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Hybridization of Photovoltaic Arrays- Modeling, Simulation, and Performance Analysis in Matlab

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Abstract

The usage of conventional energy sources such as fossil fuels are a major concern to the environment. The renewable energy sources surpassed all the disadvantages of them causing an evolution by reducing the greenhouse effect. Solar photovoltaic energy has made its own importance among all the renewable sources of energy because of the advantages it possesses such as import – independent, dust free, inexhaustible, very low cost of maintenance, fuel free source. In photovoltaic (PV) systems, solar irradiation is a crucial factor as it directly affects the amount of electrical energy that can be generated. PV panels convert sunlight into electricity, and their efficiency depends on the intensity and angle of the incident sunlight. Factors such as geographical location, time of year, weather conditions, and the orientation and tilt of the solar panels influence the amount of solar irradiation received, thereby impacting the overall performance and energy output of the PV system. Hence to maintain sustainable output of PV system, the most capable reconfiguration approach is considered. Reconfiguring the array allows for improved power generation by altering the connections to minimize the impact of shading or to adapt to changing environmental conditions. The project aims to propose Series-Parallel, Total Cross Tied (TCT), Bridge Link (BL) and Honey Comb (HC), Hybrid reconfiguration techniques to maintain sustainable output in a solar PV array.

1. Introduction

The increasing in the pollution also increasing the usage of fossil fuels causing the increasing the environmental effect like temperature increasing, polluting the atmosphere etc. [1-3] by overcoming this we can use renewable energy sources to decreasing the usage of fossil fuels. The renewable energy sources are like wind, solar, hydro energy sources are used to reduces the usage of fossil fuels and protect the environmental, the most advantage of these renewable energy sources are these are eco-friendly to the environmental and non-exhaustible, and we can generate the power throughout our life. Present generation solar energy is the one of the most popular renewable energy sources we can generate the energy by using solar energy conversion technique, this involves converting solar irradiance to electricity and other energy forms as we required, in this process solar photovoltaic arrays is used to convert the solar energy into another energy. [4-7]

2. Literature Survey

A Novel Benzene Structured Array Configuration for Harnessing Maximum Power from PV Array Under Partial Shading Condition with Reduced Number of Cross Ties.ai (1) The proposed system is novel benzene structure to improve the outpower and reduces the connection of a cell. It has suggested to introduce the new configuration for increasing the power output and comparing the output of benzene structure to Series, Parallel, Bridge Link (BL), Total Cross Tied (TCT), Honey comb (HC) under different partial conditions. Reconfiguration of Solar Photovoltaic Panels for Water Pumping Applications.ai (2) has suggested fluctuating solar irradiation will produce fluctuating output power, minimize the switch count and uses the parallel switching network and also decreases the power losses, this reconfiguration system is coupled with pumping motor and concluded this configuration is 33% better. Novel reconfiguration approach to reduce line losses of the photovoltaic array under various shading conditions.ai (3) has reconfiguring the solar PV array to reduces the losses under different shading conditions. It has performed the various kind of partial shading conditions to reduces the line losses and to increases the output. It has proposed the Skyscraper (SS) technique to reduces the partial shading impact to the PV arrays and also proposed the various shading techniques like row wise, column wise, diagonal wise [7-8]

3. Proposed Method

The proposed method in new hybrid method which merge two different configurations those are Honey Comb and benzene configuration and named it as a hybridization configuration there are 2 main components i) Solar irradiation ii) PV Array configuration. I) solar irradiation will be changed every time it will not constant throughout the day, here we can't control the solar irradiation based on the solar irradiation is key for generating the better and high output. Solar irradiation is more the photons released by the sun is high hence the input to the system is high ii) PV array is the responsible for generating the electricity from the solar energy, for getting the better output from the PV array we can reconfigure the PV array in this paper introduces new hybrid technique to improve the output parameter like voltage, current and power. Combining the two existing methods i.e. Honey comb and Benzene structure configuration the output parameters are compared to the existing Series, Parallel, Honey comb (HC), Bridge Link (BL), Total Cross Tied (TCT), and Benzene structure configuration output parameters [9]

4. Solar Energy Conversion System

The PV characters of solar panel at standard temperature is shown below. The irradiation levels from 400 W/m2 to 1200 W/m2. (Figure 1)

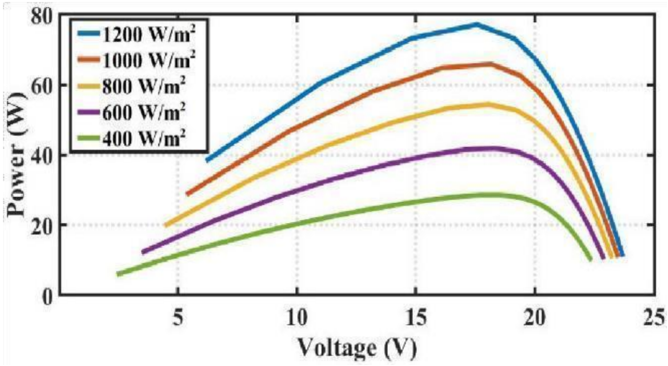

Figure 1 Voltage and Power Curves in Different Irradiance

Effect of irradiance on PV array performance at T=250C.

The power at the PV panel is

Ppv = VI (1)

where, V is the voltage across the terminals of the PV panel and I is the current through it. [9-10]

5. Solar Energy Conversion System

Table 1 Module Parameters

Parameter	Value
Maximum Power of Module, Pmax	200.13W
Open Circuit Voltage, Voc	32.9V
Voltage at MPP, Vmp	26.4V
Current at MPP, Imp	7.58A
Short Circuit Current, Isc	8.21A
Temperature coefficient of voltage, Kv	-0.1230V/K
Temperature coefficient of current, Ki	0.0032 A/K

6. Circuit Diagram Design

In the circuit the two existing configurations those are Honey comb and benzene reconfigurations are merged and form another new reconfiguration, and named it as a hybrid configuration, the parameter of the cell module is same for this new reconfiguration is same from the existing reconfiguration.

There are following blocks are used for this circuit diagram: [11]

- Solar PV module
- Diode
- Voltage measurement block
- Current measurement block
- Product block
- Scope
- To workshop block

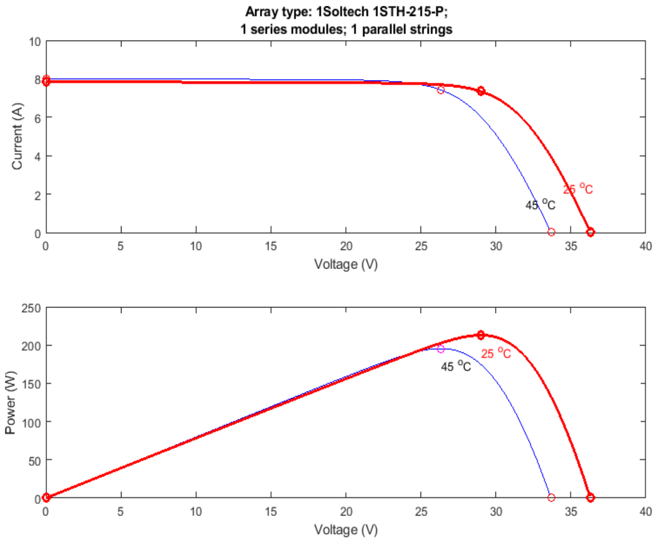

Figure 2 PV Curves

6.1. Solar PV Module

It will consist 2 inputs ports i.e. temperature, irradiance and 2 output ports anode and cathode. Input ports: One port is temperature block; It is constant for all the PV module because here the output values are taken at standard temperature as 250C.

The Other Port is Irradiance Block

It will vary based on the partial shading condition this partial shading condition irradiance values are shown below, for different PV module the irradiance will be changed based on the shading effect either it is row wise shading or column wise shading or diagonal wise shading. [13]

6.2. Diode

It will bock the flow of current in opposite direction and allow the flow of current in one direction.

6.3. Voltage Measurement Block

This block is used to measure the output voltage of circuit diagram

6.4. Current Measurement Block

This block is used to measure the output current of circuit diagram [14]

6.5. Product Block

This block is used to product the output current and output voltage of the circuit which is gives the result as a output power

6.6. Scope

Scope is used to plot the graphs or it will use to analyze the output paraments of the circuit diagram.

6.7. To Workshop Block

This block is used to read the circuit's voltage, current, power values to the MATLAB Simulink to the Workshop where we can analyze the characteristics of the circuit. [12]

Characteristics Analysis

By using the MATLAB Simulink software to design the all the configuration circuit diagram (TCT, BL, HC, BZ, Hybrid). And applying all the partial shading effects to each configuration and analyze the output maximum Voltage, maximum Current, maximum Power, comparing the all the output parameter with new proposed hybrid method is shown in table No.2 From this hybrid structure is the connections of the circuit diagram is changed hence the output parameter will also change, these output parameters are compared with already existing reconfiguration technique output parameter like maximum power, maximum voltage, maximum current the comparison values shown table No.2

7. Analysis of Partial Shading

This method introduces the 10 different types of partial shading effect shown below including row wise, column wise and diagonal wise

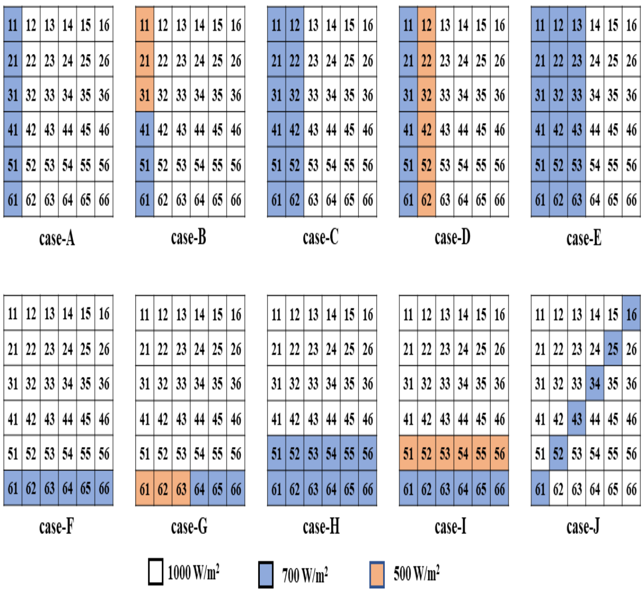

Figure 3 Analysis

8. Simulation Result

There is total 8 partial shading conditions are verified and observe the output PV characteristics of each shading condition. Analyses the output power, power of each condition. (Figure 4) [15-18]

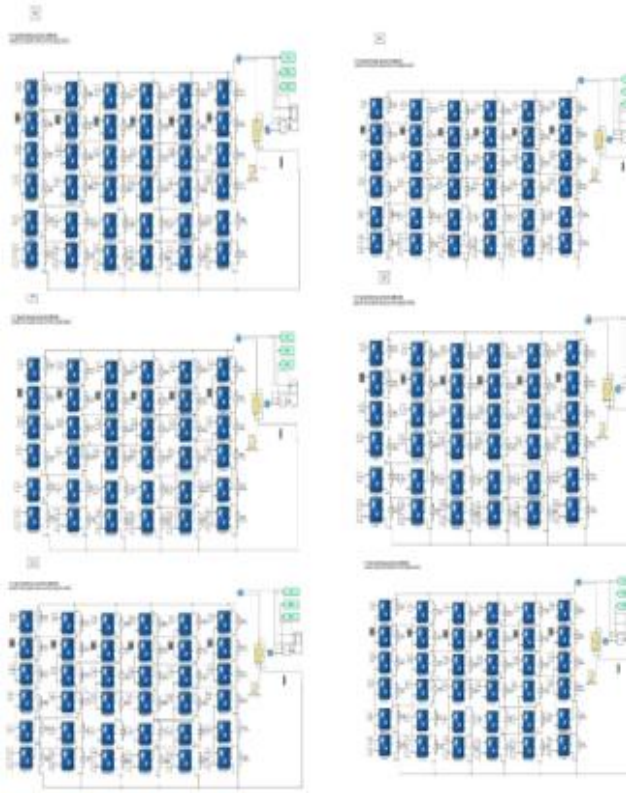

Figure 4 **Simulation Result**

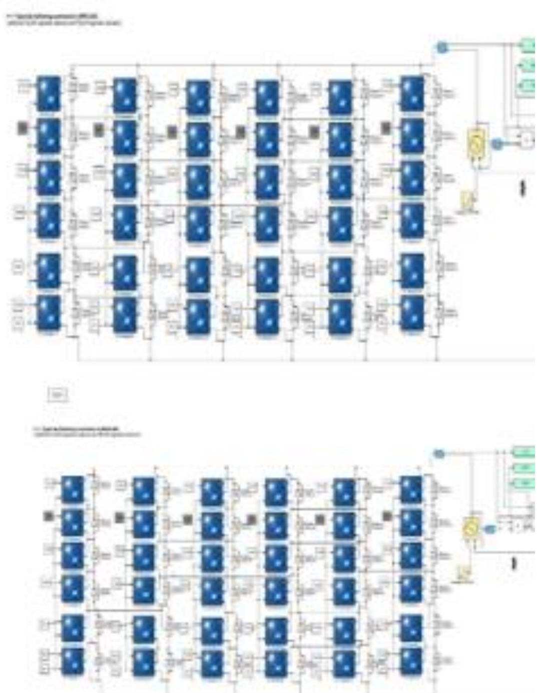

Figure 5 **Simulation Circuit Diagrams**

Hybrid Model Output Waveforms

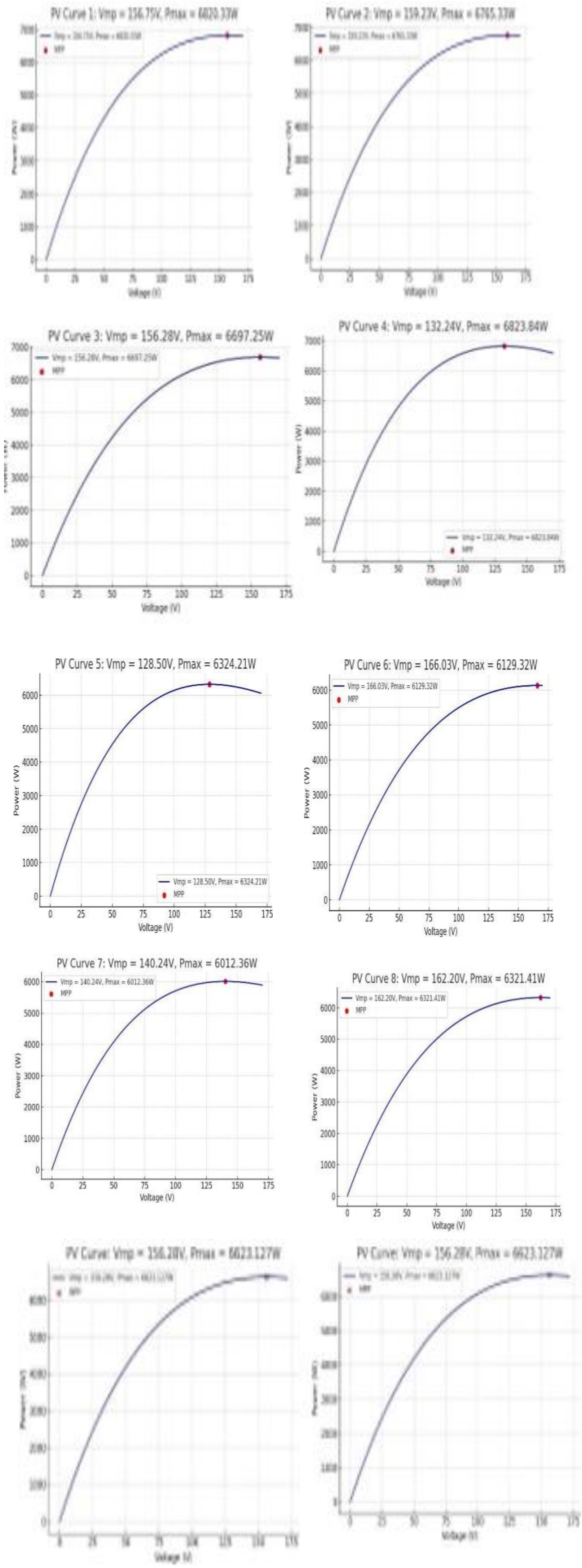

Figure 6 **Hybrid Model Output Waveforms**

Table 2 Global Maximum Power Point (GMPP)

Case	TCT	BL	HC	BZ	HYB
Uniform	7164.979	7164.979	7164.979	7164.979	7164.979
Case A	7164.979	6286.449	6675.57	6789.45	6820.33
Case B	6655.721	6797.324	6377.33	6639.801	6765.33
Case C	6422.623	6425.69	6507.856	6409.639	6697.25
Case D	6174.452	6173.194	6210.528	5644.938	6823.84
Case E	6063.182	6063.645	6039.063	6449.961	6324.21
Case F	5926.341	5925.63	6104.951	6027.031	6623.12
Case G	5926.341	4682.357	5432.195	5300.38	6129.32
Case H	5525.448	6311.674	5180.072	5687.418	6012.356
Case I	4837.51	5526.434	4720.505	6221.958	6321.41
Case J	6795.99	6311.674	6995.872	6712.706	6810.65

Table 3 %Mismatch Losses(%ML)

Case	TCT	BL	HC	BZ	HYB
Case A	5.145430	12.26144	6.830571	5.241173	4.81018
Case B	7.107599	5.13127	10.99303	7.329791	5.577811
Case C	10.36089	10.31809	9.171317	10.54211	6.527988
Case D	13.82456	13.84212	13.32105	21.21487	4.761200
Case E	15.37753	15.37107	15.71415	9.979345	11.73442
Case F	17.28739	17.29731	14.79457	15.88208	7.562604
Case G	17.28739	34.64939	24.18407	26.02378	14.45445
Case H	22.88256	11.90938	27.70290	20.62198	16.08689
Case I	32.48396	22.86880	34.11697	13.16153	11.77350
Case J	5.149896	11.90938	2.360188	6.312272	4.945290

Table 4 Fill Factor (FF)

Case	TCT	BL	HC	BZ	HYB
Case A	0.698927	0.646493	0.685477	0.698221	0.701349
Case B	0.684475	0.69903	0.65542	0.682831	0.69571
Case C	0.660495	0.660812	0.669263	0.659161	0.688790
Case D	0.634982	0.634849	0.638685	0.580520	0.701690
Case E	0.623535	0.623588	0.621052	0.663308	0.650461
Case F	0.609461	0.609388	0.627827	0.619814	0.680951
Case G	0.609461	0.481526	0.558642	0.545086	0.630279
Case H	0.579581	0.573151	0.532714	0.584889	0.618278
Case I	0.497486	0.355950	0.48542	0.639860	0.650023
Case J	0.698894	0.649080	0.719449	0.690328	0.700236

Table 5 Output Parameter Comparison Table

Column	Parameter	TCT	BL	HC	BZ	HYB
	Voltage(V)	157.86	157.86	157.86	157.86	157.86
Uniform	Current(A)	45.388	45.388	45.388	45.388	45.388
	Power(W)	7164.979	7164.979	7164.979	7164.979	7164.979
	Voltage(V)	157.213	156.321	156.321	157.236	156.7785
case A	Current(A)	43.23	40.215	42.64	43.18	43.5
	Power(W)	7164.979	6286.449	6675.57	6789.45	6820.33
	Voltage(V)	157.039	157.652	154.58	156.821	155.7005
Case B	Current(A)	42.383	43.116	41.23	42.34	43.45
	Power(W)	6655.721	6797.324	6377.33	6639.801	6765.33
	Voltage(V)	155.259	157.45	157.32	156.245	156.7825
case C	Current(A)	41.367	40.811	41.367	41.023	42.72
	Power(W)	6422.623	6425.69	6507.856	6409.639	6697.25
	Voltage(V)	155.014	158.483	158.23	160.231	159.2305
case D	Current(A)	39.832	38.952	39.25	35.23	42.851
	Power(W)	6174.452	6173.194	6210.528	5644.938	6823.84
	Voltage(V)	158.536	158.461	156.25	156.321	132.24
case E	Current(A)	38.245	38.266	38.65	41.261	47.83
	Power(W)	6063.182	6063.645	6039.063	6449.961	6324.21
	Voltage(V)	129.244	129.099	131.23	133.25	156.28
case F	Current(A)	45.854	45.9	46.521	45.231	42.37
	Power(W)	5926.341	5925.63	6104.951	6027.031	6623.12
	Voltage(V)	129.244	104.797	128.36	128.65	128.505
case G	Current(A)	45.854	44.68	42.32	41.2	47.693
	Power(W)	5926.341	4682.35	5432.	5300.	6129.32

			7	195	38	
	Voltage(V)	167.324	168.25	166.012	166.056	166.034
case H	Current(A)	33.682	33.125	31.203	34.25	36.21
	Power(W)	5525.448	6311.674	5180.072	5687.418	6012.356
	Voltage(V)	138.738	104.797	141.231	139.256	140.2435
case I	Current(A)	34.868	33.028	33.424	44.68	45.07
	Power(W)	4837.51	5526.434	4720.505	6221.958	6321.41
	Voltage(V)	158.533	128.932	165.145	159.25	162.1975
case J	Current(A)	42.868	48.953	42.362	42.152	41.98
	Power(W)	6795.99	6311.674	6995.872	6712.706	6810.65

Table 5: maximum voltage, Current, Power Values of a different configuration at various partial shading condition. [19]

Conclusion

The reconfiguration is playing a crucial role in the conversion of energy from solar irradiation. The proposed PV configuration is better performance compared to the other configuration like TCS, BL, HC, BZ the hybrid is better output power for some partial conditions and also it will decrease the power losses for increases the output power [20]

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