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Performance Evaluation of PV Panel Configurations Considering PSC's for PV Standalone Applications

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ABSTRACT

One of the major concerns for continuous solar photovoltaic (PV) generation is partial shading. The movement of clouds, shadow of buildings, trees, birds, litter and dust, etc., can lead to partial shadow conditions (PSCs). The PSCs have caused inconsistent power losses in the PV modules. This leads to a shortage of electricity production and the presence in the PV curve of several peaks. One of the simplest solutions to PSC's is the PV configurations. The objective of this paper is modelling and simulation of solar PV system in various shading scenarios for KC200GT 200 W, 5 x 5 configurations that includes Series/Parallel (SP), Total-Cross-Tied (TCT), Triple-Tied (TT), Bridge-Link (BL) configurations. Real time PSC's such as corner, center, frame, random, diagonal, right side end shading conditions are evaluated under all PV array configurations. A comparative analysis is carried out for the parameters such as open circuit voltage, short circuit current, maximum power point, panel mismatch losses, fill factor, efficiency under all PV configurations considering PSC's. From the comparison analysis best configuration will be presented.

1. INTRODUCTION

The need for electricity demand is increasing all over the world [1]. The best solution for ever-increasing electricity demand is through renewable energy sources (RES). Solar, wind, geothermal and biomass sources are some of the RES. Among the RES solar energy is popular. However, cost associated with installation and poor energy harnessing capabilities impact negatively. The uncertain non-linear power-voltage (P-V) and current-voltage (I-V) characteristic of PV panel are the key components of solar energy. The series and parallel connections of PV cells build a module. The performance and the reliability of the PV panel usually depends primarily on the occurrence of solar irradiance (G) and temperature (T) [2] insulation. Maximum power of PV module can be tracked using various techniques [3]. The major factors that affect maximum power point are partial shading conditions (PSC). PSC's not only come from passing clouds, but also from shades of birds, dust, surrounding buildings, and snow covering etc., [4]. All PV modules receive different insolation levels under PSC which lead to voltage and current differences between modules, thus creating hot spots in shaded PV modules. The diode is annexed as bypass diode [5] in order to avoid hot spot issues. Due to PSC's multiple maximum power point's will be created in P-V curve also called as local maximum power point. The best of local maximum power point's is called as global maximum power point. Due to the multiple maximum power points power losses increases, degrades the energy conversion efficiency etc.

Many researchers have recommended several methodologies to overcome PSC's, such as MPPT tracking methodologies, PV converter control strategies, PV panel reconfiguration strategies etc. Several MPPT techniques are discussed by Bollipo et al. [3] under PSC's. Conventional MPPT methods like P&O, IC and HC are not capable to track global maximum power point [6]. Intelligent based MPPT techniques shows the better performance than the conventional methods to track the global maximum power point [7-9]. Nevertheless, intelligent methods are complex in hardware implementation. Ali et al. [10] addressed the drawbacks of intelligent MPPT methods. Bingöl and Özkaya [11] reviewed and compared several PV panel configurations S, S-P, T-C-T, B-L, H-C, T-T. In this paper is modelling and simulation of solar PV system in various shading scenarios for KC200GT 200 W, 5 x 5 configurations that includes SP, TCT, TT, BL configurations. Real time PSC's such as corner, center, frame, random, diagonal, right side end shading conditions are evaluated under all PV array configurations. A comparative analysis is carried out for the parameters such as Maximum Voltage Vmp (V), Maximum Current Imp (A), Maximum Power Pmp (W), Open Circuit Voc (V), Short Circuit Current Isc (A), Fill Factor FF (%), PV Mismatch losses Pml (%), Efficiency η (%) under all PV configurations considering PSC's. From the comparison analysis best configuration will be presented.

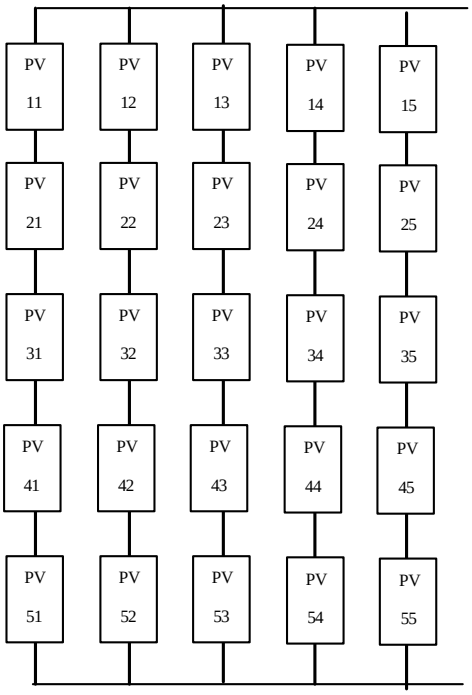
2. CASE SYSTEM

In this paper a 200 W, 5 X 5 KC200GT PV system is considered as test case. The specifications of KC200GT PV panel are tabulated in Table 1. The test case is implemented

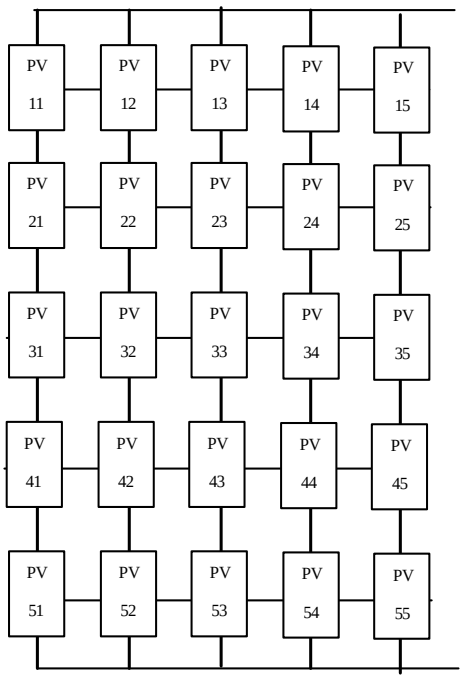
for SP, TCT, TT, BL configurations shown in Figure 1. PSC's such as corner, center, frame, random, diagonal, right side end shading conditions are evaluated under all PV panel configurations shown in Figure 2.

Table 1. PV panel specifications

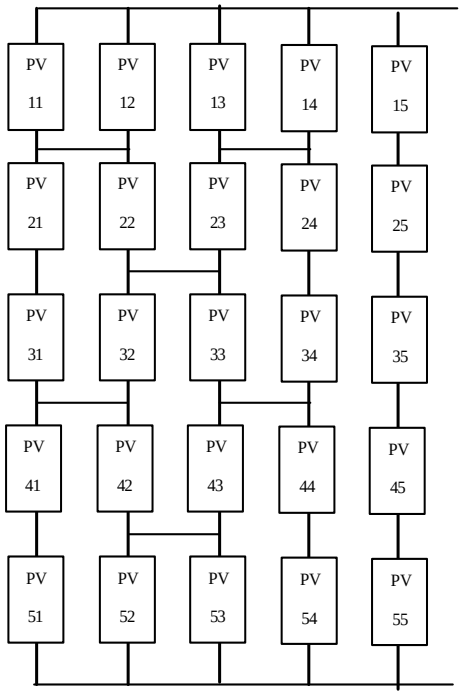
Name	Specification
Maximum Power P_{mp}	200.14 W
Maximum Voltage V_{mp}	26.3 V
Maximum Current I_{mp}	7.6 A
O. C. Voltage V_{oc}	32.9 V
S. C. Current I_{sc}	8.2 A
No.of Cells	54



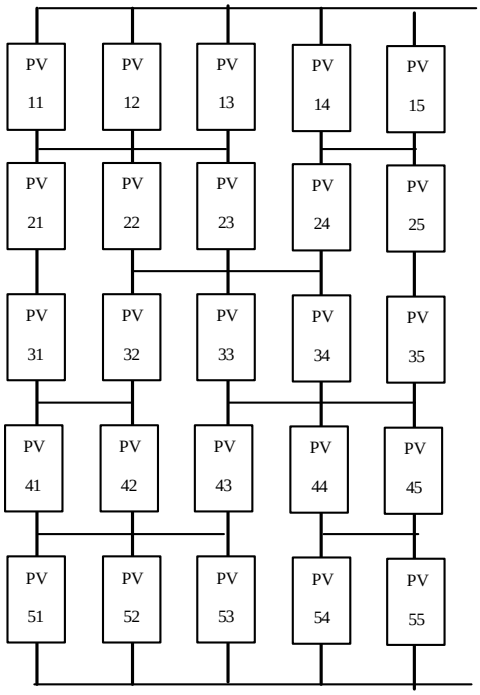
(a) SP PV panel configurations



(b) TCT PV panel configurations



(c) BL PV panel configurations



(d) TT PV panel configurations

Figure 1. PV panel configurations

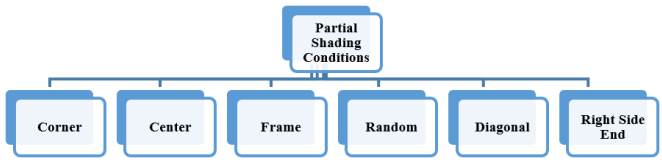


Figure 2. Partial Shading Conditions (PSC's)

3. RESULTS AND DISCUSSIONS

In this paper 200 W, 5 X 5 KC200GT PV system is

implemented under several PSC's considering SP, TCT, BL, TT configurations. The PSC's considered are shown below (Figure 3).

- Uniform (without PSC);
- Corner PSC;
- Center PSC;
- Frame PSC;
- Random PSC;
- Diagonal PSC;
- Right Side End PSC.

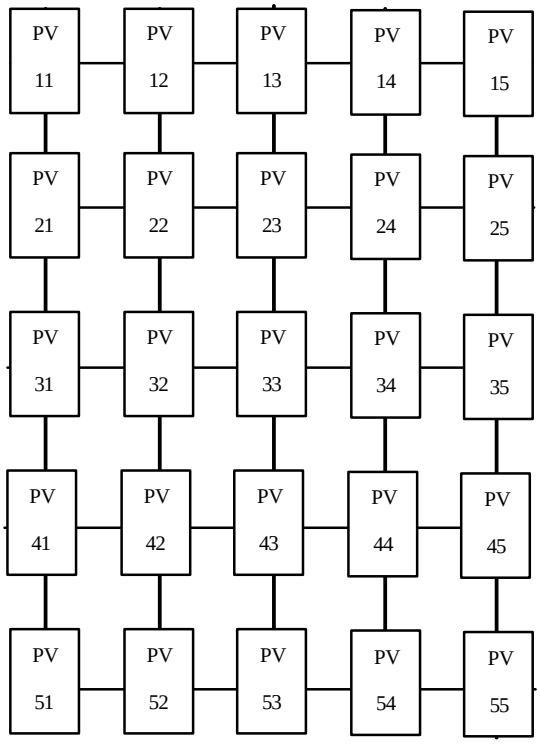


Figure 3. 5 X 5 PV configuration

3.1 Performance evaluation considering uniform (without PSC) condition

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Uniform (without PSC) condition. In Uniform (without PSC) condition solar irradiance is considered uniformly as 1000 W/m^2 and temperature as 25℃ for all 5 X 5 panels. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 2.

In the Uniform (without PSC) Condition for all configurations the Efficiency η (%) is same i.e. 14.155.

3.2 Performance evaluation considering corner PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Corner PSC. In Corner PSC, for 1 X 1, 1 X 2, 2 X 1, 2 X 2 panels, solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, 800 W/m^2 respectively, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25℃. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 3.

In the Corner PSC Condition TCT configuration recorded the maximum Efficiency η (%) i.e. 12.255%.

3.3 Performance evaluation considering center PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Center PSC. In Center PSC, for 2 X 1, 2 X 2, 2 X 3 panels, solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, respectively, similarly for 3 X 1, 3 X 2, 3 X 3 and 4 X 1, 4 X 2, 4 X 3 panels, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25℃. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 4.

Table 2. Performance evaluation considering uniform (without PSC) condition

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	131.505	38.051	5003.846	164.490	41.108	74.002	0.000	14.155
TCT	131.505	38.051	5003.846	164.490	41.108	74.002	0.000	14.155
BL	131.505	38.051	5003.846	164.490	41.108	74.002	0.000	14.155
TT	131.505	38.051	5003.846	164.490	41.108	74.002	0.000	14.155

Table 3. Performance evaluation considering corner PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	127.563	32.522	4148.526	162.685	41.095	62.053	20.618	11.735
TCT	141.665	30.583	4332.486	162.845	41.077	64.769	15.496	12.255
BL	125.960	31.744	3998.476	162.770	41.088	59.787	25.144	11.311
TT	140.235	30.014	4209.001	162.800	41.080	62.936	18.884	11.906

Table 4. Performance evaluation considering center PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	127.938	32.032	4098.083	162.285	41.083	61.467	22.102	11.592
TCT	143.440	30.534	4379.842	162.455	41.049	65.679	14.247	12.389
BL	139.050	29.814	4145.639	162.365	41.069	62.171	20.702	11.727
TT	142.125	30.053	4271.299	162.350	41.066	64.066	17.151	12.082

In the Center PSC Condition TCT configuration recorded the maximum Efficiency η (%) i.e. 12.389%.

3.4 Performance evaluation considering frame PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Frame PSC. In Frame PSC, for 1 X 1, 1 X 2, 1 X 3, 1 X 4, 1 X 5 panels, solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, 800 W/m^2, 1000 W/m^2 respectively, similarly for 1 X 1, 1 X 2, 1 X 3, 1 X 4, 1 X 5, 2 X 5, 3 X 5, 4 X 5, 5 X 5, 5 X 1, 5 X 2, 5 X 3, 5 X 4, 5 X 5 panels, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25°C. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 5.

In the Frame PSC Condition TCT configuration recorded the maximum Efficiency η (%) i.e. 11.648%.

3.5 Performance evaluation considering random PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Random PSC. In Random PSC, solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, 800 W/m^2, 1000 W/m^2 for random panels, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25°C. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 6.

In the Random PSC Condition TT configuration recorded the maximum Efficiency η (%) i.e. 12.703%.

3.6 Performance evaluation considering diagonal PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Diagonal PSC. In Diagonal PSC, for all diagonal panels solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, 800 W/m^2, 1000 W/m^2 respectively, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25°C. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 7.

In the Diagonal PSC Condition TT configuration recorded the maximum Efficiency η (%) i.e. 13.407%.

3.7 Performance evaluation considering right side end PSC

In this case performance of proposed PV system is evaluated considering SP, TCT, TT, BL configurations under Right Side End PSC. In Right Side End PSC, for 5 X 1, 5 X 2, 5 X 3, 5 X 4, 5 X 5 panels solar irradiance is considered as 200 W/m^2 400 W/m^2, 600 W/m^2, 800 W/m^2, 1000 W/m^2 respectively, for remaining panels solar irradiance is considered as 1000 W/m^2 and temperature as 25°C. Performance parameters such as V_{mp} (V), I_{mp} (A), P_{mp} (W), V_{oc} (V), I_{sc} (A), (%), P_{ml} (%), η (%) are evaluated and tabulated in Table 8.

In the Right Side End PSC Condition TCT configuration recorded the maximum Efficiency η (%) i.e. 13.098%.

Table 5. Performance evaluation considering frame PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	120.425	25.883	3116.914	158.072	32.808	60.103	60.539	8.817
TCT	143.918	28.612	4117.726	159.071	28.712	90.159	21.520	11.648
BL	143.577	22.325	3205.287	158.840	32.849	61.431	56.112	9.067
TT	141.885	26.808	3803.669	158.915	31.118	76.918	31.553	10.760

Table 6. Performance evaluation considering random PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	111.000	35.308	3919.167	161.947	41.097	58.886	27.676	11.086
TCT	142.775	30.367	4335.593	162.470	37.684	70.814	15.413	12.264
BL	142.815	27.707	3957.034	162.320	41.075	59.350	26.455	11.193
TT	143.205	31.358	4490.610	162.305	41.014	67.460	11.429	12.703

Table 7. Performance evaluation considering diagonal PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	110.550	38.017	4202.770	162.510	41.100	62.924	19.061	11.889
TCT	145.905	32.484	4739.624	162.875	36.864	78.939	5.575	13.407
BL	116.290	36.784	4277.566	162.665	38.561	68.196	16.979	12.100
TT	135.960	34.066	4631.656	162.860	36.925	77.020	8.036	13.102

Table 8. Performance evaluation considering right side end PSC

Configuration Type	V_{mp} (V)	I_{mp} (A)	P_{mp} (W)	V_{oc} (V)	I_{sc} (A)	FF (%)	ΔP_{ml} (%)	η (%)
SP	124.000	34.156	4235.358	161.822	36.124	72.454	18.145	11.981
TCT	140.675	32.915	4630.376	161.900	36.043	79.351	8.066	13.098
BL	137.754	31.518	4341.705	161.873	36.142	74.212	15.251	12.282
TT	138.765	32.116	4456.509	161.885	36.105	76.247	12.282	12.606

4. COMPARISON ANALYSIS

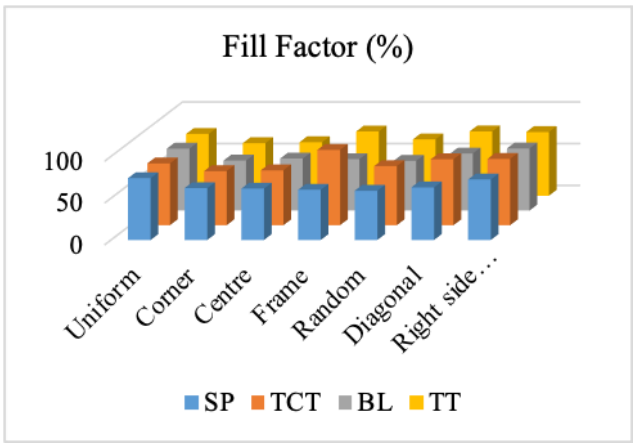


Figure 4. Fill Factor comparison

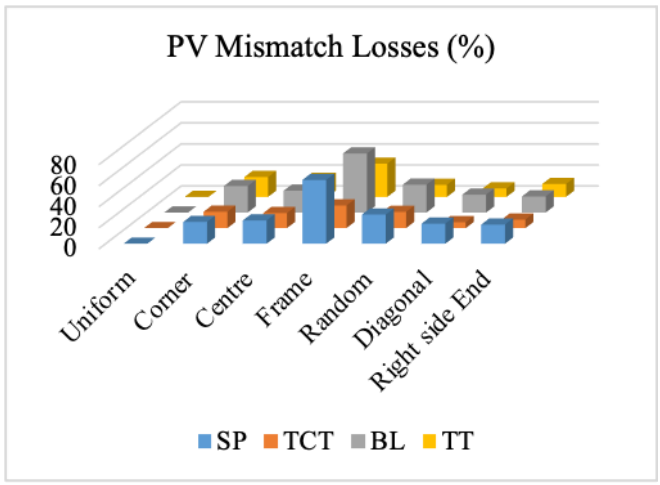


Figure 5. PV Mismatch losses comparison

Performance evaluation parameters Fill Factor FF (%), PV Mismatch losses P_{ml} (%), Efficiency η (%), Maximum Power P_{mp} (W) are compared for all configurations under proposed PSC's and shown in Figure 4, Figure 5, Figure 6, Figure 7 respectively.

In all the configurations TCT configuration exhibits best performance under all PSC's shown in Table 9.

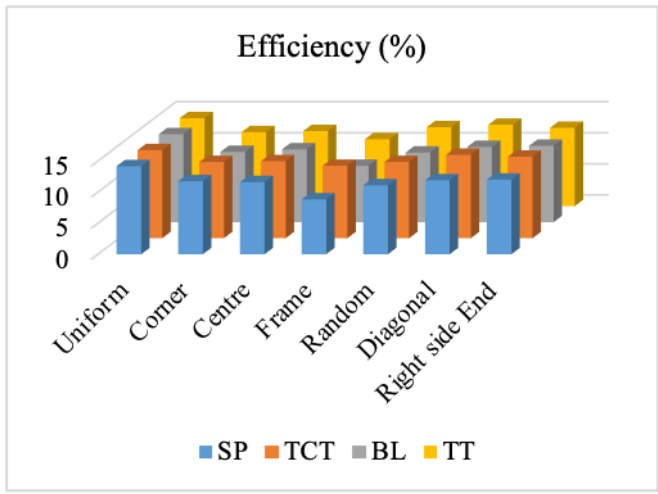


Figure 6. Efficiency comparison

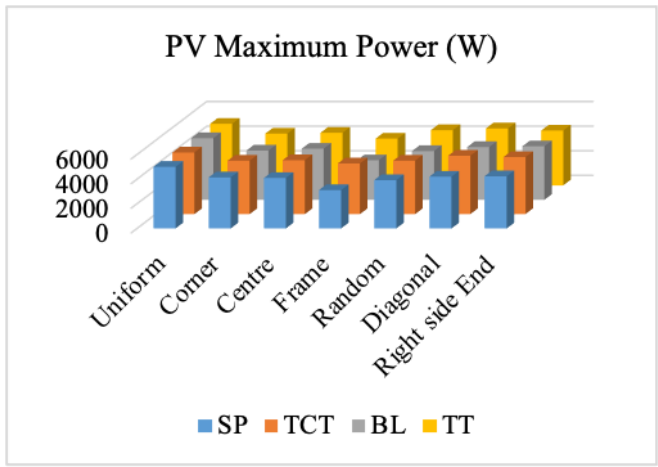


Figure 7. PV Maximum power

Table 9. Performance of TCT Configuration

Confg.\PSC	Uniform	Corner	Centre	Frame	Random	Diagonal	Right side End
Fill Factor (%)	74.00	64.77	65.68	90.16	70.81	78.94	79.35
PV Mismatch Losses (%)	0.00	15.50	14.25	21.52	15.41	5.57	8.07
Efficiency (%)	14.15	12.26	12.39	11.65	12.26	13.41	13.10
Maximum Power (%)	5003.85	4332.49	4379.84	4117.73	4335.59	4739.62	4630.38

5. CONCLUSIONS

In this paper modelling and simulation of solar PV system in various shading scenarios for KC200GT 200 W, 5 x 5 configurations that includes Series-Parallel (SP), Total Cross-Tied (TCT), Triple-Tied (TT), Bridge-Link (BL) configurations are presented and implemented in MATLAB/Simulink environment. Real time PSC's such as corner, center, frame, random, diagonal, right side end shading conditions are evaluated under all PV array configurations. A comparative analysis is carried out for the parameters such as open circuit voltage, short circuit current, maximum power point, panel mismatch losses, fill factor, efficiency under all PV configurations considering PSC's. It is observed from the comparison analysis, TCT configuration exhibits best performance under all PSC's. Hence this paper proposes TCT configuration for grid connected and standalone applications.

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