Experimental Analysis of Shading Effect on PV Array for Different Array Configuration.

A Project and Thesis Submitted in Partial Fulfillment of the Requirements for the Award of Degree of
Bachelor of Science in Electrical and Electronic Engineering

Submitted by

Md.Forhad Hossen ID: 172-33-504
Md.Arafat Hosen ID: 172-33-487

Supervised by

MR. FARHAN SADIK SIUM
Lecturer
Department of EEE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
DAFFODIL INTERNATIONAL UNIVERSITY

Certification

This is to certify that this project and thesis entitled "**Experimental Analysis of Shading Effect on PV Array for Different Array Configuration"** is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering of Daffodil international university in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering.

The project and thesis entitled "**Experimental Analysis of Shading Effect on PV Array for Different Array Configuration."** submitted by **Md. Forhad Hossen; ID:172-33-504, Md. Arafat Hosen ID :172-33-487** ; Session: spring 2021 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering on31 january 2021.

Dedicated to. . .

Our Parents

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ABSTRACT

It is a well-documented fact that partial shading of a photovoltaic array reduces it output power capability. However, the relative amount of such degradation in energy production cannot be determined in a straight forward manner, as it is often not proportional to the shaded area. This paper clarifies the mechanism of partial PV shading on a number of PV cells connected in different configuration. The analysis is presented in simple terms and can be useful to someone who wishes to configure PV array in any areas where shades effect on PV power. First we collect some small PV cell and measure their power. Then made arrangements with all required components including halogen lights, data logger, aluminum frames etc. We chose five PV array configuration. Those are SP, TCT, BL, HC, HC-TCT. And we choose four shading patterns and named them as shading pattern 1, shading pattern 2, shading pattern 3 and shading pattern 4. We applied all those shading patterns on all five configurations. Then measured power of those configurations. We got best power without shading at BL, for shading pattern 1 HC provided best power. For shading pattern 2 HC-TCT is best. And for shading pattern 1 & 2 BL provides best power.

CHAPTER 1

INTRODUCTION

1.1 Solar Cell

Photovoltaic modules, commonly called solar modules, are the key components used to convert sunlight into electricity. Solar modules are made of semiconductors that are very similar to those used to create integrated circuits for electronic equipment. The most common type of semiconductor currently in use is made of silicon crystal. Silicon crystals are laminated into n-type and p-type layers, stacked on top of each other. Light striking the crystals induces the "photovoltaic effect," which generates electricity. The electricity produced is called direct current (DC) and can be used immediately or stored in a battery. For systems installed on homes served by a utility grid, a device called an inverter changes the electricity into alternating current (AC), the standard power used in residential homes.

High purity silicon crystals are used to manufacture solar cells. The crystals are processed into solar cells using the melt and cast method. The cube-shaped casting is then cut into ingots, and then sliced into very thin wafers.

1.2 Operating Principle of Solar Cell

Solar cell, also called photovoltaic cell, any device that directly converts the energy of light into electrical energy through the photovoltaic effect. The overwhelming majority of solar cells are fabricated from silicon—with increasing efficiency and lowering cost as the materials range from amorphous(no crystalline) to polycrystalline to crystalline (single crystal) silicon forms. Unlike batteries or fuel cells, solar cells do not utilize chemical reactions or require fuel to produce electric power, and, unlike electric generators, they do not have any moving parts. A solar cell is basically a p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms: in the case of the n-layer, atoms with one more valence electron, called donors, and in the case of the p-layer, with one less valence electron, known as acceptors. When the two layers are joined together, near the interface the free electrons of the n layer are diffused in the p-side, leaving behind an area positively charged by the donors.

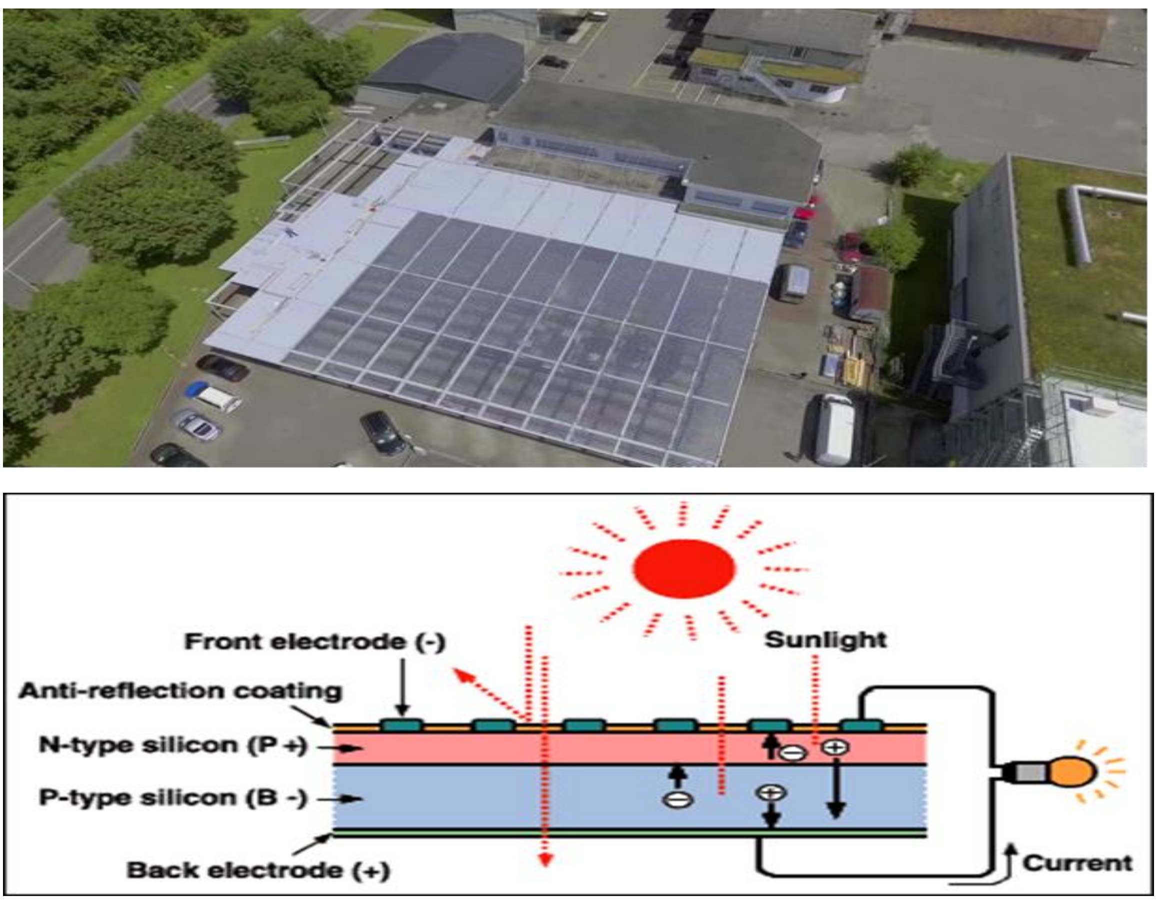


Fig: 1.1:- Photo voltaic Array

1.3 Shading effect:

Shading can have a huge impact on the performance of solar photovoltaic panels. It is obvious that the best solution is to avoid shading altogether, though this isn't possible in practice due to factors like cloud, rain etc. but what many people don't realize is that even if a small section of the solar photovoltaic panel is in shade, the performance of the whole solar photovoltaic panel will significantly reduce. This is because solar photovoltaic panels actually consist of a number of solar photovoltaic cells that are wired together into a series circuit. This means that when the power output of a single cell is significantly reduced, the power output for the whole system in series is reduced to the level of current passing through the weakest cell. Therefore, a small amount of shading can significantly reduce the performance of your entire solar photovoltaic panels system. One of the main causes of losses in energy generation within photovoltaic systems is the partial shading on photovoltaic (PV modules). These PV modules are composed of photovoltaic cells (PV cells) serial or parallel connected, with diodes included in different configurations. The curve of a PV cell varies depending on the radiation received and its temperature. Furthermore, the modules have diodes that allow the current flows through an alternative path, when enough cells are shaded or damaged. There are two typical configurations of bypass diodesoverlapped .and no-overlapped .It should be noted that the analysis in modules with overlapped diodes is a more complex one, because there may be different paths for current flow. This paper examines the individual behaviour of a PV module and a photovoltaic array of PV modules (PV array) connected to an inverter with shadows in both cases. The impact of partial shading on PV system has been studied at great length in the past,Some past studies assume that the decrease in power production is proportional to the shaded area and reduction in solar irradiance, thus introducing the concept of shading factor. While this concept is true for a single cell, the decrease in power at the module or array level is often far from linearity with the shaded portion. Other past studies tend to be rather complicated and difficult to follow by someone with limited knowledge on electronic/solid-state physics. The specific objective of this work is to clarify the impact of shading on a solar panel performance in relatively simple terms that can be followed by a power engineer or PV system designer without difficulty. First, the circuit model of a PV cell and its I-V curve are reviewed. This is followed by the impact of partial shading on the I-V and P-V curves of a circuit containing two cells with and without bypass diodes and more.

1.4 Various Array Configuration

1.4.1 Random Configuration:

We are analysis to have 4*10 solar cell array configuration, after that we are check measure their current capacity, then tis is marked, when this is are connected to the solar cell with randomly, that should it's called Random connection.

1.4.2 Vm Configuration:

We are analysis to have 4*10 solar cell array configuration, after that we are check measure their current capacity, then tis is marked, when this is are connected to the solar cell with voltage basis, that should it's called Vm connection.

1.4.3 Im Configuration:

We are analysis to have 4*10 solar cell array configuration, after that we are check measure their current capacity, then tis is marked, when this is are connected to the solar cell with Current basis, that should it's called Im connection.

1.5Configuration connection

- SP [Series-parallel] array configuration
- TCT [Total Cross Tied] array configuration
- BL [Bridge-link] array configuration
- HC [Honeycomb] array configuration
- SP-TCT [Series-parallel-Total Cross Tied]array configuration
- HC-TCT [Honeycomb- Total Cross Tied] array configuration
- LD [ladder diagram] array configuration
- LD-TCT [ladder diagram- Total Cross Tied] array configuration.

1.6Thesis outlet

- Objective
- List of the components to develop this Thesis
- Diagram
- Some real image
- Result comparison
- Advantages
- Applications
- Conclusion

CHAPTER 2

LITERATURE REVIEWS

Abstract

In this paper, a comprehensive study is carried out on the solar photovoltaic (PV) array topologies underdiagonally shading scenario. The aim of extensive analysis is to investigate the power mismatch losses in PV array under non-uniform irradiations. The partial shading affects not only power but also exhibitsextreme non-linearity along with multiple maximum power points on P-V and I-V characteristics. The investigation is based on designing of the optimal layout of PV modules in a array to extract maximum power under partial shading conditions (PSCs). In this context, a novel structure (NS) of PV array is designed and compared with the classical configurations such as total cross-tied (TCT), hybrid series parallel-total cross-tied (SP-TCT), bridge link-total cross tied (BL-TCT) and bridge link-honey comb (BLHC)under considered shadowing scenario. The modeling of all the considered PV array configurations has been done in MATLAB/Simulink environment. The performance of proposed NS configuration is found superior for some cases of shading effect. NS configuration of PV array has minimum power losses and improved fill factor (FF) as compared to others under PSCs.

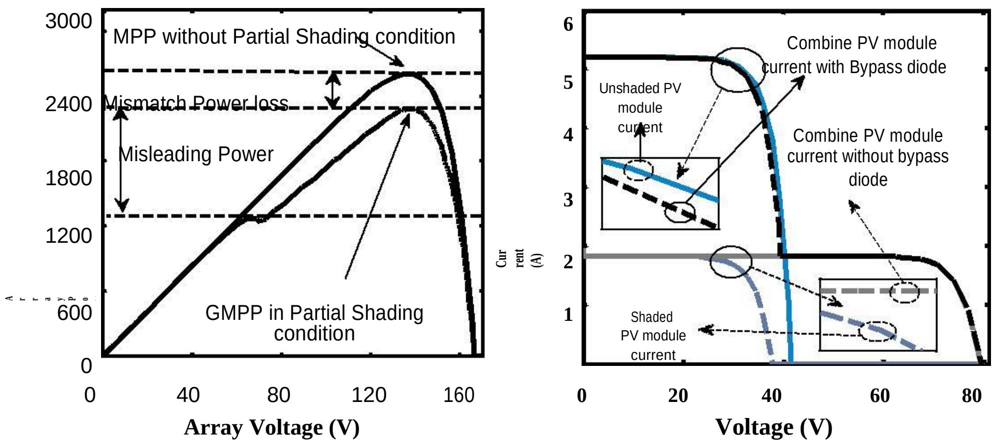
1. Introduction

Energy crisis is experienced worldwide, which inspired the development of renewable energy sources e.g. photovoltaic, wind turbine, bio-fuel and geothermal energy systems, etc. Due to exhausting fossil fuels and environmental pollution issues, the researchers explored more sustainable energy sources (Bishop, 1988). Today, PV based power generation is attaining more popularity due to its eco-friendly feature. Recently, the deteriorating performance during PSCs is a partial shading condition is a matter of research (Kovach and Schmid, 1996).

The PV based power system are facing many challenges like variation of short ~~circuit~~ current (I_{sc}) of PV cell due to non-uniform irradiation. The main causes of occurring PSCs on PV array are dust accumulation and shadow caused by tree, pole, building and passing clouds. The shading has predominant effect on PV modules performance in an array, which thereby minimizes the produced power. For the performance enhancement of PV based power generation system, the numbers of PV modules are connected in some pre-defined configurations (Quaschningt and Hanitscht, 1996). In these situations, it is inspiring task to enhance the performance as well as reducing the effect of PSCs. These research aspects make the extensive study to assess the impacts of PSCs on PV array performances (De-Blas et al., 2002). The effect of shading on the P-V and I-V characteristics is shown in Fig. 1.

The various types of existing configurations of PV array are observed in terms of their performance, reliability, and scope of implementation in available literature (Kaushika and Gautam, 2003; Karatepe et al., 2007; El-Dein et al., 2011, 2013; Bindram et al., 2012; Villa et al., 2012; Mohammadnejad et al., 2016; Buddala et al., 2013; Lun et al., 2014; Rani et al., 2013; Pareek and Dahiya, 2014, 2016; Vijayalekshmy et al., 2015a, 2015b, 2016; Braun et al., 2016; Belhachat and Larbes, 2015; Celik et al., 2015; Malathy and Ramaprabha, 2015a, 2015b; Deshkar et al., 2015; Potnuru et al., 2015; Yadav et al., 2016a, 2016b; Yadav et al., 2017; Nguyen and Lehman, 2008; Parlak, 2014; Storey et al., 2014; Picault et al., 2010; Moballegh and Jiang, 2014; Kumar et al., 2016). An exhaustive study is offered, which is related to the accuracy, robustness, efficiency and execution of each method.

In Kaushika and Gautam (2003) and Karatepe et al. (2007), the electrical characteristics of PV array interconnections such as SP, TCT and BL (9 _ 4, 6 _ 6, 2 _ 6, 6 _ 2, 3 _ 4 and 4 _ 3) are



(a) P-V characteristics (b) I-V characteristics

investigated under shading effect. Moreover, the obtained results of TCT configuration are compared with other configurations in terms of maximum power at GMPP and FF. The authors of El-Dein et al. (2011), Bindram et al. (2012), Villa et al. (2012), Mohammadnejad et al. (2016) have investigated 6 _ 4, 5 _ 3 sizes of SP, BL, TCT and HC configurations of PV array under PSCs. Among all the array configurations, TCT has minimum power losses. PV modules are arranged in series, parallel, SP, TCT, BL and HC configurations and performance has been investigated for different shading scenario in Buddala et al. (2013), Lunet al. (2014). The authors of El-Dein et al. (2013) investigated SP, TCT, BL, Half Reconfiguration Photovoltaic Array (HRPVA) and Full Reconfiguration Photo-voltaic Array (FRPVA) of size 6 _ 4 PV array under PSCs. The performance of HRPVA is found superior than considered other configurations. In Rani et al. (2013), the authors investigated that the physical locations of the 9 _ 9 size PV modules are connected in array and this arrangement has been configured based on Su-Do-Ku puzzle pattern to distribute the shading effect over the entire array, which shows the best performance. In Pareekand Dahiya (2014, 2016), Vijayalekshmy et al. (2015a), Braun et al. (2016), SP, TCT and BL array interconnections are considered for the investigation under shading effect and minimum power losses are found in TCT configuration. In Belhachat and Larbes (2015) and Celik et al. (2015), the existing PV array configurations e.g. series,parallel, SP, TCT, BL and HC of sizes 6 _ 4 and 8 _ 3 are carried out for investigation under PSCs. The TCT configuration has shown improved performance such as minimum power losses and high FF. In Malathy and Ramaprabha (2015a) and Deshkar et al. (2015),an optimization based approach is considered to reconfig-ure the TCT configuration of PV array, in which the physical loca-tions of the PV modules remain unchanged while the electrical contacts are changed. Furthermore, a Genetic Algorithm (GA) based optimization technique is used to disperse the shadow on Su-Do-Ku based PV array configuration. GA based shade dispersed Su-do-Ku array configuration has shown to have best performance in comparison to other configurations. In Malathy and Ramaprabha (2015b) and Vijayalekshmy et al. (2015b), TCT and Reconfiguration TCT (RTCT) configuration of PV array with shade dispersion method are investigated in terms of power losses and FF and the performance of RTCT has better than classical configuration. In Potnuru et al. (2015), a strategy of optimal Su-Do-Ku arrangement is formulated to overcome shading effect and to make such an interconnection practicable for very large PV array size of 36 _ 36 viewed as a 4 _ 4 array or a 9 _ 9 micro arrays. In Yadav et al. (2016a, 2016b, 2017), TCT, SP-TCT and Su-Do-Ku sizes of 4 _ 4, hybrid configurations such as SP-TCT, BL-TCT, New Scheme-1 (NS-1), New Scheme-2 (NS-2) Su-Do-Ku (4 _ 5 size) and BL-HC, Magic square (MS), Reconfiguration TCT (RTCT), Recon-figuration SP-TCT (RSP-TCT), Reconfiguration BL-TCT (RBL-TCT), Reconfiguration BL-HC (RBL-HC) of size 4 _ 4 configurations are investigated in terms of power losses, FF, etc. The authors (Vijayalekshmy et al., 2016) used a novel Zig-Zag technique to modify the existing interconnections of PV modules in TCT config-uration to improve performance in terms of minimum power losses and highest FF. An electrical switch matrix is used to recon-figure the series, parallel, SP and TCT array configuration with adaptive solar PV bank (Nguyen and Lehman, 2008). In Parlak (2014), a novel algorithm entitled configuration-scanning is con-sidered to obtain the possible connections between PV modules in an array. Adaptive solar PV modules are used under shading sit-uations.

In Storey et al. (2014), the authors presented a modified configuration to produce the maximum power from TCT configura-tion of PV array. In Picault et al. (2010), the authors assessed the power mismatch losses of SP, TCT, BL configurations PV array of size 6 _ 4 topologies for both normal and PSCs for an extensive comparative study. In which, TCT has minimum power losses for simulation and experimental systems. In Moballegh and Jiang

The objective of the paper is to provide the rearrangement of physical position of PV modules in an array without changing the electrical connections to enhance the performance of PV array under PSCs.

(a) The proposed NS configuration is distributing the shadow effect over the array and minimizing the effect of PSCs.

(b) The proposed NS configuration method can apply to any dimension (m = n and m – n, where m and n are row and column) of PV array.

2. Modeling and description of PV array configurations Modeling strategies which are assumed in the proposed work are explained in the following section.

2.1. Modeling of PV cell The combination of various PV cells into series-parallel configuration to generate more electrical power are formed a PV array.

2.2. Mathematical modeling of PV module PV module is varying only by the interconnections of solar cells. If N_s solar cells are connected in series, PV module voltage is equal to N_S times of the individual PV cell voltage and PV module current is equal to that of every individual PV cell.

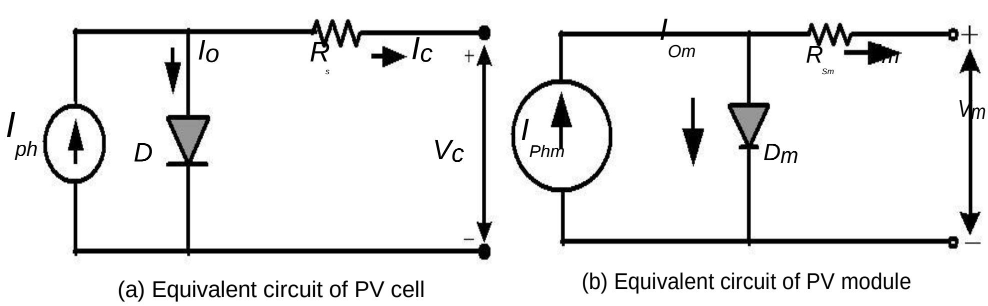


Fig. 2.1 (a)-(b) Electrical circuit of PV cell and module.

2.3.1. Partial shading losses Fig. 1(a)-(b) shows various types of losses in PV array, which are accommodated to establish, correctness of PV array configuration under

PSCs. The dissimilarity between global maximum power point (GMPP) and local maximum power point (LMPP) presents the cause of misleading power; and PV array interconnections are affecting PV performance in terms of power losses. The mismatch power losses of PV arrays can be expressed as.

2.3.2. Fill factor It is observed that FF of PV array affected due to power losses under PSCs. The FF depends directly upon open circuit voltage (V_{OC}) and short circuit current (I_{SC}) of PV Array, which observed at the P-V and I-V characteristics. The observed value of FF can be estimated as,

2.3.3. Performance ratio of PV array configurations The performance ratio of PV array configurations is defined as the normalized value of power at GMPP under PSCs to the ideal conditions and has determined by Eq. (14) as,

2.3.4. PV array configurations Fig. 3 shows different types of PV array configurations e.g. TCT, hybrid SP-TCT, BL-TCT, BL-HC and proposed NS. Fig.3(a) presents a classical TCT configuration, which is obtained from the SP interconnected PV modules by connecting ties across each row of junctions to minimize the power losses of PV array and generated more power as compared to conventional PV array configurations.

Fig.3(b)-(d) shows hybrid configurations of PV array, these arrangements are simply obtained by the combination of conventional SP, BL and HC configurations with the help of TCT configuration as,

Above Fig.3(e) represents the proposed NS puzzled pattern based PV array configuration, these PV modules are located with-out changing the electrical interconnections but its physical position is changed according to NS puzzle pattern. Fig.3(f) shows NS puzzle pattern, in which the first digit of each module represents the row and second digit denotes the column of 6 _ 4 size PV arrays. For example, the PV module 42 (4^{th} row, 2^{nd} column) is physically moved to the 1^{st} row and 2^{nd} column but the electrical connections remains in the same co-ordinates. Similarly, all PV modules have physically moved on according to NS puzzle pattern but its electrical connections are similar to TCT PV array arrangement.

2.3.5. Generalized rule for proposed NS puzzled array configuration In NS configuration, the row and column position of a 6 _ 4 size PV array are arranged and the number of rows and columns are 6 and 4 respectively. For indexing the row in NS pattern, space of partition (m = 3) and number of cycles (q = 2) is n = 2 (the distance of partition or states of cycles) are obtained by using Eq. (15)as,where u is the q states of cycles, which depends upon the number of q cycles (1, 1, 2, 2, 3, 3 as q = 2). Determining the row index (R)according to Eq. (16). The first row indexes are 1, 4, 2 and 5 and it has been tabulated in Table 2 as,

The next row indexes R_n of the first column is determined by incrementing R,Due to the shade dispersion effects, power generation is more as compared to the TCT and hybrid configurations due to large cur-rent generation at a known voltage range for a diagonally and other tested shadow movements. In this approach, only physi-cal location of PV modules is changed, without changing the electrical connections of modules.

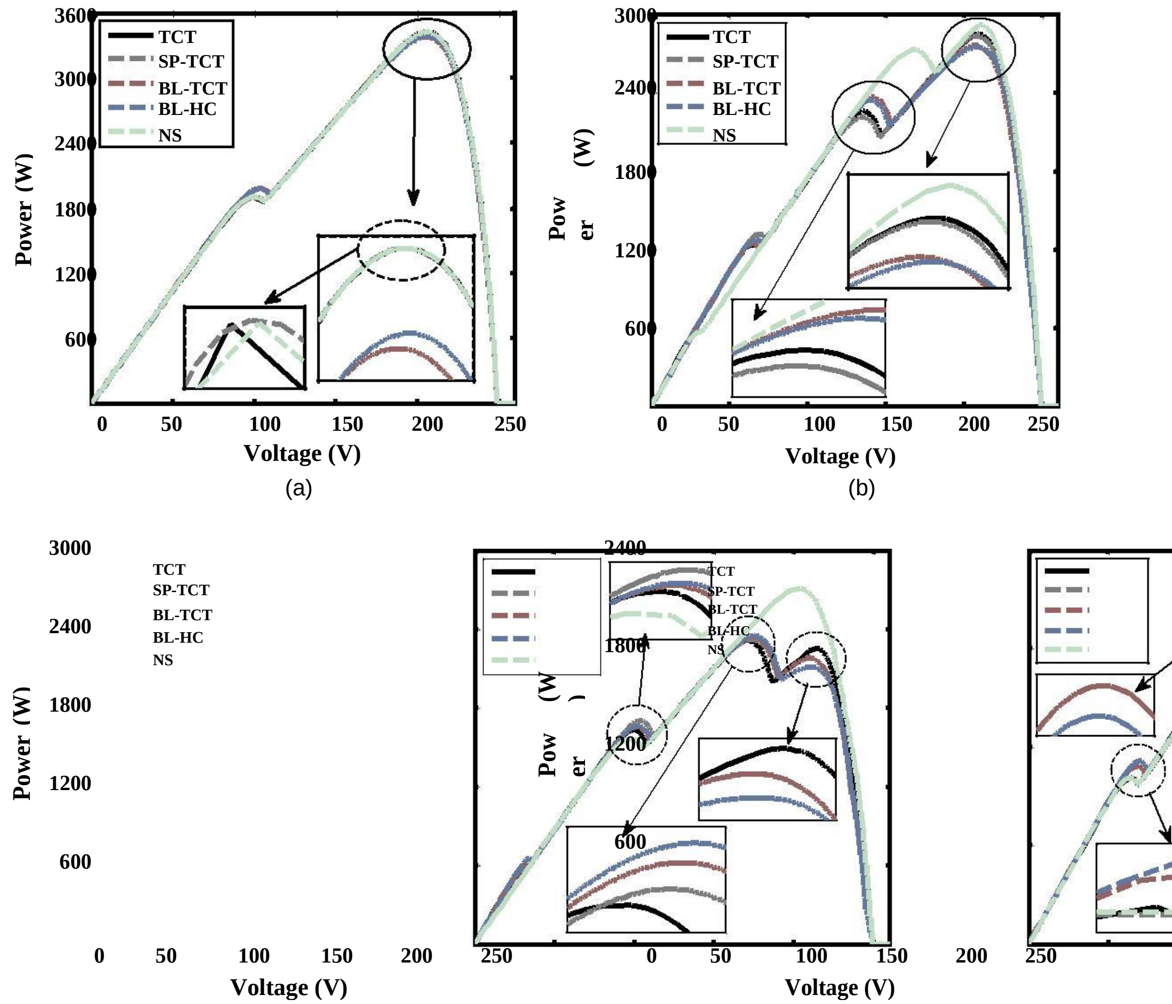
The proposed NS PV array configurations distributes the effect of shadow movements over the array and reduces the predominant shading of modules in any one row thereby increasing the generated PV power as compared to normal configurations. The performance of the system is studied for various shadow movements and it is discovered that positioning the modules in the array according to NS puzzle model shows better performance under various shadow movements.

In diagonally shadowing movement of case-4a, as the PV modules in row 1st, 2nd and 3rd receive the equal solar irradiation of 1000 W/m^2. Moreover, in 4th, 5th and 6th row, three modules receive 350 W/m^2 and other modules receive 1000 W/m^2

2. Results and discussion

2.1.P-V characteristics for various shadow movements at STC

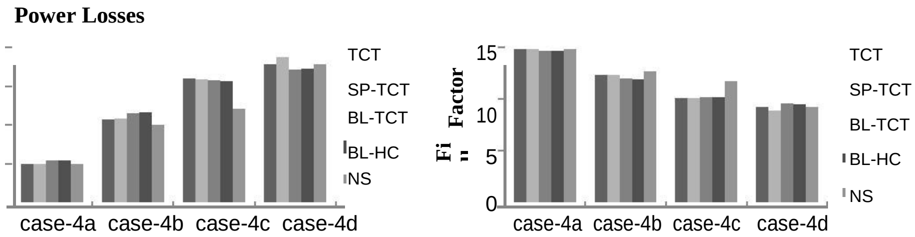
The P-V characteristics of considered all arrangements of PV array for shading movement cases ‘4a-4d’ are shown in Fig. 6. According to shadow movement of Fig. 4(a), two MPPs are observed at P-V characteristics, shown in Fig. 6(a). It is noticed from the figure that LMPP is at a distance from the GMPP and effect of shading increases observable on P-V curves. The maximum power in TCT, SP-TCT and NS configurations is 3419 W and is a true GMPP for the shadow condition of Fig. 4(a). The power at other two types of hybrid configurations of PV array e.g. BL-TCT and BL-HC are 3372 W and 3379 W respectively and found closer to true GMPP for the shadow cases Fig. 4(a).For the shadow movement case shown in Fig.4(b), it is noticed that the shadow movements are increasing diagonally and multiple LMPPs are observed and shown in Fig. 6(b). In NS configuration, the GMPP is having 2914 W for the shadow movement of Fig. 4(b). The GMPP of TCT, hybrid SP-TCT, BL-TCT and BL-HC PV array is at a distance from the NS and increasing the effect of shading on the power curves has been observed clearly.



(a) (b) (c) (d)

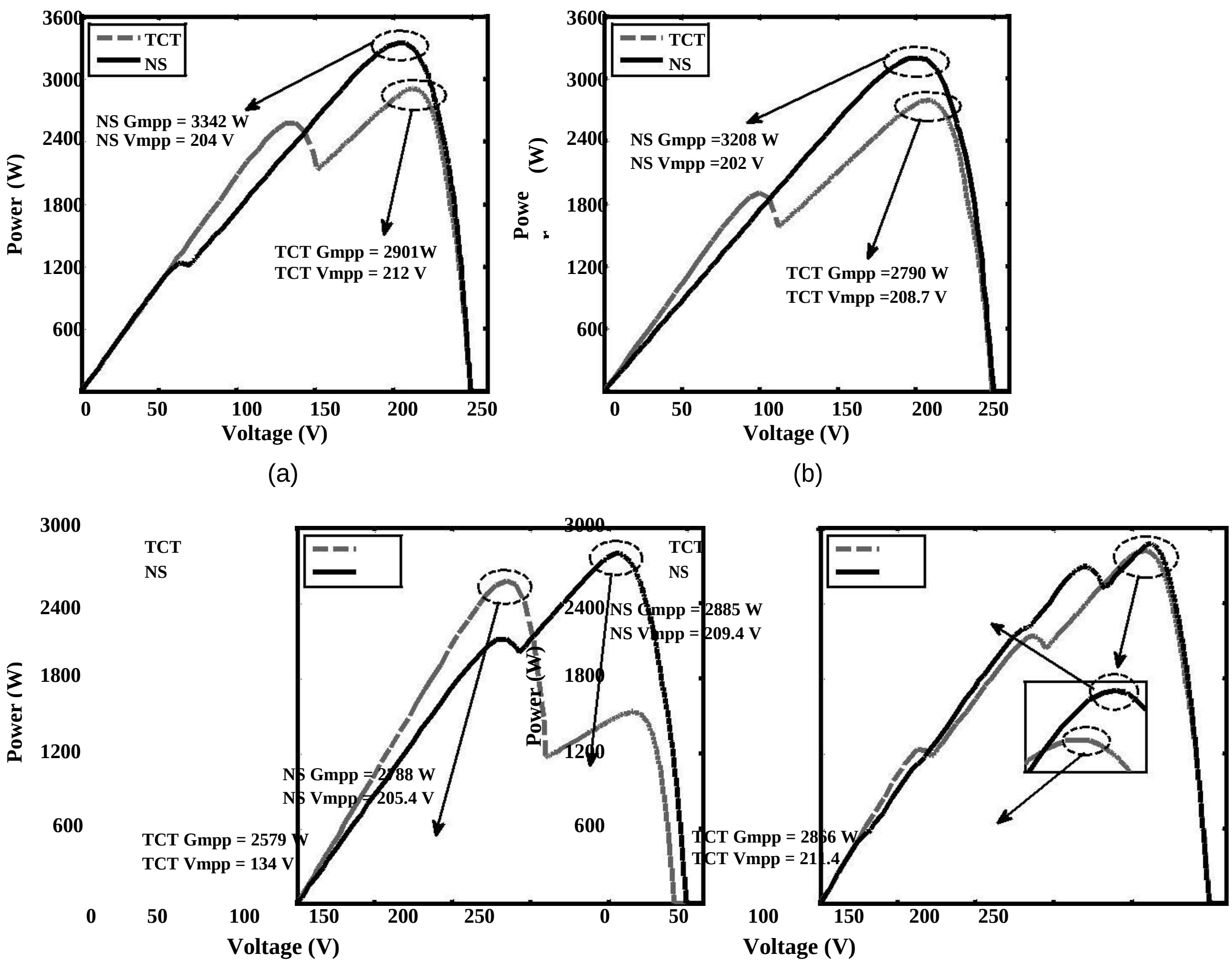
Table 7
Power, voltage, power loss and FF for various configurations for considered shading cases.

Topologies	Case-4a				Case-4b				Case-4c				Case-4d			
	P_m	V_m	PL	FF	P_m	V_m	PL	FF	P_m	V_m	PL	FF	P_m	V_m	PL	FF
TCT	3419	206.1	496	14.87	2844	209	1071	12.37	2313	206.3	1602	10.06	2132	171.9	1783	9.27
SP-TCT	3419	206.3	496	14.87	2835	208.4	1080	12.33	2322	174.6	1683	10.10	2037	203.2	1878	8.86
BL-TCT	3372	206.5	543	14.67	2758	206.4	1157	11.99	2338	175.3	1577	10.17	2199	168.3	1716	9.56
BL-HC	3379	207	536	14.70	2748	208.5	1167	11.95	2349	175.3	1566	10.22	2191	168.3	1724	9.53
NS	3419	206.1	496	14.87	2914	210	1001	12.67	2709	208	1206	11.78	2132	172.3	1783	9.27
Best topology	TCT/SP-TCT/NS				NS				NS				BL-TCT			



(a) Power losses (W) (b) Fill factor

Fig. 7.Effect of diagonally shadow movements on power losses and FF.



(a) (b)

(c) (d)

Fig. 8. Effects of other tested shadow movements on P-V characteristics for TCT and NS PV array

4. Conclusion

The study and performance analysis of 6 _ 4 sizes TCT, SP-TCT, BL-TCT, BL-HC and NS configurations PV array have been carried out in this paper. The obtained voltage, current, power at GMPP, power loss, FF and PR have been considered to assess the performance of considered PV array configurations. The shade dispersion effect on proposed configuration is also investigated. The extensive simulation results have been analyzed. The results show that NS configuration contains minimum power losses, higher FF and PR of under various shadowing scenario. Following are the major concluding points as,

The performance of NS configuration has more efficiency with the maximum enhanced power of 13.2%, maximum reduction in power losses by 496 W, maximum increment in FF by 1.92 and PR is 85% as compared to TCT configuration for diagonally shadowing movements.
Overall, it is concluded that the proposed NS configuration of PV array with shade dispersion enhanced the performance as com-pared to the TCT configuration of PV arrays under the considered PSCs.

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Chapter 3

Methodology

Introduction

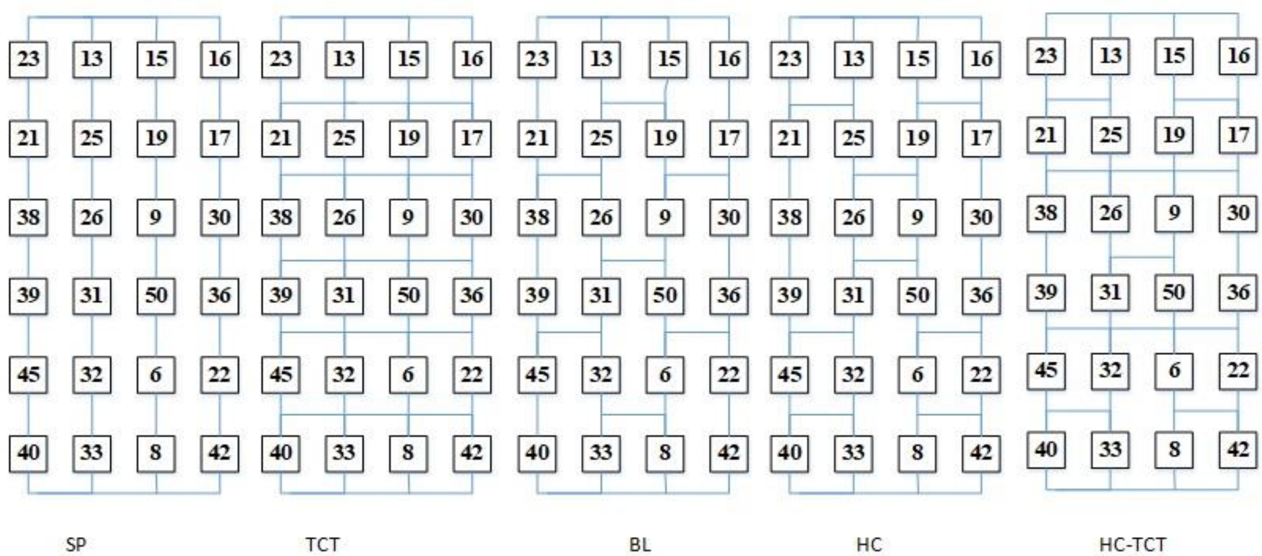
This chapter gives an explanation on the method and step used in designing the Shading Effect on PV System. It includes the description of the design flow, design architecture and detail explanations for the hardware development of Shading Effect on PV System.

3.1 List of the components

- Solar cell
- Mercury light
- Required wires
- Data logger device
- Multimeter
- Temperature meter
- Power switch
- Variable resistor
- Computer
- Crocodile clip

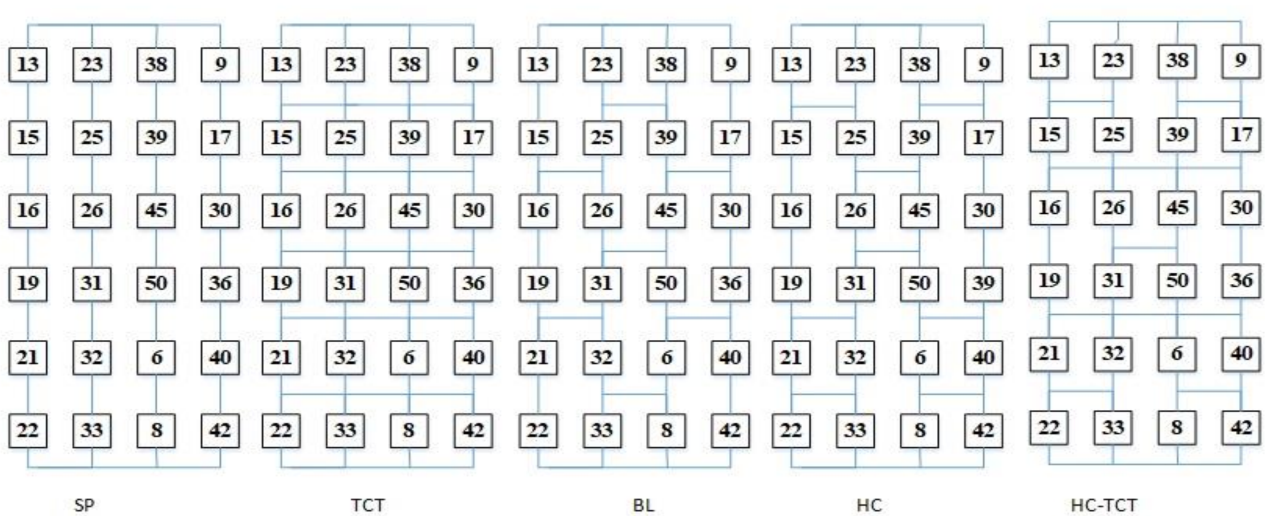
3.2 Same configuration Without Shading

The impact of partial shading on PV system has been studied at great length in the past. Some past studies assume that the decrease in power production is proportional to the shaded area and reduction in solar irradiance, thus introducing the concept of shading factor. While this concept is true for a single cell. There are Same configuration Without Shading in below-



We have worked on the best twenty four out of one hundred solar panels.

Fig 3.1- Random configuration



We have arranged the current that we have received in twenty four solar panels in serial.

Fig 3.2- Im configuration

3.3 Same configuration With Shading

Shading on a single solar cell in a particular series string renders the entire column ineffective as the cells carry the same current. The shaded cell in the series string produces reverse voltage and starts consuming power than generating to the load. The output power reduces significantly for the series string. If many cells are shaded in 29 parallel this causes severe degradation effects. However, researchers have shown that, this architecture is attractive for use when percentage of shading can be kept really low [23]. In that case, it performs very well without the need of protective bypass diodes. Thus it makes a simpler and cost-effective design. The cells in the solar panel can also be tied in three other configurations. They are Series-Parallel (SP), the Total Cross Tied (TCT), Bridge Linked (BL), Honey Comb (HC) and (HC-TCT) as shown in Fig. 3.3-

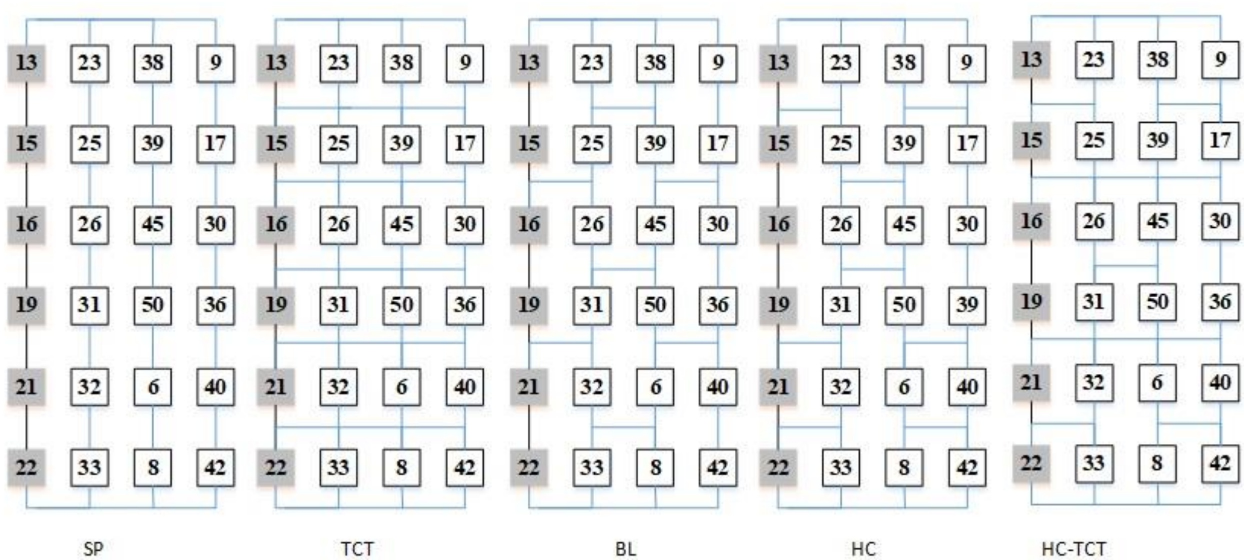


Fig 3.3.1 Series(6X1) Shading

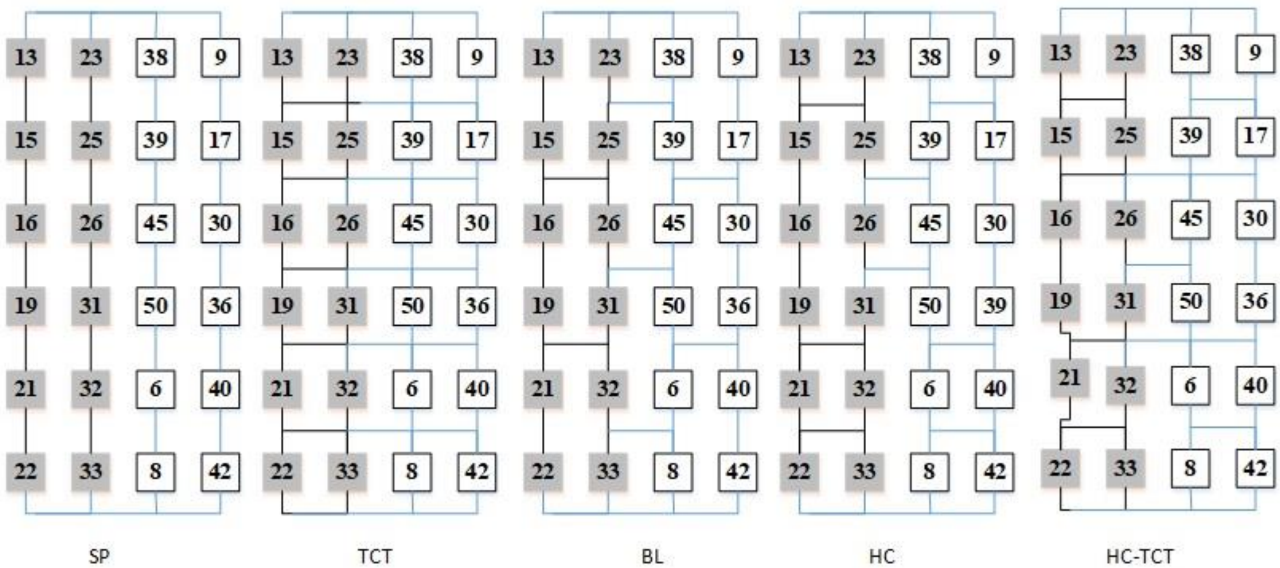


Fig 3.3.2 Series(6X2) Shading

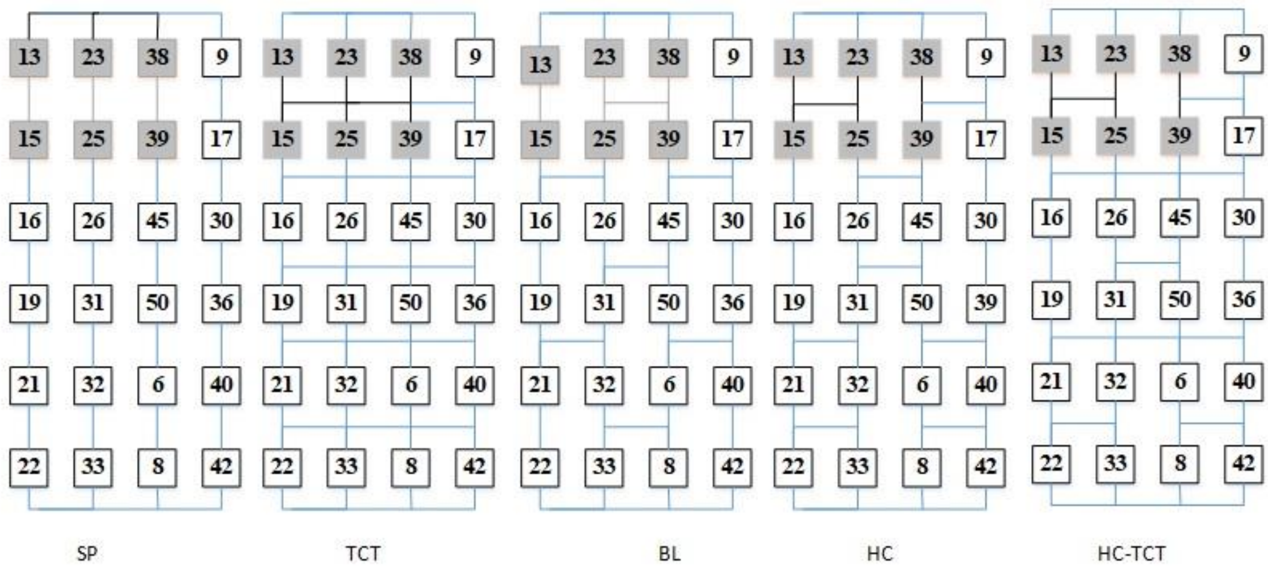


Fig-3.3.3: Parallel(3X2) Shading

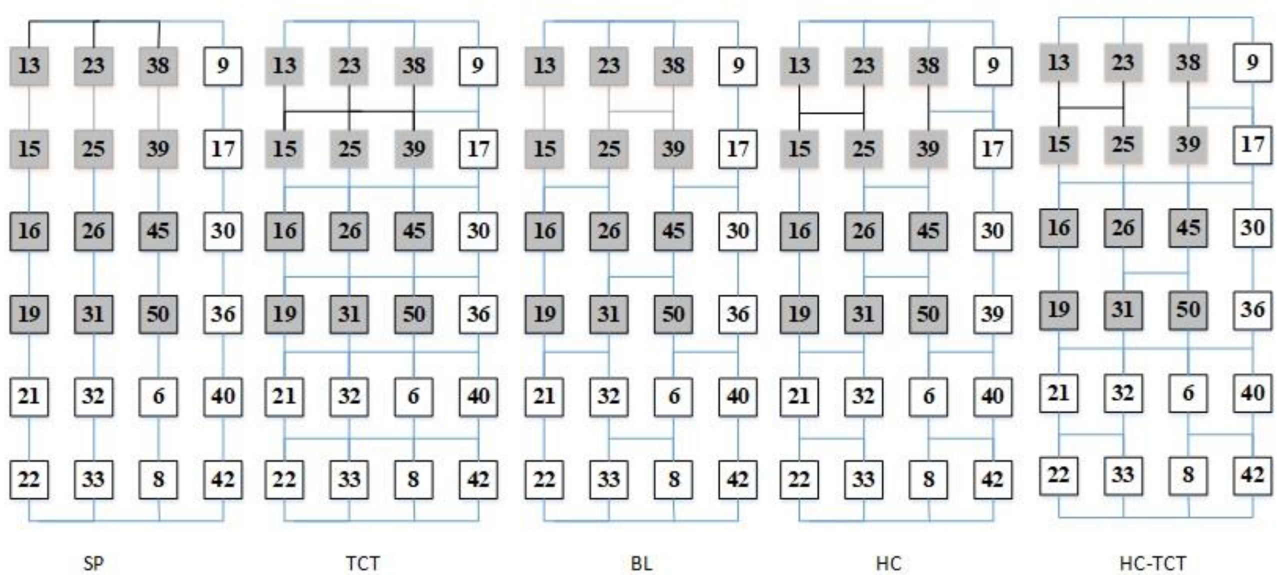


Fig-3.3.4: Parallel(3X6) Shading

3.4 Series-parallel (SP) Array Configuration

Solar cells are connected in series so that voltage across each cell can be accumulated at the output. The cells in series carry the same current irrespective of the fact whether one or more cells under shade produce less photonic current. As the shading increases in a cell, its output voltage starts to fall. Under some shading conditions, in order to maintain the same output current a shaded cell can get reverse biased. Then the shaded cell consumes power instead of delivering power. This power is drawn from illuminated cells and thus reduces the overall power generated by the array. Power losses in the individual shaded cells would increase the temperature creating thermal stress on the entire module and cause hot spots and local defects

3.4.1 Without Shading in Series-parallel (SP) Array Configuration

Time	Date	I	V	P
14:55:58,	15/11/2020	0.603	0	0
14:55:59,	15/11/2020	0.585	6.847	4.003
14:56:4,	15/11/2020	0.566	10.366	5.868
14:56:8,	15/11/2020	0.522	11.457	5.977
14:56:12,	15/11/2020	0.426	12.248	5.212
14:56:14,	15/11/2020	0.359	12.575	4.514
14:56:16,	15/11/2020	0.233	13.148	3.066
14:56:22,	15/11/2020	0.093	13.721	1.271
14:56:24,	15/11/2020	0.052	13.884	0.721
14:56:26,	15/11/2020	0	14.048	0

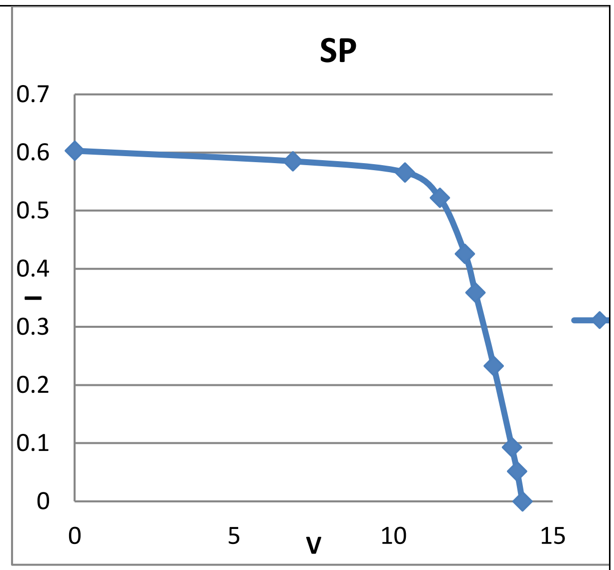


Fig.3.4.1:-Series-parallel (SP) Array Configuration and graph

3.4.2 Shading pattern 1 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
15:29:4,	15/11/2020	0.481	0	0
15:29:6,	15/11/2020	0.459	6.547	2.955
15:29:8,	15/11/2020	0.454	8.156	3.622
15:29:10,	15/11/2020	0.444	10.366	4.603
15:29:14,	15/11/2020	0.414	11.457	4.748
15:29:18,	15/11/2020	0.344	11.975	4.121
15:29:22,	15/11/2020	0.281	12.493	3.514
15:29:26,	15/11/2020	0.2	12.984	2.596
15:29:30,	15/11/2020	0.122	13.148	1.607
15:29:36,	15/11/2020	0	13.53	0

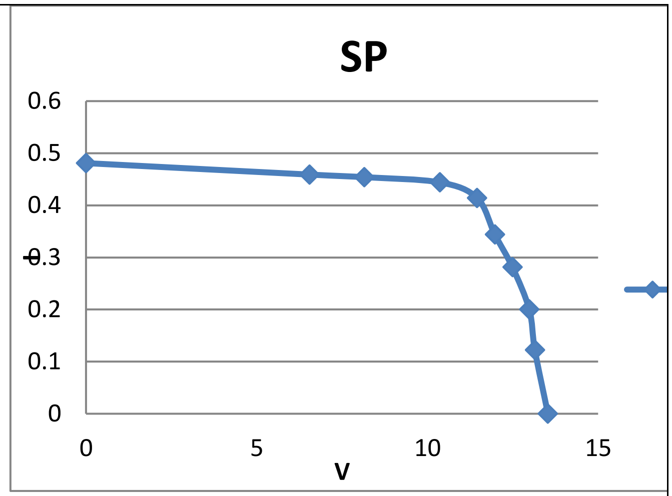


Fig.3.4.2:-Series-parallel (SP) Array Configuration and graph

3.4.3 Shading pattern 2 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
15:35:38,	15/11/2020	0.311	0	0
15:35:40,	15/11/2020	0.31	2.782	0.896
15:35:44,	15/11/2020	0.282	9.247	2.533
15:35:48,	15/11/2020	0.266	11.32	3.017
15:35:54,	15/11/2020	0.189	11.866	2.24
15:35:59,	15/11/2020	0.17	12.084	2.058
15:36:10,	15/11/2020	0.096	12.548	1.209
15:36:12,	15/11/2020	0.082	12.548	1.023
15:36:14,	15/11/2020	0	12.711	0

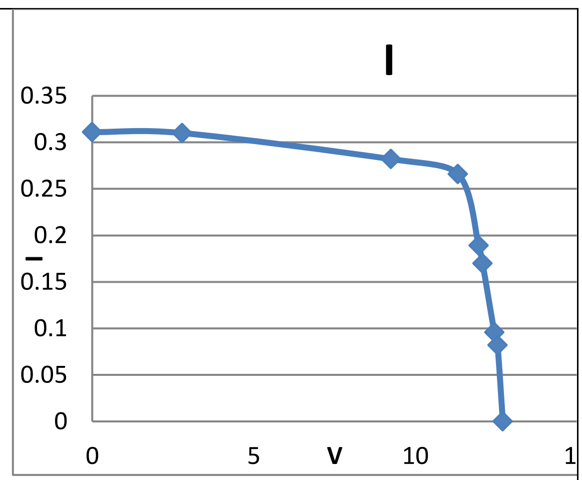


Fig.3.4.3:-Series-parallel (SP) Array Configuration and graph

3.4.4 Shading pattern 3 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
15:40:44,	15/11/2020	0.142	0	0
15:40:52,	15/11/2020	0.139	4.746	0.633
15:40:59,	15/11/2020	0.137	8.729	1.099
15:41:6,	15/11/2020	0.136	11.238	1.457
15:41:8,	15/11/2020	0.133	12.084	1.611
15:41:16,	15/11/2020	0.089	12.548	1.116
15:41:18,	15/11/2020	0.067	12.766	0.852
15:41:20,	15/11/2020	0	13.093	0

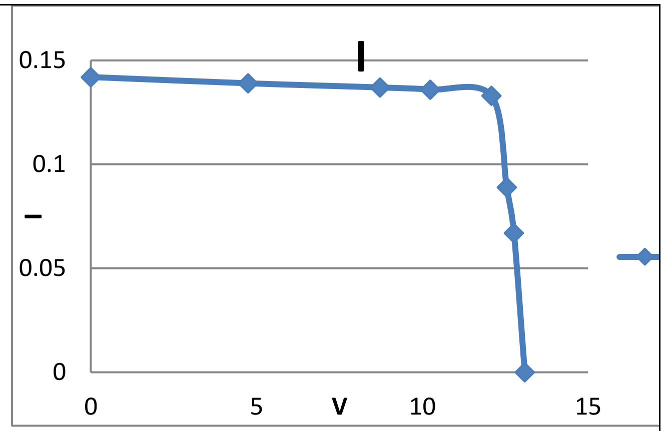


Fig.3.4.4:-Series-parallel (SP) Array Configuration and graph

3.4.5 Shading pattern 4 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
15:49:24,	15/11/2020	0.14	0	0
15:49:34,	15/11/2020	0.135	8.729	1.164
15:49:36,	15/11/2020	0.135	9.82	1.345
15:49:40,	15/11/2020	0.133	11.293	1.506
15:49:46,	15/11/2020	0.115	11.648	1.337
15:49:50,	15/11/2020	0.089	12.002	1.067
15:49:52,	15/11/2020	0.074	12.057	0.894
15:49:54,	15/11/2020	0	12.52	0

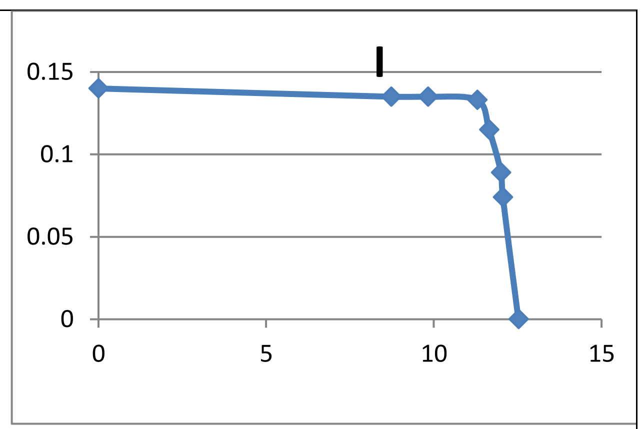


Fig.3.4.5:-Series-parallel (SP) Array Configuration and graph

3.5 Total Cross Tied (TCT) Array Configuration

Novel TCT PV array configurations are considered for performance investigation under PSCs, in which recently proposed novel TCT configuration has shown better response in maximum power at GMPP, minimum power loss, improved FF, and higher performance ratio.

3.5.1 Without Shading Total Cross Tied (TCT) Array Configuration

Time	Date	I	V	P
17:5:54,	15/11/2020	0.677	0	0
17:5:56,	15/11/2020	0.644	6.738	4.338
17:5:58,	15/11/2020	0.622	8.183	5.087
17:5:59,	15/11/2020	0.603	9.274	5.593
17:6:2,	15/11/2020	0.537	9.82	5.269
17:6:4,	15/11/2020	0.459	10.093	4.631
17:6:6,	15/11/2020	0.418	10.366	4.334
17:6:10,	15/11/2020	0.207	11.075	2.296
17:6:14,	15/11/2020	0.104	11.484	1.191
17:6:16,	15/11/2020	0.056	11.457	0.637
17:6:18,	15/11/2020	0	11.538	0

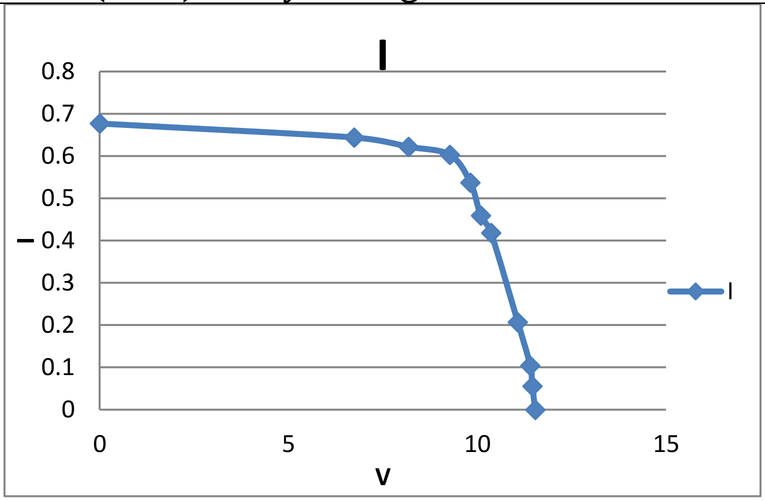


Fig.3.5.1:-Total Cross Tied (TCT)Array Configuration and graph

3.5.2 Shading pattern 1 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
17:14:22,	15/11/2020	0.522	0	0
17:14:24,	15/11/2020	0.511	5.128	2.619
17:14:26,	15/11/2020	0.507	6.547	3.319
17:14:28,	15/11/2020	0.507	7.774	3.941
17:14:32,	15/11/2020	0.496	8.729	4.328
17:14:34,	15/11/2020	0.433	9.274	4.015
17:14:38,	15/11/2020	0.377	9.793	3.696
17:14:46,	15/11/2020	0.263	10.284	2.702
17:14:48,	15/11/2020	0.215	10.584	2.272
17:14:50,	15/11/2020	0.137	10.884	1.491
17:14:52,	15/11/2020	0.096	10.966	1.056
17:14:56,	15/11/2020	0.059	11.047	0.655
17:14:58,	15/11/2020	0	11.266	0

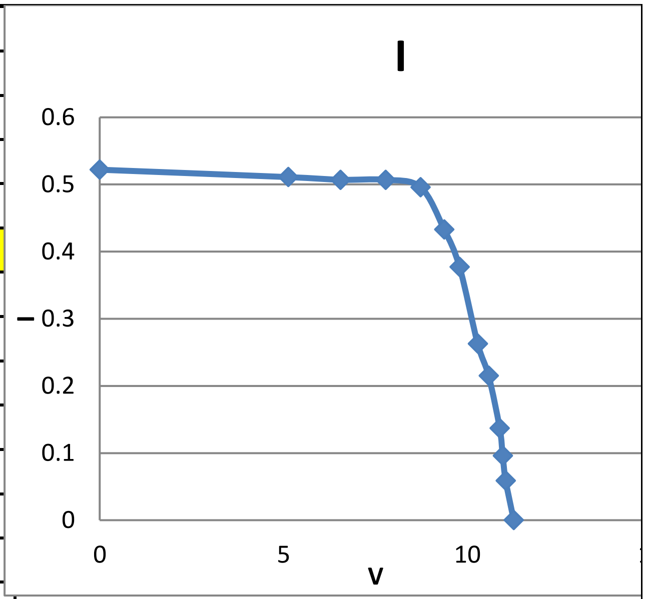


Fig.3.5.2:-Total Cross Tied (TCT)Array Configuration and graph

3.5.3 Shading pattern 2 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
17:21:10,	15/11/2020	0.374	0	0
17:21:12,	15/11/2020	0.374	1.473	0.551
17:21:14,	15/11/2020	0.367	5.619	2.038
17:21:16,	15/11/2020	0.366	7.61	2.788
17:21:18,	15/11/2020	0.296	8.702	2.576
17:21:20,	15/11/2020	0.226	9.684	2.186
17:21:24,	15/11/2020	0.148	10.366	1.535
17:21:26,	15/11/2020	0.126	10.502	1.322
17:21:28,	15/11/2020	0.085	10.802	0.921
17:21:32,	15/11/2020	0	10.911	0

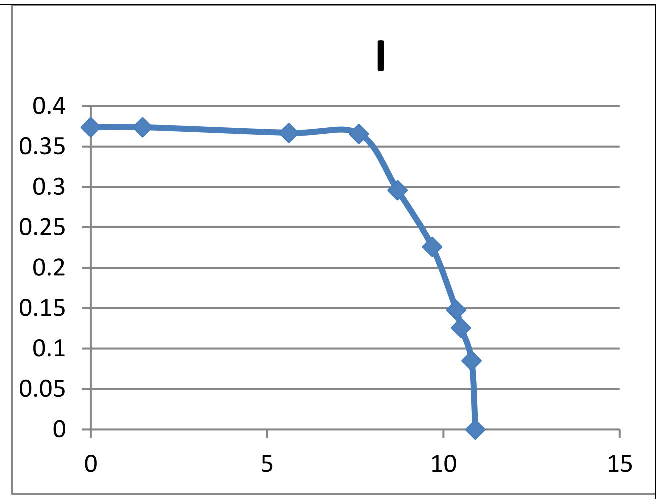


Fig.3.5.3:-Total Cross Tied (TCT) Array Configuration and graph

3.5.4 Shading pattern 3 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
17:27:32,	15/11/2020	0.161	0	0
17:27:34,	15/11/2020	0.159	1.064	0.15
17:27:38,	15/11/2020	0.158	2.728	0.384
17:27:52,	15/11/2020	0.157	6.465	0.91
17:27:59,	15/11/2020	0.156	9.302	1.447
17:28:6,	15/11/2020	0.126	10.366	1.305
17:28:16,	15/11/2020	0.045	10.911	0.486
17:28:18,	15/11/2020	0	10.938	0

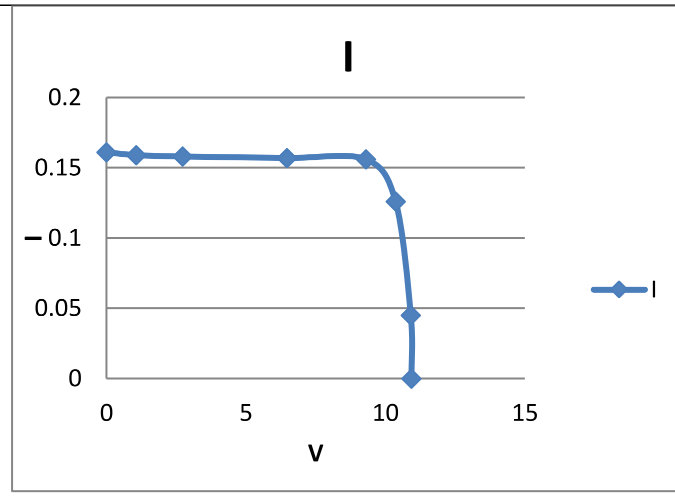


Fig.3.5.4:-Total Cross Tied (TCT) Array Configuration and graph

3.5.5 Shading pattern 4 of Series-parallel (SP) Array Configuration

Time	Date	I	V	P
17:39:52,	15/11/2020	0.167	0	0
17:39:54,	15/11/2020	0.167	1.064	0.154
17:39:59,	15/11/2020	0.167	6.547	1.018
17:40:4,	15/11/2020	0.167	8.183	1.363
17:40:8,	15/11/2020	0.137	9.274	1.271
17:40:12,	15/11/2020	0.1	10.366	1.037
17:40:14,	15/11/2020	0.078	10.366	0.807
17:40:20,	15/11/2020	0.037	10.638	0.395
17:40:22,	15/11/2020	0	10.693	0

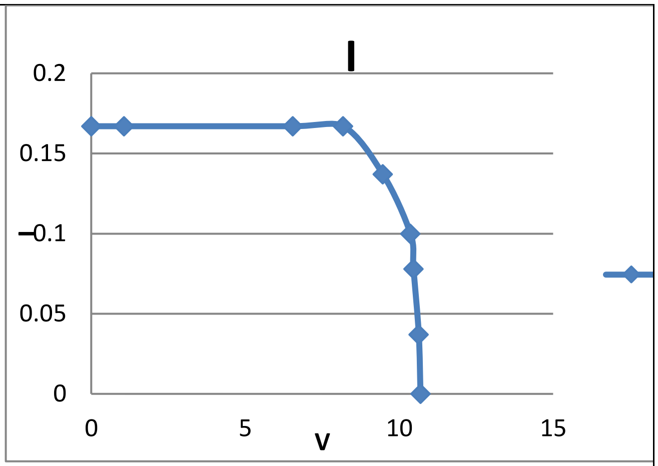


Fig.3.5.3:-Total Cross Tied (TCT) Array Configuration and graph

3.6Bridge Links (BL) Array Configuration

Bridge-Link' (BL) structures under partial shading conditions. 'Bridge-Link' and 'Series-Parallel' configurations stand on the 2 nd and 3 rd performance stages respectively while a Series-Parallel connection presents the least system complexity.

3.6.1 Without Shading of Bridge Links (BL) Array Configuration

Time	Date	I	V	P
19:57:52,	15/11/2020	0.647	0	0
19:57:54,	15/11/2020	0.636	6.601	4.201
19:57:56,	15/11/2020	0.633	9.902	6.192
19:57:59,	15/11/2020	0.625	11.375	7.113
19:58:2,	15/11/2020	0.57	11.757	6.699
19:58:4,	15/11/2020	0.463	12.548	5.804
19:58:6,	15/11/2020	0.381	13.011	4.959
19:58:10,	15/11/2020	0.13	14.021	1.817
19:58:14,	15/11/2020	0	14.184	0

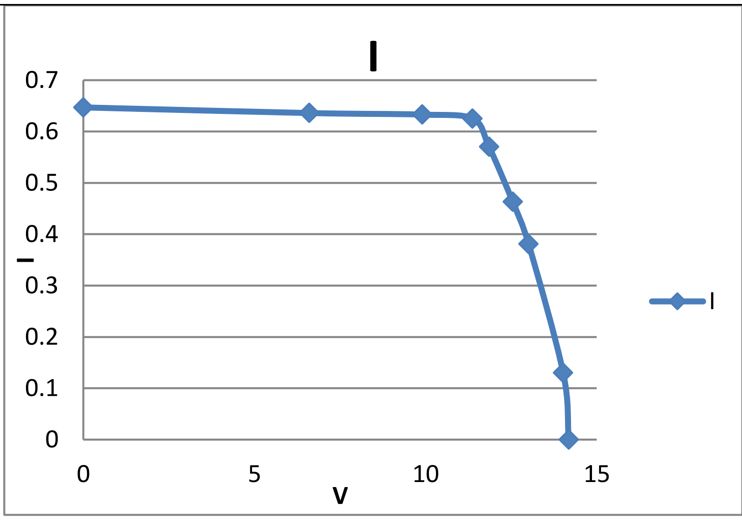


Fig.3.6.1:-Total Cross Tied (TCT)Array Configuration and graph

3.6.2 Shading of Bridge Links (BL) Array Configuration

Time	Date	I	V	P
20:3:10,	15/11/2020	0.533	0	0
20:3:12,	15/11/2020	0.54	3.082	1.665
20:4:18,	15/11/2020	0.522	9.547	4.981
20:4:20,	15/11/2020	0.5	10.475	5.232
20:4:24,	15/11/2020	0.44	11.484	5.057
20:4:26,	15/11/2020	0.359	12.193	4.377
20:4:28,	15/11/2020	0.218	13.093	2.86
20:4:30,	15/11/2020	0.104	13.421	1.392
20:4:32,	15/11/2020	0	13.612	0

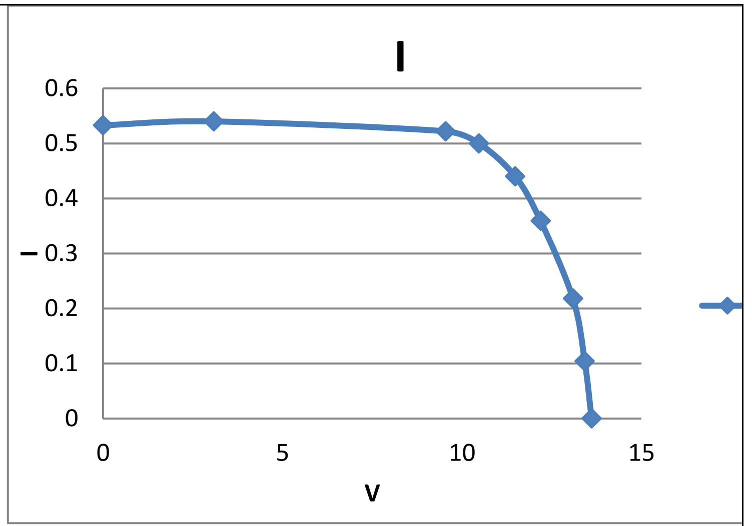


Fig.3.6.2:-Total Cross Tied (TCT)Array Configuration and graph

3.6.3 Shading of Bridge Links (BL) Array Configuration

Time	Date	I	V	P
20:5:30,	15/11/2020	0.34	0	0
20:5:32,	15/11/2020	0.333	5.483	1.826
20:5:34,	15/11/2020	0.326	8.702	2.834
20:5:36,	15/11/2020	0.311	10.556	3.282
20:5:38,	15/11/2020	0.3	11.375	3.41
20:5:40,	15/11/2020	0.274	11.648	3.19
20:5:44,	15/11/2020	0.207	12.493	2.59
20:5:46,	15/11/2020	0.141	12.902	1.816
20:5:48,	15/11/2020	0.122	12.957	1.584
20:5:50,	15/11/2020	0	13.175	0

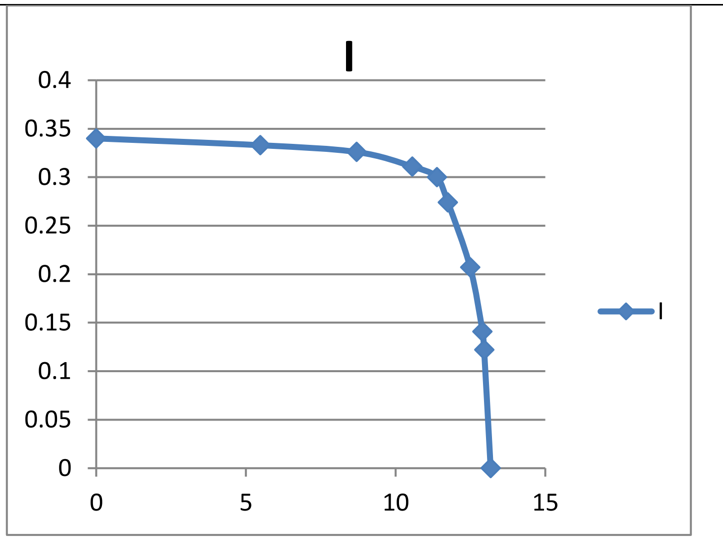


Fig.3.6.3:-Total Cross Tied (TCT)Array Configuration and graph

3.6.4 Shading of Bridge Links (BL) Array Configuration

Time	Date	I	V	P
20:10:46,	15/11/2020	0.165	0	0
20:10:48,	15/11/2020	0.164	3.873	0.574
20:10:54,	15/11/2020	0.163	10.366	1.65
20:10:59,	15/11/2020	0.163	12.548	2.044
20:11:2,	15/11/2020	0.137	13.039	1.786
20:11:4,	15/11/2020	0.122	12.957	1.584
20:11:6,	15/11/2020	0	13.093	0

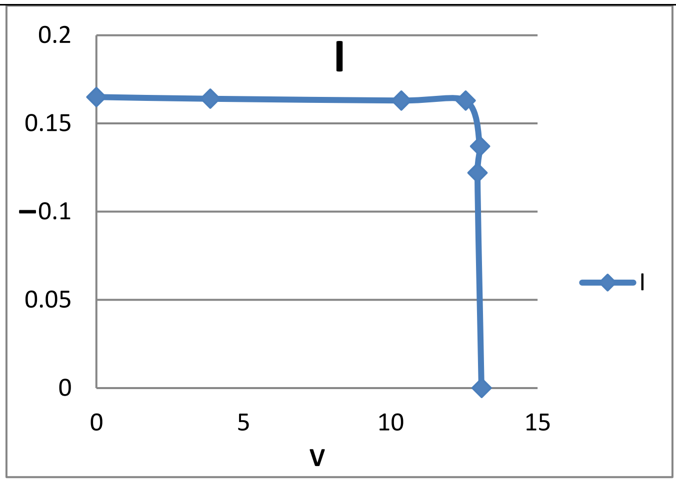


Fig.3.6.4:-Total Cross Tied (TCT) Array Configuration and graph

3.6.5 Shading of Bridge Links (BL) Array Configuration

Time	Date	I	V	P
20:15:50,	15/11/2020	0.154	0	0
20:15:52,	15/11/2020	0.156	6.028	0.937
20:15:59,	15/11/2020	0.152	12.248	1.859
20:16:4,	15/11/2020	0.133	12.493	1.666
20:16:8,	15/11/2020	0.1	12.602	1.261
20:16:10,	15/11/2020	0	13.093	0

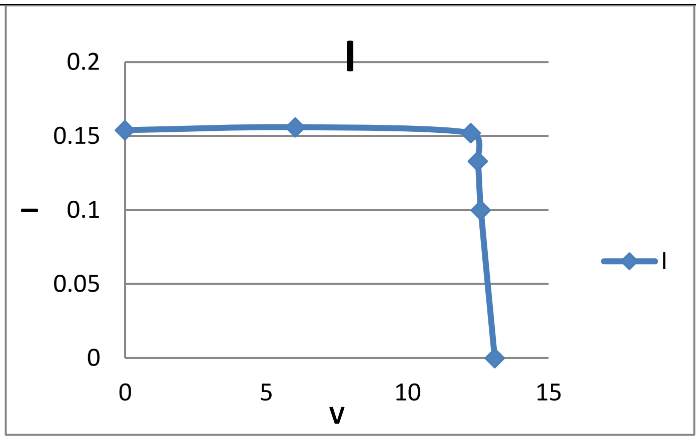
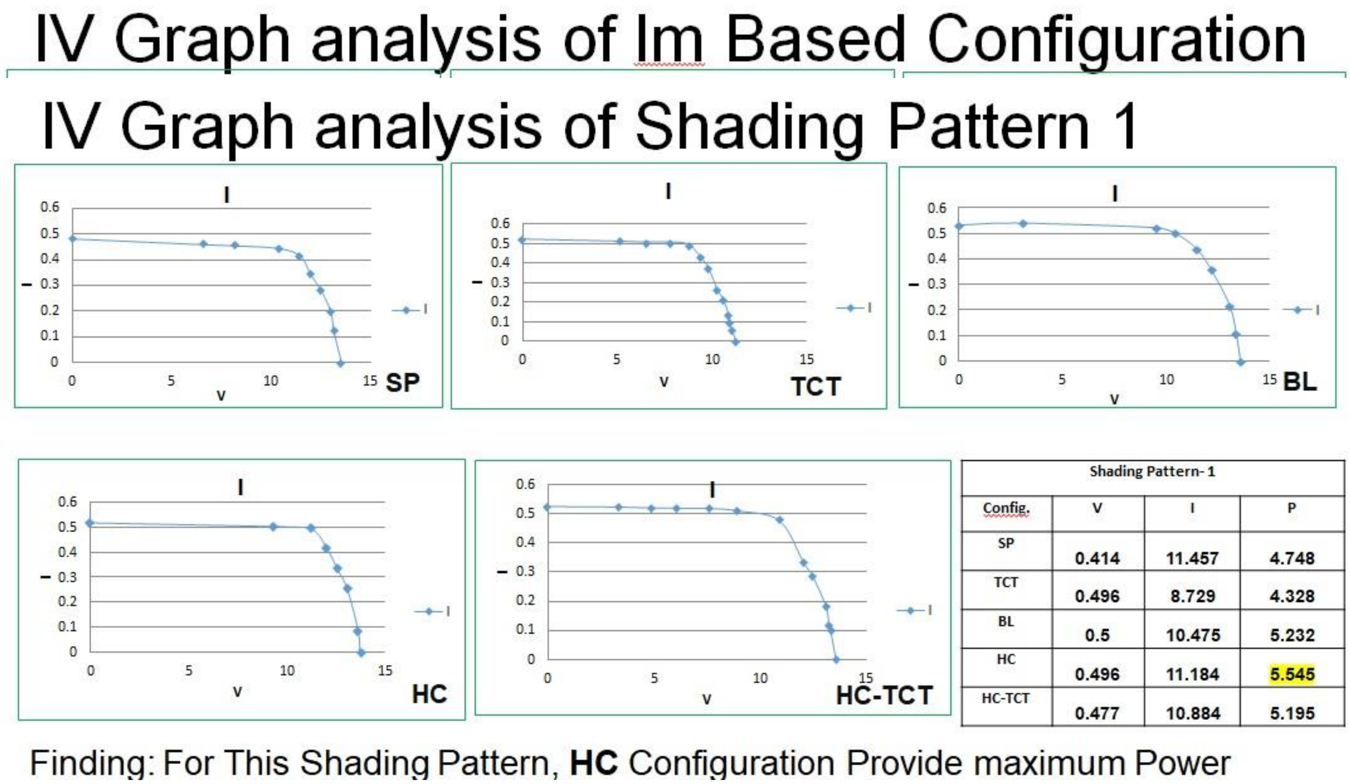


Fig.3.6.5:-Total Cross Tied (TCT)Array Configuration and graph

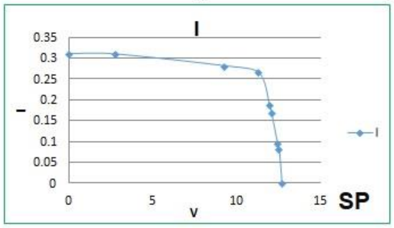
3.7 All I-V Characteristics for table and graph

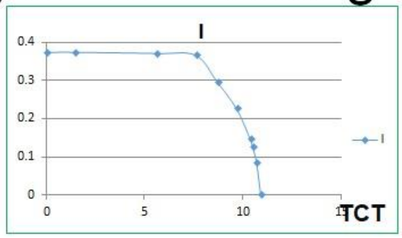
The cells in the solar panel can also be tied in five other configurations. They are the Series-parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL), Honey Comb (HC) and (HC-TCT) as shown in Figure. All I-V Characteristics for table.

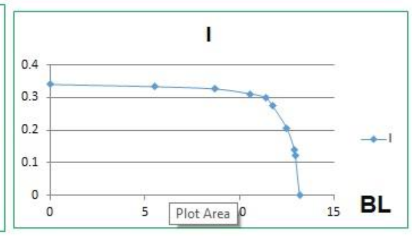


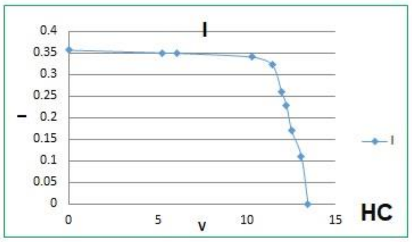
Shading Pattern- 1			
Config.	V	I	P
SP	0.414	11.457	4.748
TCT	0.496	8.729	4.328
BL	0.5	10.475	5.232
HC	0.496	11.184	5.545
HC-TCT	0.477	10.884	5.195

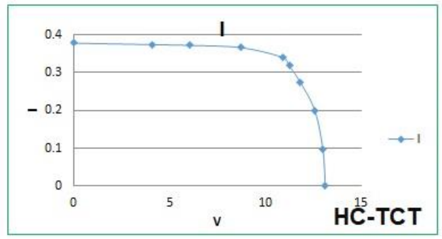
IV Graph analysis of Shading Pattern 2







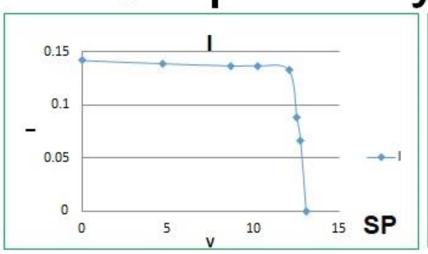


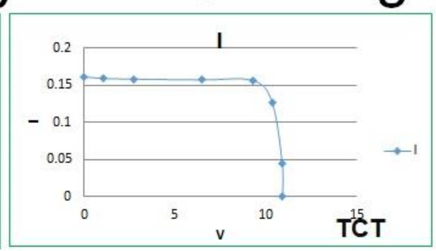


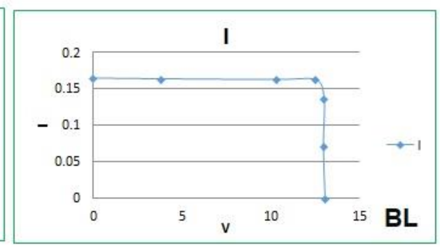
Shading Pattern- 2			
Config.	V	I	P
SP	0.266	11.32	3.017
TCT	0.366	7.61	2.788
BL	0.3	11.375	3.41
HC	0.322	11.457	3.689
HC-TCT	0.34	10.911	3.715

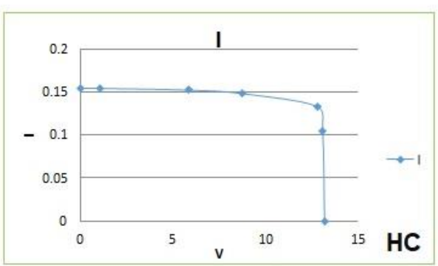
Finding: For This Shading Pattern, **HC-TCT** Configuration Provide maximum Power

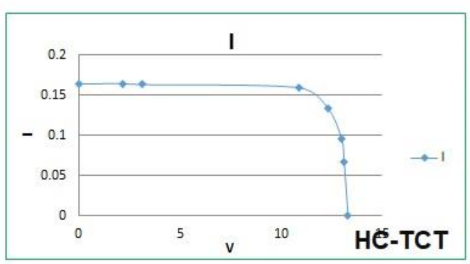
IV Graph analysis of Shading Pattern 3







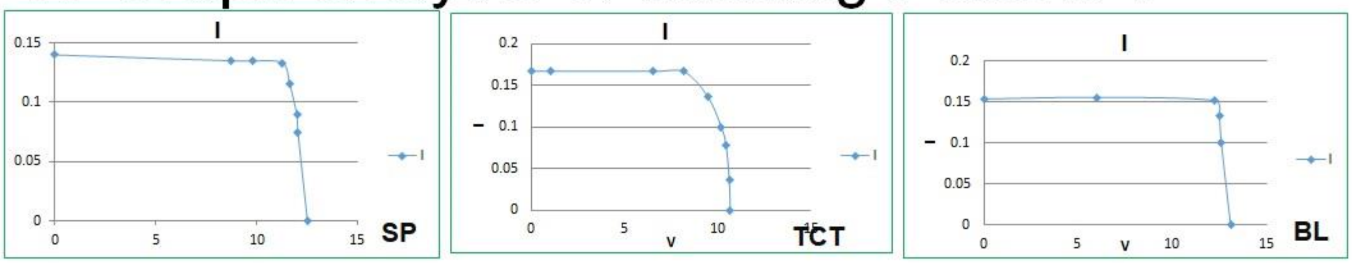


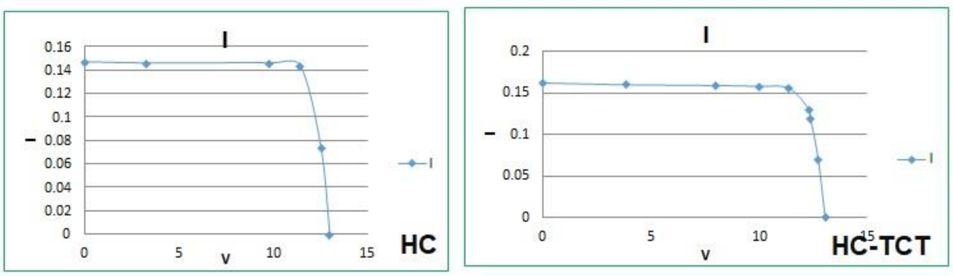


Shading Pattern- 3			
Config.	V	I	P
SP	0.133	12.084	1.611
TCT	0.156	9.302	1.447
BL	0.163	12.548	2.044
HC	0.133	12.793	1.706
HC-TCT	0.159	10.911	1.737

Finding: For This Shading Pattern, **BL** Configuration Provide maximum Power

IV Graph analysis of Shading Pattern 4





Shading Pattern- 4			
Config.	V	I	P
SP	0.133	11.293	1.506
TCT	0.167	8.183	1.363
BL	0.152	12.248	1.859
HC	0.144	11.429	1.651
HC-TCT	0.156	11.375	1.769

Finding: For This Shading Pattern, **BL** Configuration Provide maximum Power

3.8 Advantages

- Photovoltaic (PV) modules typically come with 20 year warranties that guarantee that the panels will produce at least 80% of the rated power after 20 years of use. The general aging effect is that panels will degrade by about each year. that’s why this aging configuration is the best way for obtain the solar power system

3.9 Applications

- Used to all thing of Residential and industrial p-v solar system.
- This system used for old panel in solar power plant.
- Used in ocean navigation system.
- Used in telecommunication system ,radio transceivers on mountain tops

Chapter 4

Results Analysis

We will compare the random and IM configuration of the values we worked with in chapter 3

4.1 Comparison of Random vs Im Based Configuration

SP Connection

Arrangement by Im		
I	V	P
0.507	11.457	5.808
0.529	11.02	5.831
0.522	11.457	5.977

Random Arrangement		
I	V	P
11.484	0.485	5.567
11.211	0.500	5.600
10.366	0.522	5.408
11.429	0.503	5.752
11.457	0.496	5.681

TCT Connection

Arrangement by Im		
I	V	P
0.444	9.738	4.324
0.562	9.793	5.508
0.603	9.274	5.593
0.577	9.274	5.353

Random Arrangement		
I	V	P
11.511	0.477	5.495
11.975	0.477	5.716
11.784	0.485	5.712
11.729	0.503	5.903
11.157	0.529	5.903

BL Connection

Arrangement by Im		
I	V	P
0.625	11.375	7.113
0.559	11.757	6.569
0.585	11.157	6.522
0.618	10.938	6.759

Random Arrangement		
I	V	P
10.202	0.544	5.549
10.993	0.500	5.491
11.075	0.511	5.655
10.911	0.525	5.733
10.857	0.529	5.744

HC Connection

Arrangement by Im		
I	V	P
0.622	11.02	6.85
0.618	10.911	6.742
0.599	10.911	6.54
0.562	11.511	6.474

Random Arrangement		
I	V	P
11.866	0.485	5.752
11.457	0.529	6.062
11.648	0.492	5.732
12.548	0.433	5.432
11.348	0.525	5.962

HC-TCT Connection

Arrangement by Im		
I	V	P
0.607	10.366	6.29
0.596	10.12	6.029
0.566	11.266	6.378
0.559	11.375	6.355

Random Arrangement		
I	V	P
11.648	0.477	5.560
11.511	0.496	5.708
11.566	0.466	5.392
11.566	0.481	5.563
11.102	0.522	5.792

Table-4.1: Comparison of Random vs Im Based Configuration

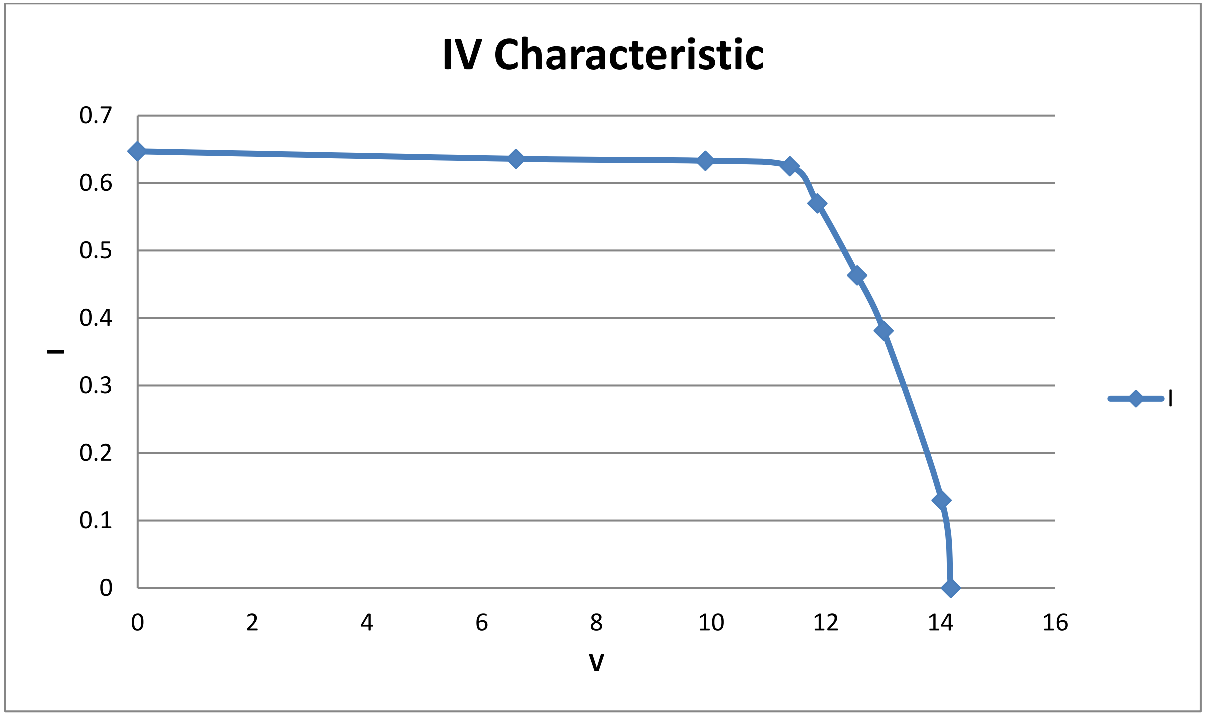


Fig:-4.1: The Highest I-V characteristic of Im based configuration of BL connection

4.2 PV cells Maximum power comparison sheet for various connection type with shading effect

PV cells Maximum power comparison sheet for various connection type with shading effect

	SP Connection			TCT Connection			BL Connection			HC Connection			HC-TCT Connection		
	I	V	P	I	V	P	I	V	P	I	V	P	I	V	P
Without Shading	0.507	11.457	5.808	0.444	9.738	4.324	0.625	11.375	7.113	0.622	11.02	6.85	0.607	10.366	6.29
	0.529	11.02	5.831	0.562	9.793	5.508	0.559	11.757	6.569	0.618	10.911	6.742	0.596	10.12	6.029
	0.522	11.457	5.977	0.603	9.274	5.593	0.585	11.157	6.522	0.599	10.911	6.54	0.566	11.266	6.378
				0.577	9.274	5.353	0.618	10.938	6.759	0.562	11.511	6.474	0.559	11.375	6.355
Shading 6*1	0.392	11.484	4.505	0.485	8.729	4.231	0.492	10.393	5.115	0.496	11.184	5.545	0.474	10.911	5.168
	0.433	10.911	4.724	0.485	8.729	4.231	0.5	10.475	5.232	0.459	11.047	5.069	0.429	11.348	4.871
	0.414	11.457	4.748	0.496	8.729	4.328				0.466	11.02	5.138	0.477	10.884	5.195
										0.437	11.457	5.002			
Shading 6*2	0.259	10.938	2.834	0.281	9.165	2.578	0.3	11.375	3.41	0.337	10.366	3.491	0.34	10.911	3.715
	0.281	10.366	2.916	0.311	8.729	2.714	0.289	11.457	3.307	0.303	10.911	3.311	0.315	10.993	3.458
	0.266	11.32	3.017	0.366	7.61	2.788				0.322	11.457	3.689	0.363	9.738	3.532
Shading 3*2	0.133	12.084	1.611	0.156	8.729	1.357	0.144	12.384	1.788	0.13	12.002	1.556	0.144	11.866	1.714
	0.115	12.002	1.378	0.156	9.302	1.447	0.163	12.548	2.044	0.133	11.92	1.589	0.159	10.911	1.737
	0.115	12.139	1.394	0.126	8.729	1.099				0.133	12.793	1.706	0.141	12.193	1.716
Shading 3*4	0.111	11.457	1.273	0.122	9.82	1.2	0.156	10.447	1.625	0.13	11.457	1.485	0.148	11.402	1.689
	0.115	11.484	1.319	0.133	9.847	1.313	0.13	12.466	1.616	0.141	11.429	1.608	0.119	12.302	1.458
	0.133	11.293	1.506	0.167	8.183	1.363	0.152	12.248	1.859	0.144	11.429	1.651	0.156	11.375	1.769

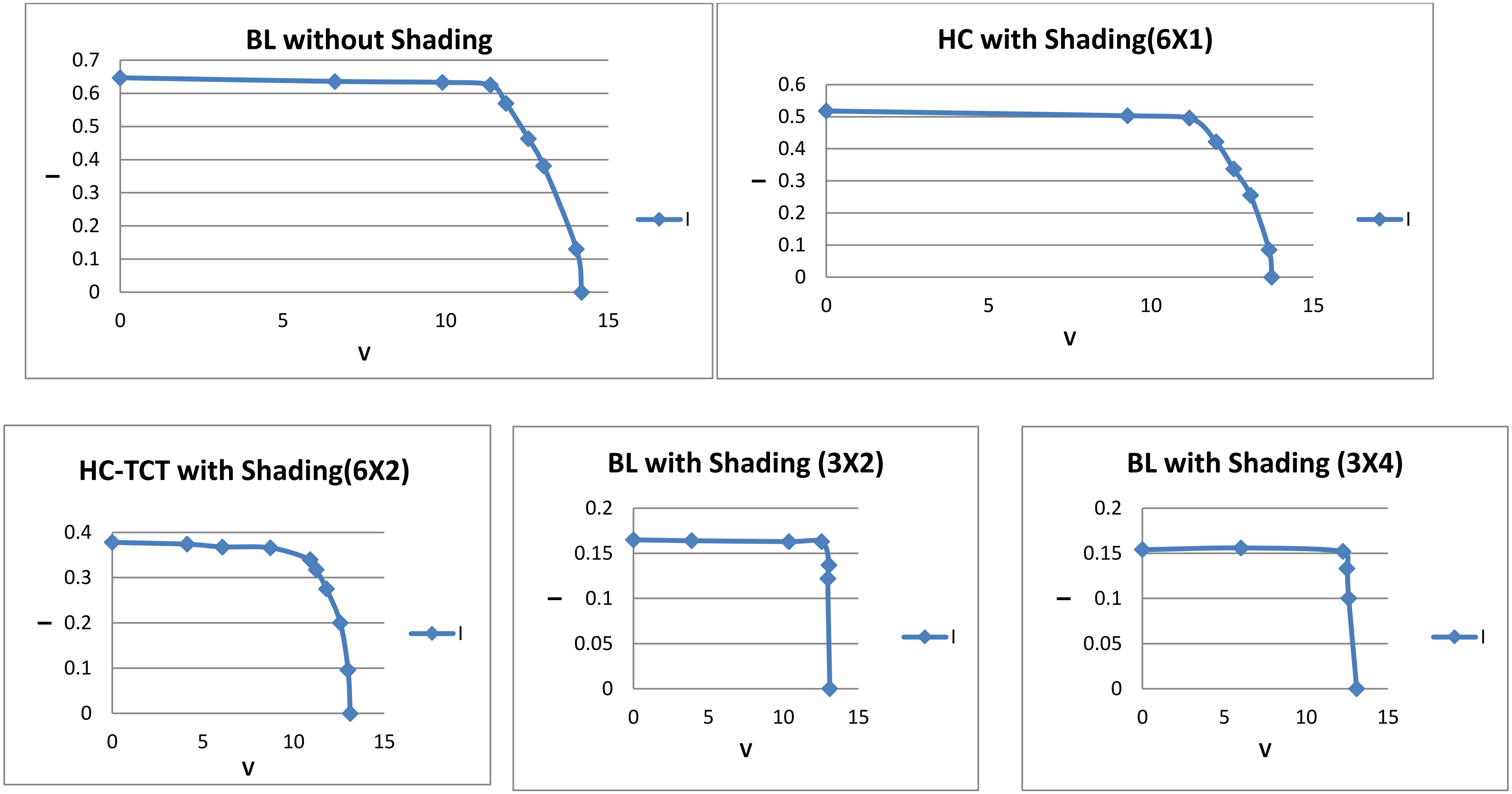


Fig:-4.2: The Highest I-V characteristic of Various configuration

4.3 Comparison of Shading Configuration

The voltage array is give the most large power of LD configuration and the Random array is give the lowest power in the series parallel configuration so our thesis is being recommended to voltage LD configuration.

CHAPTER 5

CONCLUSIONS

The objective of this thesis is “**Experimental Analysis of Shading Effect on PV Array for Different Array Configurations”** we mean by the thesis is that, by configuration the best output detected finding the cell with the best and lowest power available. Here we were many configuration array in aged effect of photo voltaic cells, in this case, we have learned voltage array is give the most large power of LD configuration and the Random array is give the lowest power in the series parallel configuration so our thesis is being recommended to voltage LD configuration.

In this paper an overview of various types of I-V tracers used as interface between photovoltaic system and load to increase the efficiency of the PV system were discussed. Each converter has its own advantages and drawbacks. The selection of a particular type of converter depends upon the output voltage requirement, cost factor and type of application used. As PV generation continues to growing the abroad, more robust and informative monitoring equipment is necessary. I-V curves offer the most information about a PV module.

A single I-V curve may show one or more of these deviations, all of which indicate a reduction in maximum power produced by the module or string under test.

A measured I-V curve may deviate from the ideal IV curve due to physical problems with the PV array under test, or may be the result of incorrect model values, test instrument settings or measurement connections. Always select the correct PV module from the onboard PV module list, double check the measurement connection, and ensure the proper temperature and irradiance values are used.

Future scopes

As a follow up, the authors are working on utilizing SOLAR PANEL System .Ipv and Vpv measurements will be implemented by differential amplifiers and their outputs power, Wpv of the module. This Guide to Interpreting I-V Curves Measurements of PV Arrays is one of a series of application notes, videos and webinars designed to support users of the PVA Analyzer. An understanding of this material will be helpful for PVA users and others who troubleshoot problems in PV strings or modules. However, this level of knowledge is not required to operate or collect data with the PV Analyzer.

To develop maximum power point tracking (MPPT) is a technique which is used commonly with photovoltaic (PV) solar systems to maximize power extraction under all conditions.

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