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Energy and Solar Irradiance Analysis for Hydroponic System

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ABSTRACT

A Simulated impact of partial shadow on photovoltaic (PV) modules and the different partial shading on the PV panel effect on the PV performance is being analysed. The setting for the report is a hydroponic plant system equipped with a solar energy source and IoT at Pangsapuri Jasa, Mutiara Rini. The system control can reduce the carbon footprint and cause no pollution to the environment, while the information gathering process is faster without requiring a lot of time and energy. By collecting the data at Pangsapuri Jasa, the suitable irradiation data is used. The power consumption cannot be monitored by users. A shadow is casted over a panel which make the amount of sunlight reaching the surface is reduced. In addition, the partial shading effects continue to be one of the most demanding issues that directly influence the effectiveness of PV networks in terms of power outputs, the development of several peaks on the power-voltage (P-V) characteristic curve, and the incidence of hot-phenomena. Furthermore, the effective strategies are not being implemented that could save the energy consumption where analysis of the system performance is not practiced consistently when there are available strategies that can improve the system. The purpose of this project is to focus on analyzing the effect of the partial shading to the PV output performance. Also, to monitor the real time monitoring of electricity usage for hydroponic system. This project also covers the analysis of the effect of different configuration of shaded area of partial shadings on PV output performance. The study focuses on a specific kind of shading where photovoltaic panels as a shading device. The study focusses on the analysis of PV output performance on different partial shading conditions. Different number of shadings are being presented to display the experimental set up by using MATLAB Simulink..

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1. INTRODUCTION

The setting for the report is a hydroponic plant system equipped with a solar energy source and Internet of Things (IoT) at Pangsapuri Jasa, Mutiara Rini. The system control can reduce the carbon footprint and cause no pollution to the environment, while the information gathering process is faster without requiring a lot of time and energy. This hydroponic farming should not be an obstacle to be applied either as a hobby or commercially, especially by urban residents who have space and time constraints.

While the availability of conventional energy sources like fossil fuels is dwindling, electrical energy demand and consumption are now rising quickly. In order to solve this, alternative energy sources including solar, wind, tidal, geothermal, and biomass are being used more widely. The most common and well-liked alternative energy source is solar photovoltaic (PV) technology. However, temperature and light intensity, which are nonlinear and may fluctuate significantly with changes in meteorological conditions, have an impact on the output of PV systems. As a result, in situations of partial shade, the properties of PV modules in an array may differ.

The solar system is a superior and dependable source of renewable energy that is free from pollution and requires low maintenance, is recyclable, and has an unlimited supply. The efficiency of photovoltaic (PV) systems is largely influenced by factors such as radiation, module temperature, and array setup. It is crucial to have an understanding of the effect of shading and its relationship with the output power of the PV array in order to optimize its performance. Partial shading occurs when the different modules in the array receive varying levels of irradiance and can be caused by conditions such as nearby buildings, trees or unpredictable events like clouds or buildings.

2. METHOD

2.1 Simulating the PV array

Solar cell is a device based on semiconductor that convert the energy from sunlight's photon into electrical signal using photovoltaic effect. Hence, they are also called photovoltaic cell. The current-voltage (I-V) characteristics of PV cell which is typical silicon that operating under typical set of parameters. Power produced by a solar cell approximately equal to current times voltage (I x V). The power curve shown may be constructed for a particular radiation intensity by integrating all voltage, from short-circuit to open-circuit, point for point.

The power consumption depending on voltage, temperature, and sun irradiation can be retrieved by performing the algorithm and retrieving all of the model parameters. The model employed in this research covers any numbers of PV cells which are already linked together and in series or parallel configurations and operate with the same temperature and sun radiation intensity. In this circumstance, a few multipliers must be added to the basic equation to accommodate for the number of cells.

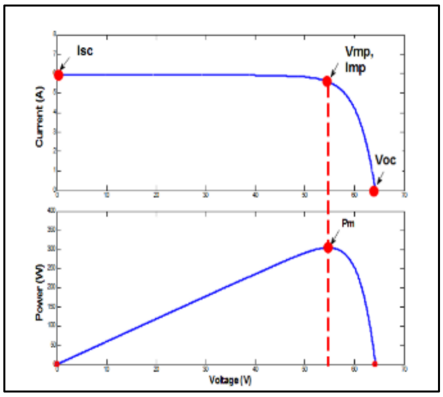

Figure 1 A typical I-V and P-V characteristics of photovoltaic module under STC (25°C and 1000 W/m2)

2.2 PV output characteristics of PV module

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The characteristics of such a PV module are strongly impacted by insolation. The output current equation of the module's I_{ph}-photo generating current value based on irradiation indicates this state. [3] As can be seen, irradiance intensity, G (W/m^2), and I_{ph} are directly related.

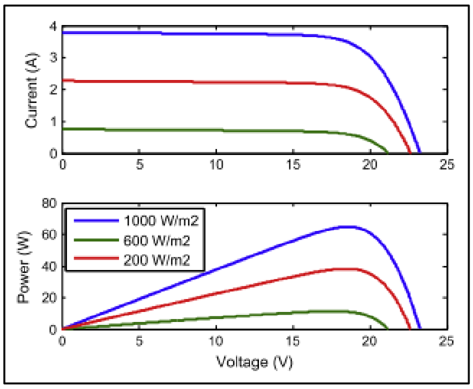

Figure2. PV module's I-V and P-V curves with different irradiance levels and constant temperature value

Figure 2 displays the I-V and P-V curves for the PV module at various insolation levels at constant temperature. The figure shows how the irradiation that enters the module affects the Isc and power values of the module.

2.3 PV output characteristics of PV module

The placement of the PV array is a crucial factor in reducing the effect of partial shading. A proper array arrangement must be preferred in order to get the PV system to produce the desired amount of power. According to the literature, the common PV array topologies are bridge linked (BL), honey comb (HC), total cross-tied (TCT), and series parallel (SP).[3].

The purpose of the recommended reconfiguration approach is to organize panels in rows of matrices that are as identical to one another as is practicable in terms of insolation levels. These modules would frequently encounter current levels, guaranteeing that the series connection would still not run into the current restriction issues. Since the insolation has a significant influence on the module's short circuit current, the PV array's output power array would rise if the adaptive panels were coupled to the fixed section by switches in a manner that made the short circuit currents of each row fairly comparable (Isc).

2.4 Analysis of partial shading condition

A component of the PV array, module, or cell won't get the required amount of irradiance quantity when there is partial shadow. Due to the presence of surrounding structures, dust, trees, and lights or electric poles, partial shading conditions may prevail. [3] In any outdoor area, the PV system might well be entirely or partially shaded by trees, passing clouds, or high-rise buildings, leading in non-uniform insolation circumstances.

Partial shading, which resulting in the photo-generated power of shaded cells being lesser compared to series-connected, un-shaded cells, is one of the primary concerns for PV modules. Without bypass diode, the reverse bias of both the shadowed PV modules would generate hotspot loss and even perhaps fatal reverse breakdown voltage. The short-circuit current Isc increases linearly as the absorbed solar irradiance increases, however the open-circuit voltage V_{OC} of the PV modules reduces linearly as the ambient temperature rises and is reliant on V_{OC}'s temperature coefficient.

2.5 Solar Irradiance Measurement Technology

The irradiance meter in the Solar Survey series is the ideal equipment for solar photovoltaic and solar thermal installers to undertake thorough solar site assessments. In addition to measuring irradiance, these tough portable devices also include an inclinometer to determine the pitch of the roof, a compass to determine the orientation of the roof, and a thermometer to determine the temperature of the surrounding air and the modules. The Solar Survey 100 and 200R are now incredibly adaptable and essential tools, delivering the best possible circumstances for any system you install thanks to these special extra capabilities.

2.6 Configurations of PV module

The placement of the PV array is a crucial factor in reducing the effect of partial shading. A proper array arrangement must be preferred in order to get the PV system to produce the desired amount of power. According to the literature, the common PV array topologies are bridge linked (BL), honey comb (HC), total cross-tied (TCT), and series parallel (SP).

2.7 Experiment and irradiance meter set up

In order to get the data to do the multiple different configurations of panel's shading patterns, the irradiation data collection have been done. The irradiation data was collected at Pangsapuri Jasa such as hydroponic systems that operated with TNB supply or solar panel. The sources of the power supply for the hydroponic systems can be used change over for the equipment for the hydroponic systems of the pumps to keep operate. The operated panel is installed near to the hydroponic system but the setting is currently having a side back for the building interference. The reading of the irradiance collected is not very high compared to the panel's that blocked by building. The irradiance meter is put parallelly to the panel solar to get the exact accurate reading of irradiance of the PV panel.

Table 1 Irradiance meter set up

Data type	**Data**
Irradiance meter used	Solar Survey 200 R Series
Address	Pangsapuri Jasa, Mutiara Rini, 81300 Johor Bahru
Irradiance meter data collected duration	Around 4 hours (9am-1pm)

2.8 Different configuration for 4x4 PV array

The 4 x 4 series parallel (SP) PV array arrangement in MATLAB/Simulink mode. All of the PV modules are linked together in this configuration in series and parallel, first to form strings that produce the desired voltage, and then these strings are linked together in parallel to produce the desired output current. The solar panel layout with 16 solar panels connected in parallel and series is displayed. In the Total Cross Tied (TCT) arrangement, the modules are initially linked in parallel to create parallel-connecting groups, which will then be linked in series. These configurations have a fully connected PV module. When compared to the standard setup, the Bridge Linked (BL) configuration tries to cut the number of connections between neighboring strings of modules in half.

2.9 Modelling and simulation of different configuration under partial shading conditions

The 4 x 4 modules are been simulated to oversee the I-V and P-V characteristics under the partial shading. Sixteen modules connected in series protected by bypass diodes. Simulations have been carried out under uniform conditions, which is at 25°C and 1000 W/m^2 and also under different radiation levels which are illustrated in Table 2.

Table 2. Random shading pattern in [W/M^2] for 4x4 pv array configuration

Row	**String**			
	1	**2**	**3**	**4**
1	800	200	400	1000
2	800	200	1000	1000
3	800	1000	1000	1000
4	1000	1000	1000	1000

3. RESULTS AND DISCUSSIONS

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3.1 Configurations I-V and P-V curve analysis under partial shading under random shading patterns for 4 x 4 modules

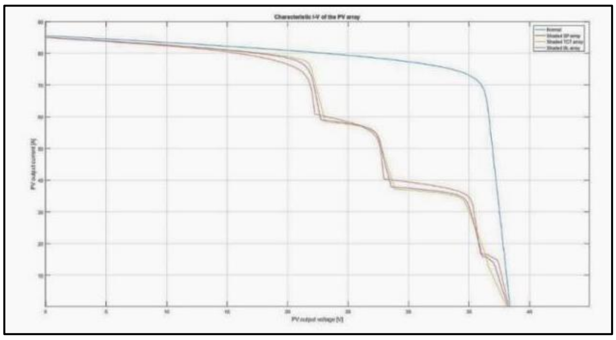
Based on the I-V characteristics of the series-parallel setup, it is observed that the fault configuration deviates from the normal characteristic curve by exhibiting inflection points. This results in a reduction of current while keeping the voltage constant. Consequently, the maximum power obtained under the shading defect is significantly lower compared to the power of a properly functioning system.

Next, model of TCT configuration for 16 PV modules connected in series. Based on the obtained I-V characteristic, the current level at the inflection point slightly decreases due to shadows affecting the PV field. However, the voltage remains at the normal operating level. As a result, the difference in maximum power output between the faulty and healthy operations is not significant. In other words, the TCT configuration during faulty operation produces power that is nearly comparable to the power output during normal functioning.

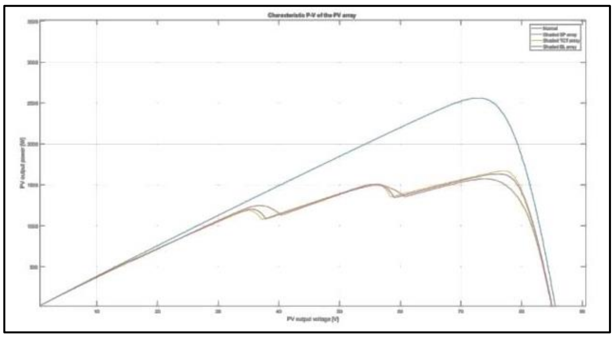
Lastly, based on the I-V characteristics BL configuration, it is observed that the drop in the current level generated by the string when it is in default mode compared to when it is functioning normally reflects the inflection points of fault in the I-V characteristics curve. When compared to the power acquired with the TCT configuration, the maximum power obtained with the BL fault arrangement is thus lower..

3.2 Comparison of results

The SP configuration is made to gain more voltage but less current at each point of inflection compared to other configurations, with a relatively low power compared to the power obtained by other configurations, according to the result obtained by the simulation under the same parameter. Due to the numerous junctions between various modules, including serial and parallel junctions with other modules, the TCT arrangement is the most dependable configuration. In comparison to the other setup, this design offers more voltage and current. As a result, this design offers more power. With one exception, the BL is a configuration similar to the TCT configuration in that it has fewer joints.



(a)



(b)

Figure 3. (a)I-V and (b) P-V characteristic of the PV array for the three configurations (SP, TCT, BL)

3.3 Simulation for a specified duration

Figure 4. shows that solar radiation strikes the PV array at Pangsapuri Jasa Mutiara Rini that indicates the reading of PV array is affected to the partial shading.

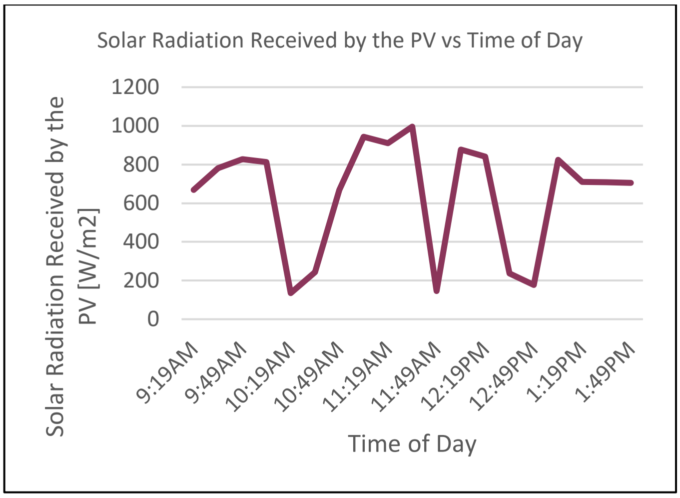


Figure 4. Solar radiation received under the specified time

3.4 Different shading patterns analysis

The indication of shading pattern is being categorized as: 300 W/m^2 – Heavily shaded / covered, 400 W/m^2 – Mild shaded / covered, 500 W/m^2 – Light shaded / covered, and 1000 W/m^2 – Standard Test Condition (STC).

Case 1 – L Shape Shading Pattern

Under this shading pattern, the L shaped positioned modules in a 4 x 4 PV array are subjected to distinct insolation levels, which is given in Table 3.

Table 3. L Shape Shading Pattern

Row	String			
	1	**2**	**3**	**4**
1	300	1000	1000	1000
2	500	1000	1000	1000
3	500	1000	1000	1000
4	500	400	400	400

Each module in a 4 x 4 PV array SP PV array arrangement generates the maximum power of 1660W @ 85.60V and 33.73A under this shade. At 85.60V and 33.72A, the TCT PV array design generates 1609W. The least amount of power is produced by the BL PV array, which puts out 1594W @ 85.60V and 33.73A. Compared to the other configurations, the mismatch power loss is considerable for the BL configuration and low for the SP configuration..

Case 2 - Diagonal Shading Pattern

Under this shading pattern, the diagonal positioned modules in a 4 x 4 PV array are subjected to distinct insolation levels, termed as diagonal shading, which is given in Table 4.

Table 4. Diagonal Shading Pattern

Row	String			
	1	**2**	**3**	**4**
1	300	1000	1000	1000
2	1000	400	1000	1000
3	1000	1000	400	1000
4	1000	1000	1000	500

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At this shading, every module in a 4 x 4 PV array TCT PV array configuration produces the utmost power of 2168 at 85.60V and 33.72A. The SP PV array configuration produces the lowest power of 1894W at 85.60V and 38.55A. The BL PV array configuration produces power of 2159W at 85.60V and 33.71A. The mismatch power loss is high for SP and low for TCT configuration compared to the other configuration.

Case 3 – Corner Shading

Under this shading pattern, the corner positioned modules in a 4 x 4 PV array are subjected to distinct insolation levels, which is given in Table 5.

Table 5. Corner Shading Pattern

Row	String			
	1	2	3	4
1	300	500	1000	1000
2	400	1000	1000	1000
3	400	1000	1000	1000
4	1000	1000	1000	1000

Each module in a 4 x 4 PV array TCT design generates the maximum power of 2168 @ 85.60V and 33.72A under this shade. 1894 W at 85.60 V and 38.55 A is the lowest power generated by the SP PV array arrangement. Power output from the BL PV array setup is 2159W at 85.60V and 33.71A. When compared to the other setup, the mismatch power loss is significant for SP and low for TCT arrangement.

3.5 Power of PV array from different PV array configuration

Several shade distributions were simulated, as shown in Fig. 5, and the results reveal that each arrangement offers the same maximum power at a uniform distribution of sun irradiation. When one or two columns are completely and equally darkened, the maximum power for any configuration is the same. The TCT configuration, however, consistently offers the optimum performance between the maximum powers and lowest relative power losses when the shadow irregularly and partially covers the installation.

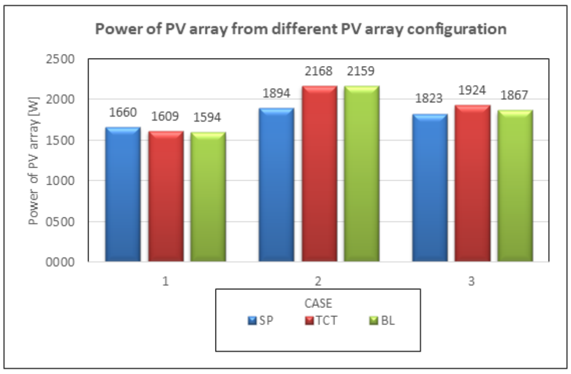

Figure 5. Power of PV array from different PV array configuration

4. CONCLUSION

By conducting simulations and analyses on different PV solar configurations, valuable data was generated, shedding light on the strengths and weaknesses of various setups under partial shading scenarios. These findings contribute to the growing body of knowledge in the renewable energy sector and provide useful information for designing and optimizing PV systems for maximum efficiency and productivity.

In conclusion, this project was successful in examining how partial shadowing affects the operation of PV systems and how that affects how much electricity is used in a hydroponic setting. The research's conclusions and findings can be used to improve the efficiency and dependability of PV systems, promoting the long-term adoption of renewable energy sources across a range of applications. The TCT design, out of the three possible configurations, usually always offers the optimum performance between the highest powers and the lowest relative power losses.

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CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Author1: Conceptualization, Methodology, Software, Project administration. **Author2**: Software, Writting – original draft. **Author3**: Writing – review & editing. **Author4**: Validation**.**

DECLARATION OF COMPETING INTERESTS

There is no competing financial interests or personal relationships.

DATA AVAILABILITY

Data will be made available on request.

REFERENCES

[1] N. Belhaouas et al., "A new approach of PV system structure to enhance performance of PV generator under partial shading effect," J. Clean. Prod., vol. 317, no. June 2020, p. 128349, 2021, doi: 10.1016/j.jclepro.2021.128349.

[2] F. Salem and M. A. Awadallah, "Detection and assessment of partial shading in photovoltaic arrays," J. Electr. Syst. Inf. Technol., vol. 3, no. 1, pp. 23–32, 2016, doi: 10.1016/j.jesit.2015.10.003.

[3] C. Saiprakash, A. Mohapatra, B. Nayak, and S. R. Ghatak, "Analysis of partial shading effect on energy output of different solar PV array configurations," Mater. Today Proc., vol. 39, pp. 1905–1909, 2021, doi: 10.1016/j.matpr.2020.08.307.

[4] C. Tubniyom, W. Jaideaw, R. Chatthaworn, A. Suksri, and T. Wongwuttanasatian, "Effect of partial shading patterns and degrees of shading on Total Cross-Tied (TCT) photovoltaic array configuration," Energy Procedia, vol. 153, pp. 35–41, 2018, doi: 10.1016/j.egypro.2018.10.028.

[5] Jordan Dirk C., Silverman Timothy J., Wohlgemuth John H., Kurtz Sarah R., and VanSant Kaitlyn T., "Modeling , analysis and comparison of shading effects in a photovoltaic array using different configurations," no. July, 2017.

[6] S. R. Pendem and S. Mikkili, "Modeling, simulation and performance analysis of solar PV array configurations (Series, Series–Parallel and Honey-Comb) to extract maximum power under Partial Shading Conditions," Energy Reports, vol. 4, pp. 274–287, 2018, doi: 10.1016/j.egyr.2018.03.003.

[7] C. Tubniyom, R. Chatthaworn, A. Suksri, and T. Wongwuttanasatian, "Minimization of losses in solar photovoltaic modules by reconfiguration under various patterns of partial shading," Energies, vol. 12, no. 1, 2019, doi: 10.3390/en12010024.

[8] B. A. Alsayid, S. Y. Alsadi, J. S. Jallad, and M. H. Dradi, "Partial Shading of PV System Simulation with Experimental Results," Smart Grid Renew. Energy, vol. 04, no. 06, pp. 429–435, 2013, doi: 10.4236/sgre.2013.46049.

[9] H. M. H. Farh and A. M. Eltamaly, "Maximum power extraction from the photovoltaic system under partial shading conditions," Green Energy Technol., pp. 107–129, 2020, doi: 10.1007/978-3-030-05578-3_4.

[10] H. S. Sahu, S. K. Nayak, and S. Mishra, "Maximizing the Power Generation of a Partially Shaded PV Array," IEEE J. Emerg. Sel. Top. Power Electron., vol. 4, no. 2, pp. 626–637, 2016, doi: 10.1109/JESTPE.2015.2498282.

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