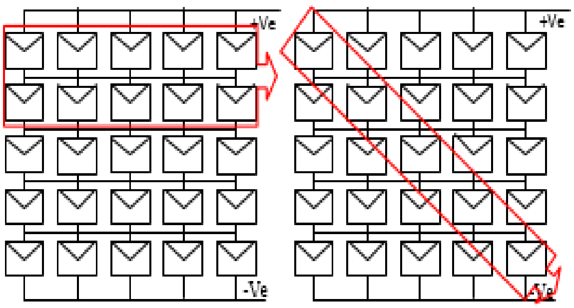
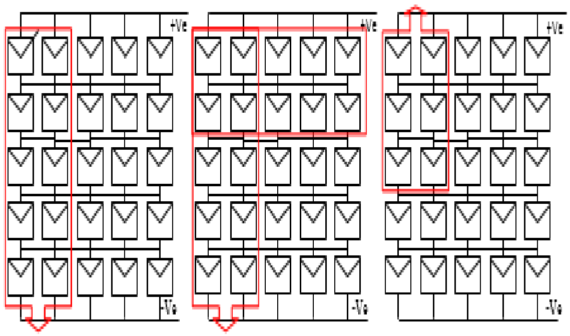


Figure 2: Types of Shades

Most widely considered shades for analysis purpose are short-wide (SW), short-narrow (SN), long-wide (LW), and long-narrow (LN) PS conditions, as shown in Figures, here special case such as diagonal shade (DI) is also included in analysis. A 5 x 5 TCT PV array is used only to demonstrate each simulated PS condition. The shade analysis is done on 6x6 PV array.



a) Short Wide b) Diagonal



c) Long narrow d) Long wide e) Short narrow

Figure 3(a)(b)(c)(d)(e): shows the shade conditions.

RESULTS AND DISCUSSION.

A 6x6 PV array is modelled using different module interconnection topologies. Each module is composed of 36 solar cells connected in series. The specifications of module is given in table 1.

Table 1: Specifications of PV module

Rated PV power	95 W
Open circuit voltage	20.6 V
Short circuit current	6.19 A
Maximum power voltage	17.2 V
Maximum power current	5.53 A
Number of cells in series NS	36
Number of cells in parallel NP	1

As discussed in previous section the shades are modelled using shade factor. The simulations are carried out in MATLAB/Simulink environment. All four topologies namely SP, TCT, BL, and HC configuration are compared for power output under partial shading conditions. Fig.5. shows the plots between output power against different shading patterns for different interconnections. The shading conditions are shown in fig.4

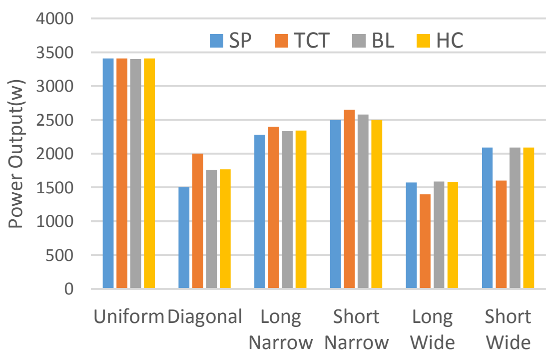


Figure 4: Comparison of power output under different shadings.

Table 2: shows comparison of power output of different topologies under shading test conditions.

Type of shade	SP(Series-Parallel) (P_{max})Watts	TCT(Total cross tied) (P_{max})Watts	BL(Bridge Link) (P_{max})Watts	HC(Honey Comb) (P_{max})Watts
Uniform	3410	3410	3400	3410
Diagonal	1500	2000	1760	1770
Long Narrow	2280	2400	2330	2340
Short Narrow	2500	2650	2580	2500
Long Wide	1572	1400	1586	1580
Short Wide	2092	1600	2090	2090

1) Uniform Irradiance condition: Under uniform irradiance condition all the stated module interconnection topologies gives approximately similar output power of 3410 watts.
2) Diagonal Shading Conditions*:* Under diagonal shading condition TCT topology gives highest output power of 2000watts as compared to other topologies. The SP topology is highly affected by diagonal shade 1500 watts as no parallel ties are connected with SP to pass the current.
3) Long & Short Narrow Shading Conditions*:* It is observed under this shade condition, TCT shows superior performance with 2400 watts and 2650 watts respectively as compared to other topologies.
4) Long & Short wide Shading Conditions: It is observed that under wide shade condition the power output of TCT decreases as compared to other topologies.

CONCLUSION

The detailed design aspects, simulation results are presented. The effects of partial shading is studied for different shading patterns. The result analysis is carried out to comparatively study the effect partial shading on performance of TCT, SP, BL, and HC configured PV array. This analysis shows that the TCT, BL and HC topology shows improved results. Out of these three connections BL and HC connections has a drawback of irregular ties connection, So TCT is found most robust topology as compared to other topologies.

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