Shade Dispersion using TCT Configuration of PV Array System under Non-uniform Irradiation: Experimental Study

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Abstract: An experimental analysis to evaluate the depletion of solar photovoltaic (PV) system under the weather.exploring the effects of blurring on the PV system under varying degrees of solar radiation In the present study, four panels of PV solar modules (20W, Manf: Usha Solar)subject to parallel (SP) weather forecast and cross-sectional rate-arrested (TCT). The test set contains an electrical performance ratingdevices with a flexible load to test the performance of the PV system under artificial lighting fixtures. In addition, performance similarities were performed over PV modules programmed into the SP and TCT modified PV modules under the shading I-II test case. The abnormal behavior of current-voltage (V-V) and power-voltage (P-V) curves in the presence ofmultiple power points such as ground mass points (GMPPT) and local maximum power points (LMPP) help to obtain a comprehensive analysis. In addition, performance indicator parameters suchas GMPP power, low power loss and fill factor (FF) were tested in both PV power assumption under separating shadow cases.

1 INTRODUCTION

The usage of electrical power is on the rise gradually as a result of transportation and communication systems etc. A very big part of energy generation is based on fossil fuels such as diesel, petrol and gas etc. It is well known that due to scarcity and limited storage capacity of fossil fuels, the researchers are doing extensive work toward searching of some more alternative energy sources. Today, renewable energy sources like PV, wind turbine and bio-fuel etc. are gaining popularity due to advantageous features. Especially, solar PV system is more acceptable in society because no advanced skills are required to use it. As the solar PV system is eco- friendly in nature and it is the most useful system for power generation in current scenarios in domestic and commercial areas. The variation of sun irradiation potential and/or non-uniform nature with respect to time is a major concern about the PV system performance reduction. Now-a-days, various researchers are exploring the solution to enhance the PV system performance under the influence of prevailing geographical conditions. The major effect of shading effect is observed in rural and urban areas due to various causes such as high-rise commercial buildings such as malls, hospitals, corporate offices. All these shadow test cases have major causes of partial shading conditions (PSCs), which are responsible to reduce the PV system performance directly. Various advanced methods are available to reduce the impact of shading out of which one of the most suitable methods available in present scenario is reconfiguration of PV modules in PV array schemes as are reported in the recent available literature from the year of spam 2013-2020.

In fact, different levels of irradiation occur during PSCs throughout the PV array system. As a result of this inconsistent radiation exposure to the PV list, it appears that many peaks of high-power points such as local and global power point (LMPP& GMPP) in the indirect environment of PV and IV signals. Comprehensive comparative studies of various configurations were conducted to determine the optimal setting on the basis of performance measurement tests. Typically, the demand for loading power is fulfilled by installing solar modules in a series of interlocking modes.Because of the dimming of one or more panels, the PV array output power decreases. The authors have prepared a complete

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cross-tied (TCT) connection of the modules in the PV series. Basically, several experiments were performed to compare the results obtained such as power loss, FF position and GMPP preparation for both under four types of blurring cases such as short narrow (SN), short wide (SW), narrow wide (NW) and long length (LW).). Local and GMPPs were identified in the experimental study and validated with the MATLAB / Simulink model under sham conditions (Rani, et al., 2013). The authors reviewed the experimental studies with the MATLAB / Simulink that attempted to achieve MPP during the series PV modules (SP), TCT and bridge-link (BL), and it is evident that the TCT suspension is more favorable than the other two (Koray , 2014). The authors conducted a study on the series and similar connections of the PV array under three dimming conditions. With the corresponding link developed by FF, a relatively different loss (MML) and a small number of GMPPs were obtained (Vijaylekshmy, et al., 2014). The authors have learned ways to enhance PSC the effects of name distribution on the TCT PV panel link and compare results with the Su-Do-Ku puzzle connection based on increased power, improved FF and low power coal (Bai, et al., 2015). The authors have proposed various ways to install PV such as series-parallel (SP), TCT, honey-comb (HC), bridge-link (BL) and proposed a new suspension of the list. 6×6 PV size for test research under PSCs and that 'new' suspension has a better response than others (Malathy and Ramaprabha, 2015). The authors see the passing of clouds because of the shadow on the PV list to study in the preparation of SP, HC, BL, TCT and Su-Do-Ku. Under the contrast pattern of standard TCT and Su-Do-Ku redesigned TCT (RTCT) suspension puzzle shows better results (Vijaylekshmy, et al., 2015a). The authors investigated TCT suspension, hybrid SP-TCT and Su-Do-Ku found that Su-Do-Ku suspension connections to PV panels show better results in features of high FF, low power loss and a small number of -MPP (smooth PV curve) (Vijaylekshmy, et al., 2015b). The authors converted the standard TCT suspension into a Magic Square (MS) puzzle for various shading conditions such as SW, LW, SN and LN and found that MS suspensions have the best effects on all shading situations (Samikannu, et al., 2016). A good connection of the PV panel to a particular compound being investigated and the juxtaposition and regular SP and TCT connection of the panels under partial blurring results and shows better performance of the good connection of the PV panels proposed by the authors (Bana and Sign, 2017). The authors investigated the configuration of SP, BL and TCT and compared the shadow dispersion scheme (SDS) for electrical connection of PV array under LN and SW shadow connection and found that SDS had the best results among all configurations (Satpathy, et al., 2017). The authors performed a performance evaluation of the PV system to assess the impacts of the model and verified it with MATLAB / Simulink modeling to ensure the reliability of a given model (Lamri, et al., 2018).

The scheme of this studyis divided into as. Section I description of thethe paper. The notable points of study are given in Section II. Section III briefs the novelty of work done in paper. In section IV, results and discussion is summarized and section V concludes in the paper.

1.1 Novelty of Work

In this paper, hypothetical investigation is performed to estimate I–V and P–V bends of 2x2 size PV system by showing PSCs impact.The important points of present study are summarized as,

- In order to study the experimental comparison of SP-TCT configuration, two type of shading cases used.
- Experimental results are useful for estimating the performances of PV systems under PSCs.

2 PV SYSTEM TECHNOLOGY AND EXPERIMENTAL SETUP

Lower conversion efficiency of solar PV system from sun light intensity into electrical energy forces to add more PV module systems in series and parallel for providing power assistance to load.The technical balancing circuit of PV module as given in Fig. 1 as,

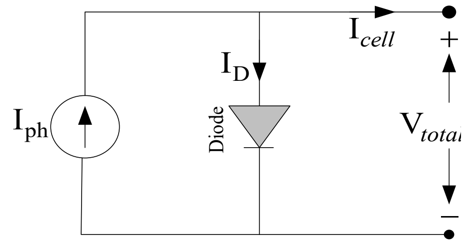


Figure 1: Illustrative diagram of PV system

The deliberated current of solar cell (I_{cell}) is given in Eq. (1) and (2) as,

$$I_{cell} = I_{ph} - I_D \tag{1}$$

$$I_{cell} = I_{ph} - I_o\left(\exp^{\left(\frac{qV_C}{AkT_C}\right)} - 1\right) \quad (2)$$

Where, I_{ph} : cell photocurrent (A), I_D : diode current (A), I_o : Reverse saturation current (A), q : charge of electron (Coulomb), V_C : cell voltage (V), A : ideality factor, k : Boltzmann's constant (J/K), T_C : cell temperature (°C).

The installed experimental setup is mainly divided into two section i.e. solar PV array and performance measurement system. In first section PV array comprised with 2×2 PV modules integrated in SP and TCT connections. Second section headed with performance measurement system. Two multimeters are used with resistive load to measure the real time voltage and current for analysis the performance. Performance index of installed system is done to show the impact on voltage and current by observation of I-V and P-V curves. The specification along with utility of all the auxiliary parts to comprise the experimental set up are given in table-1 with the experimental setup, shown in Fig. 2 as,

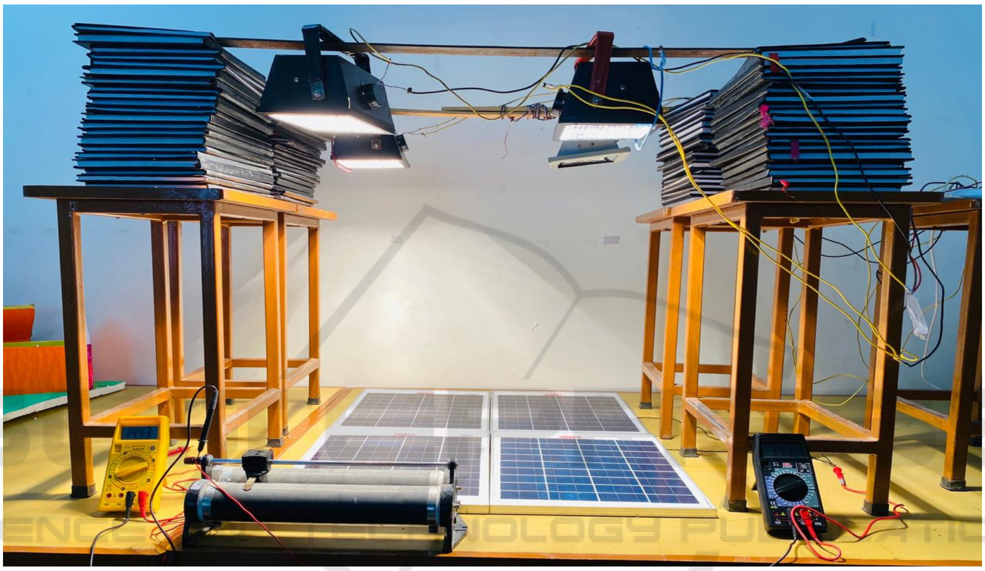


Figure 2: Experimental system for study

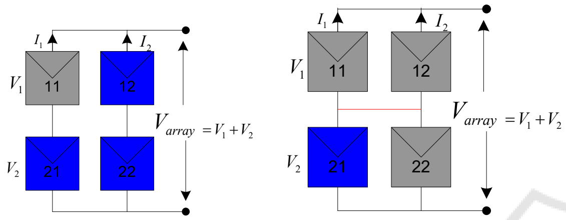
Table 1: Provision and role of supportive parts of Laboratory setup

Segment	Parts	Provision	Role
• Solar PV array(2x2)	• PV array system	• Power: 20 W • O. C. voltage: 21.997 V • S. C. current: 1.2586 A • Impp: 1.12A, Vmpp: 18V • PV module no.: 4 (2x2 array) • Cell technology: Poly-Si • Dimension (mm): 356×490×25 • Manf.: USHA SHRIRAM Technologies (Model NO: US 20/12V)	• 2x2 size PV array is used to design SP, TCT configurations for performance investigation is carried out shadow test cases.
	• Artificial solar lamp	• Total number of lamps- 4(2x2) • Light intensity 50- 650W/m2	• Solar lamp for light intensity to perform study
• Performance measurement system	• Multi-meter used as ammeter	• Number of ammeter: 1 • Measurement range: 0.01 to 10A DC • Mastech Technology	• Measurement of voltage ofSP,TCTconfigurations under different test cases.
	• Multi-meter used as voltmeter	• No. of voltmeter: 1 • Measurement range: 0.1 to 250V DC • Mastech Technology	• Measurement of current of SP, TCT configurations under different test cases.
	Decade resistive load	• Number of resistive load:2 • Range: 0.1 to 250 ohm	• Variable load (decade resistive box) is used to characterize the solar PV system from 0 Ω to maximum required load accordingly.

3 PV ARRAY CONFIGURATIONS AND SHADING ANALYSIS

The technical arrangement of PV modules are shown primarily in SP to achieve maximum current and voltage values. But due to climatic challenges TCT configuration is introduced for performance investigation under shading cases.

The TCT is modify version of SP configuration after addition of cross-tied between two parallel connected strings. The schematic sketch of both configurations i.e. SP and TCT are shown in Fig. 3 as,



(a) SP (b) TCT

Figure 3: Schematic diagram of PV array configuration with shading patterns

Two shadow test cases are taken for performance analysis such as (i) 3 PV modules- 12, 21, 22 are shaded (ii) Single PV module-21 shaded. The present study briefly reflects the impact of these considered shadow conditions.

In shading case- 1, as the three PV modules at locations 12,21 and 22 receive the low irradiation as 75W/m^2 and treated as shaded but one PV module at location 11 receives normal sun irradiation as 266 W/m^2 and treated as non- shaded.

The 2x2 size of SP configuration based PV system generated current for shadow cases-(a) and (b) is obtained as,

(a) Current generated for shadow case-(a)

$$\left.\begin{aligned} I_{R1} &= \left(\frac{S}{S_{STC}}\right) I_m + \left(\frac{S}{S_{STC}}\right) I_m = \left(\frac{75}{1000}\right) \times I_m + \left(\frac{266}{1000}\right) I_m = 0.341 I_m \\ I_{R2} &= \left(\frac{266}{1000}\right) \times I_m + \left(\frac{266}{1000}\right) I_m = 0.532 I_m \end{aligned}\right\} \quad (3)$$

(b) Current generated for shadow case-(b)

$$\left.\begin{aligned} I_{R1} &= \left(\frac{S}{S_{STC}}\right) I_m + \left(\frac{S}{S_{STC}}\right) I_m = \left(\frac{75}{1000}\right) \times I_m + \left(\frac{75}{1000}\right) I_m = 0.15 I_m \\ I_{R2} &= \left(\frac{266}{1000}\right) \times I_m + \left(\frac{266}{1000}\right) I_m = 0.532 I_m \end{aligned}\right\} \quad (4)$$

The theoretical values of the voltage and power of the PV array such as SP and TCT adjustment can be similarly tested under similar shading test cases 3 (a) - (b).

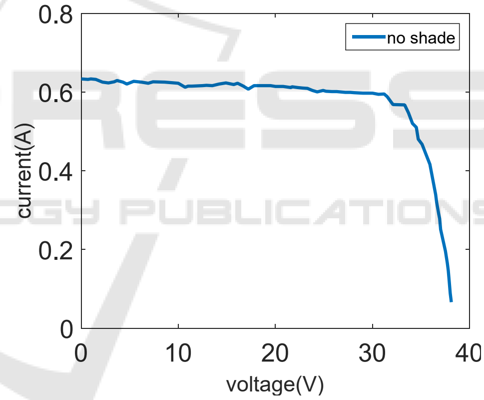
4 RESULTS AND DISCUSSION

The combination of the two configurations as mentioned above in the PV array is configured. In this unusual situation, the features of the V and P-V curve are drawn in the tests. Results are summarized as:

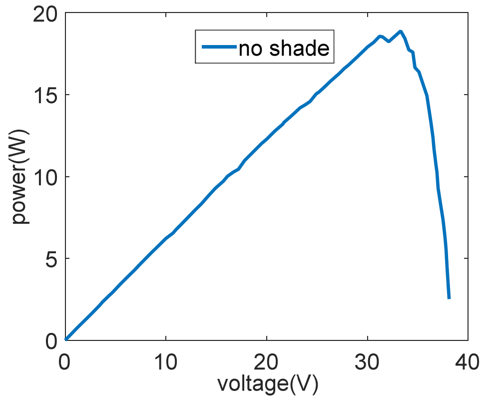
- P-V and I-V curve of SP and TCT PV under under uniform conditions.
- Impact on SP and TCT configuration due to shading pattern-1
- Impact on SP and TCT configuration due to shading pattern-2

4.1 P-V and I-V Characteristics of SP and TCT Array at No Shade

The complete PV and IV feature of the SP and TCT fixed PV under the uniform distribution of light intensity of 266 W / m2 is from Fig. 4 (a) - (b). It is evident that the IV and P-V curve is smooth (no GMPP and LMPP).,



(a) I-V curve



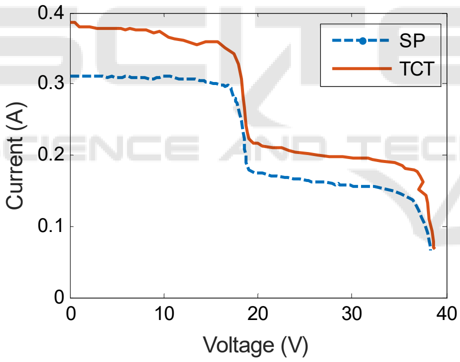
(b) P-curve

Figure 4: Performance characteristics of SP and TCT configurations under ideal conditions

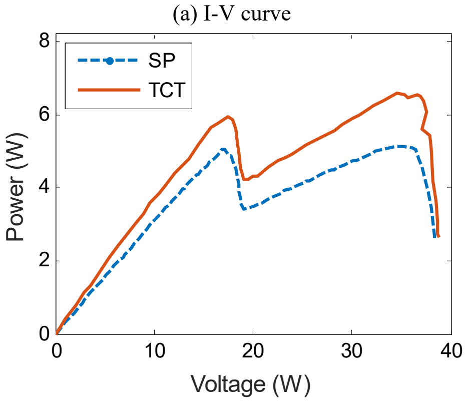
4.2 Effect of Shadow Pattern-1

The condition of PSC's is, when in PV array one or more than one panel is under the shadow due to which it cannot receive the full solar irradiation. PSCs may be due to the cloudy weather and may be due to the shadow of tree and buildings over the panel, PSCs decrease the output efficiency of the panel and shows dark zone and hike in the graphical figure of the I-V and P-V curve.

Under this analysis, three panels are shaded and one panel remains under full solar irradiation. The shaded panel receives 75W/m^2 and the non-shaded panel receives 266W/m^2 which create disturbance in the operating performance of the panels which can be easily observed in the graphical curve of Fig.6. Under this case of shading, the V_{oc} for SP is 38.3V and 38.7V for TCT configuration. The I_{sc} is 0.31A and 0.38A for SP and TCT respectively, under this case the V_m are 35.2V and 34.6V for SP and TCT whereas the power at GMPP for SP is 5.13 W and 7.57 W for TCT. The obtained FF for SP is 0.80 and for TCT it is 0.42, misleading power is 0.10 for SP and 0.02 for TCT and the PL is 12.14 and 11.31 for SP and TCT respectively



(a) I-V curve



(b) P-V curve

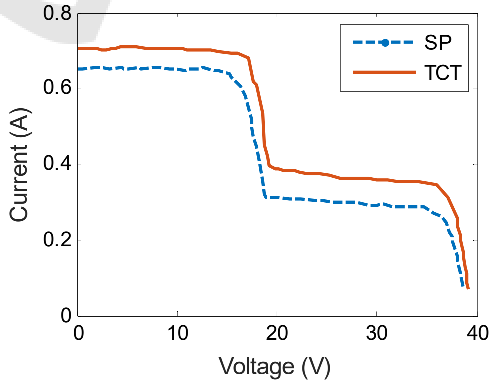
Figure 5: Performance characteristics of SP and TCT configurationsunder shading test case- 1

Table 2: Performance parameters of SP and TCT configurations under shade pattern-1

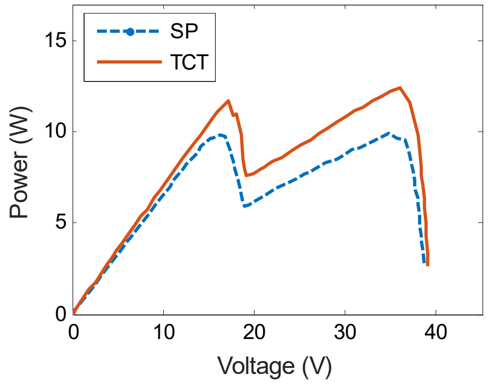
Parameters	SP	TCT
O. C. Voltage (V)	38.3	38.7
S.C current (A)	0.31	0.38
Max voltage (V)	35.2	34.6
Max current (A)	0.14	0.18
Power at GMPP (W)	5.13	7.57
Misleading Power (W)	0.10	0.02
Power loss (W)	12.14	11.31
Fill Factor	0.80	0.42

4.3 Effect of Shadow Pattern-2

In this study, three panels remain to normal irradiation and one panel is shaded, hence the output of the 2×2 array shows peaks in the graph which indicate that non- shaded part ofmodulesabsorbe 266 W/m^2 irradiation whereas the shaded panel receives the 75 W/m^2 as given in Fig. 6. The generated power decreases and power loss increases due to the shaded panles.The open-circuit voltage(V_{oc}) for SP is found 38.6V and for TCT 39.1V. Moreover, the short circuit current(I_{sc}) is observed as 0.65A and 0.70A for SP and TCT configurations respectively. The maximum voltage(V_m) generated under this case is found 36.5V for SP and 36V for TCT configurations. The maximum current(I_m) for SP observed is 0.27A and for TCT is 0.34A. The power at GMPP is found 9.89W and 12.46W for SP and TCT configurations. Improved FF is observed 0.39 for SP and 0.44 for TCT configurations. In case of misleading power, it is 0.29W for SP and 0.8W for TCT configurations. The power loss (PL) is 7.38W for SP and 6.42W for TCT.



(a) I-V curve



(b) P-V curve

Figure 6: Performance characteristic of SP and TCT configuration undershading test case-2

Table 3: Performance parameters of SP and TCT configurations under shade pattern-2

Parameters	SP	TCT
O. C. voltage (V)	38.6	39.1
S.C current (A)	0.65	0.70
Max voltage (V)	36.5	36
Max current (A)	0.27	0.34
Power at GMPP(W)	9.89	12.46
Misleading Power(W)	0.29	0.8
Power loss	7.38	6.42
Fill Factor(W)	0.39	0.44

5 CONCLUSIONS

Under this experimental study, a comprehensive assessment of the PSC impact was presented on the PV modules compiled by SP and TCT. Extended experiments were completed using transparent part-dimensional shading patterns, one shading-1 single-panel case with a transparent and shaded case-2 three-dimensional panels and one panel are not black. The results obtained indicate that the blurring in part greatly affects the display of PV modules under experimental studies.

- With the above mentioned partial shading condition, TCT designed PV module supposedly has ideal execution over the SP arrangement.
- The decreases in power are seen in SP and TCT configured PV modules but TCT has better execution when contrasted with SP setup.
- The decreases in power for SP and TCT arranged PV module are accounted for to be 7.38Wand 6.42W (shading pattern-1); 12.14W and 11.31W (shading method-II) respectively.
- The determined FF factor for SP and TCT configurations under shading pattern-1 are found to be as 0.39 and 0.44 respectively. Overall, TCT has best performance.
- On the basis of above discussion, it is found that TCT arrangement is better than SP arrangement of panels under above discussed shading effects-1 and 2.

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