Design and Simulation and Performance of Grid Connected Photovoltaic System for Small, Tall Building in Malaysia

Wei Kang Lai[1], Kim Soon Chong[1,*], Mohammad Arif Bin Ilyas[1], Sew Sun Tiang[1], Zhi Ying Yeoh [1], Jia Wei Tan[1], Wei Hong Lim[1]
[1]Department of Electrical and Electronics Engineering, Faculty of Engineering, Technology and Built Environment, UCSI University, 56000 Cheras, Kuala Lumpur, Malaysia
E-mail: 1001953677@ucsiuniversity.edu.my, chongks@ucsiuniversity.edu.my, MohammadArif@ucsiuniversity.edu.my, tiangss@ucsiuniversity.edu.my, 1001954348@ucsiuniversity.edu.my, 1001953809@ucsiuniversity.edu.my, limwh@ucsiuniversity.edu.my
([1]UCSI University, Malaysia)

Abstract

In Malaysia's rapidly urbanizing landscape, sustainable energy for small, tall buildings is increasingly vital. This study addresses this need through the design, simulation, and performance analysis of grid-connected photovoltaic systems tailored for these unique structures. Utilizing AutoCAD and PVSyst for design and simulation, the research details rooftop array dimensions, PV panel wiring, and system components aligned with MS 1837-2018 standards. Results indicate the designed system can save 526.70MWh annually, costing RM 339,306.98, with a 9.8% return on investment (ROI) and a 13-year breakeven point, emphasizing its sustainability and economic viability.

Keywords: PVSyst, AutoCAD, Cost saving, ROI, Breakeven point

1. INTRODUCTION

In recent years, as non-renewable energy sources such as coal, oil, natural gas, chemical energy, and nuclear fuel have begun to run out and sustainable development has begun to be threatened, the use of renewable energy has become increasingly important. All these energy sources are also harmful to the environment and can lead to environmental problems such as greenhouse gas (GHGs) emissions and hazardous chemical waste [1], [2], [3]. Therefore, research and development of renewable energy sources is crucial.

Among various renewable energy options, rooftop solar photovoltaic (PV) systems are a popular and effective method for collect solar energy [1]. A grid-connected rooftop solar photovoltaic system is a solar power generation system that is connected to the grid and can transmit excess energy back to the grid. In addition, Malaysia is one of the countries with the greatest potential for solar energy utilization due to its strategic location near the equator. Through the research, the monthly solar irradiance for Malaysia is estimated at 400-600 MJ/m^2 as well as its hot and sunny weather throughout the year, thus the potential for solar power is very large [4]. However, the design and implementation of a grid-connected rooftop solar PV system requires careful consideration of several factors, including the selection of appropriate solar panels, system sizing, inverter selection, and system integration with existing electrical infrastructure.

In Malaysia, the rapid growth of urbanization has led to an increased demand for sustainable energy solutions. Despite the potential benefits of grid-connected photovoltaic (PV) systems in meeting this demand, there is a lack of comprehensive research addressing the design, simulation, and performance analysis tailored specifically for the unique challenges posed by small, tall buildings in the Malaysian context. The main objective of this paper is to bridge this gap by investigating the optimal design parameters, conducting detailed simulations, and performing a thorough performance analysis of grid-connected PV systems. The outcomes of this study are expected to provide valuable insights into the feasibility and efficiency of implementing grid-connected PV systems in this specific urban setting, contributing to the advancement of sustainable energy solutions for the region.

2. METHODOLOGY

2.1. *Calculation and Selection for Solar Panel*

In this study, one of the buildings in the UCSI university was selected for installing the PV panels. The selected building, named Block C, located at No. 1, UCSI Heights, Jalan Puncak Menara Gading, Taman Connaught, 56000 Cheras, Federal Territory of Kuala Lumpur. As shown in Fig. 1, the satellite view shows that there are 12 faces on the rooftop with the tilts of 30 degrees in each azimuth. The area of the rooftop was calculated to be 3194m^2. However, only 8 faces are decided to install the PV panels which is 2129m^2 and the other 4 faces are for cleaning and technical maintenance. These data were then used to create a 3D model of the rooftop in 3D AutoCAD, and the appropriate PV array size was decided using 1120 modules of SunPower X22-360 solar panels based on calculated by using expected power for each orientation which is 50kW and spaces on the rooftop. Below is the calculation:

$$Area\ for\ placing\ PV\ panels = \frac{3{,}194m^2}{12} \times 8$$
$$= 2{,}129m^2$$

$$No.of\ PV\ panels = \frac{50{,}000W}{360W}$$
$$= 140\ modules$$

$$Total\ no.of\ PV\ panels = 140\ module\ \times 8$$
$$= 2{,}129m^2$$

$$Power\ generated = 1{,}120\ modules\ \times 8$$
$$= 403{,}200W$$

Apart from that, to convert the DC power generated by the solar panels into AC power, the model of Goodwe GW50KLV-MT inverter had been selected.

The SunPower X22-360 Solar panel is a high-performance solar panel designed for residential and commercial applications. In a six-story building, SunPower's X22-360 solar panels can be used to generate renewable energy to offset the building's energy consumption. The electricity generated by the solar panels can be used to power lighting, heating, ventilation, and air conditioning (HVAC) systems and other electrical equipment in the building, while excess energy can be fed back to the grid to generate revenue for the university through a net metering program. Additionally, the X Series panels have a 25-year warranty and are made to be long-lasting and robust. This long-term durability improves X-Series panels a cost-effective, sustained producing electricity for many years [5].

The Goodwe GW50KLV-MT is a three-phase grid-tied inverter intended to transform the direct current (DC) power produced by the solar panel arrays into alternating current (AC) power that can be supplied into the utility system. Goodwe GW50KLV-MT has also built-in safety features like ground fault protection (GFP) and surge protection devices (SPDs) for both DC and AC inputs, which provide both the safety of the solar PV system and the building's occupants [6].

The inverters of the system were installed at exterior placement to create a more spacious indoor environment and address safety concerns related to preventing electrical hazards. Placing the inverters at exterior placement not only minimizing energy waste from cable resistance but also enhance efficiency by reducing the length of the DC wire between the solar panel and the inverter.

Figure 1: Satellite view of a building's rooftop

2.2. *Solar panel layout design*

The floor plan of the roof PV panels was construct based on the Google Maps satellite images as shown in Fig. 1. The dimensions of the SunPower X22-360 were obtained from the data sheet in order to arrange the panels in the most effective and aesthetically acceptable way possible. The route of the DC wires from the PV panels to the inverter and the AC cables from the inverter to the electrical panel was also determined at this point. Thorough the analysis, a 3D model of PV system design on the rooftop was showed in 3D AutoCAD shown in Fig. 2.

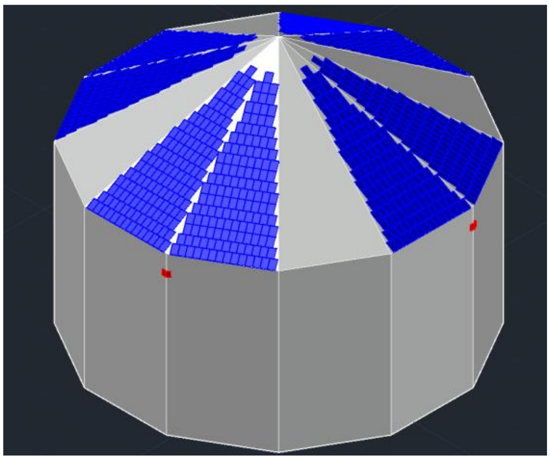


Figure 2: 3D Modelling rooftop design

2.3. Wire Connection

Leapfrog chain wiring, as outlined in Fig. 3 is the best and suitable wiring design for string panels that are not organized in a straight line due to its simplicity, ease of use, cost saving and electromagnetic loop reduction which represent less voltage drop [7], [8].

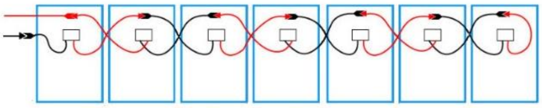


Figure 3: Leapfrog Wiring

According to the MS 1837-2018 standard, single-line diagram of the system shown in Fig. 4 was designed and outlined the minimum requirements for the installation of grid-connected PV systems. This diagram provides a clear and concise representation of the system components, including the arrangement of PV array, inverters, DC and AC disconnects, and electrical panels. It also includes details on the system grounding and protection devices, such as surge protectors and overcurrent devices [9].

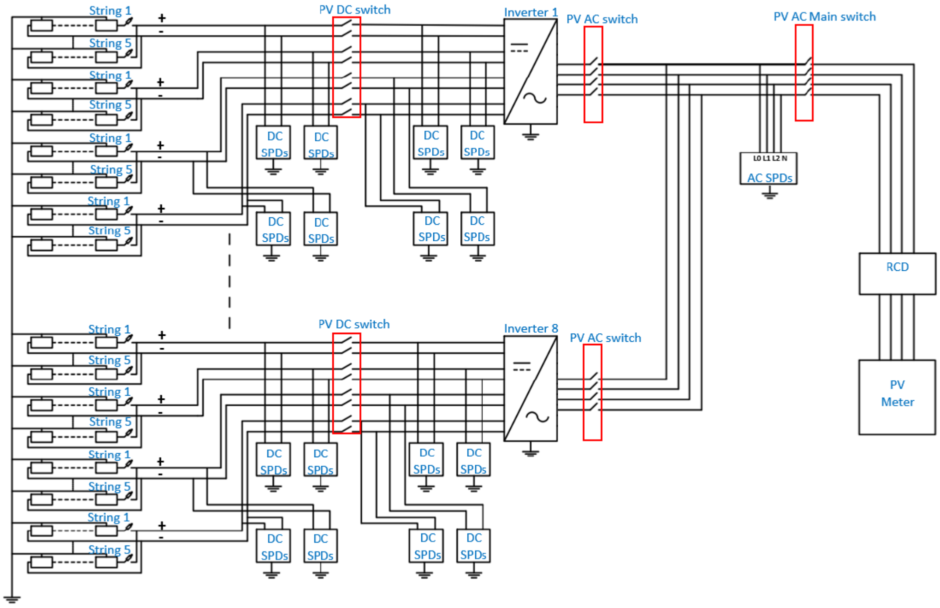


Figure 4: Single-line diagram

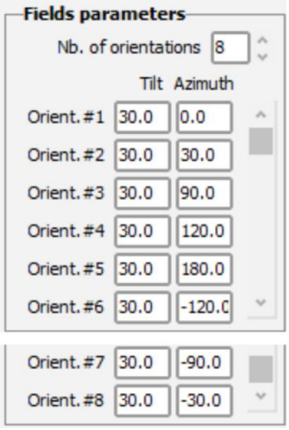
In Fig. 4, the direct current (DC) electricity produced by the 5 strings of 7 solar panels was routed through DC surge protective devices (SPDs) positioned before and after the PV DC switch. The DC SPDs safeguard the system against surges and overvoltage. The DC electricity was then routed through the PV DC switch to the eight generators. Each inverter has four MPPT (maximum power point tracking) sources to optimize electricity production from the panels.

The wires before and after the PV DC switch and the wires before and after the PV AC switch were selected as MC4 compatible for the head and tail of the wire and through calculation. Due to the design of 7 module of solar panels in series connection and each module can generate 60.6V at maximum power point, the output of the voltage will be 424.2V.

Through the calculation, the voltage for the wires required to withstand is at least 424.2V. Thus, due to the critical safety aspect, THHN/THWN-2 wire which can withstand 600V was selected to prevent the wiring from overheating and overload that may cause fire hazard and short circuit. While the other reason for choosing THHN/THWN-2 wire was the temperature rating for this wire is 90 degrees Celsius and could use in wet conditions [10].

2.4. *Selection in PVsyst software*

In Fig. 5, it depicts the desired tilts and azimuths. Azimuths of 0°, 30°, 90°, 120°, 180°, -120°, -90°, -30° have been selected for placing the solar panels on the rooftop.



Fields parameters

Nb. of orientations 8

	Tilt	Azimuth
Orient. #1	30.0	0.0
Orient. #2	30.0	30.0
Orient. #3	30.0	90.0
Orient. #4	30.0	120.0
Orient. #5	30.0	180.0
Orient. #6	30.0	-120.0
Orient. #7	30.0	-90.0
Orient. #8	30.0	-30.0

Figure 5: Orientations (Tilts and Azimuths)

In the PVSyst software, the selection and application of dimensions, photovoltaic modules and inverters are shown in Fig. 6. The SunPower X22-360 model for the solar panel and the Goodwe GW50KLV-MT model for the inverter were chosen for each orientation in PVSyst software. The inverters will conduct 4 MPPTs each, as the operating DC voltage needs to fall within the MPPT voltage range of the inverter. Therefore, 5 strings that are connected in parallel will be connected to one of the MPPT for the inverter. A total of 20 strings, each consisting of 7 solar panels per string, will be subject to application based on the expected power determined in PVSyst software, which is 50 kW.

After all the values and the selection was applied, the voltage maximum power point obtained is 367V and 418V at 60 degrees and 20 degrees, while AC voltage is 531V. Moreover, the value of array nominal power at Standard Test Conditions (STC) also determine as 50.4kWp.

Besides, to account for the various variables that may influence the system's real performance as opposed to the idealized circumstances anticipated in laboratory testing, the Thermal Losses, Ohmic Losses, Power Loss at Maximum Power Point(MPP), Soling Loss, and Aging Losses has been applied in the PVsyst software. These variables may include shading, weather, soiling, inefficient modules, and inverters, among other practical and environmental problems that could eventually result in a drop in power production. It is possible to get a more accurate estimate of the system's real energy yield and financial success by including these losses in the simulation. It is also possible to find prospective areas for optimisation and development.

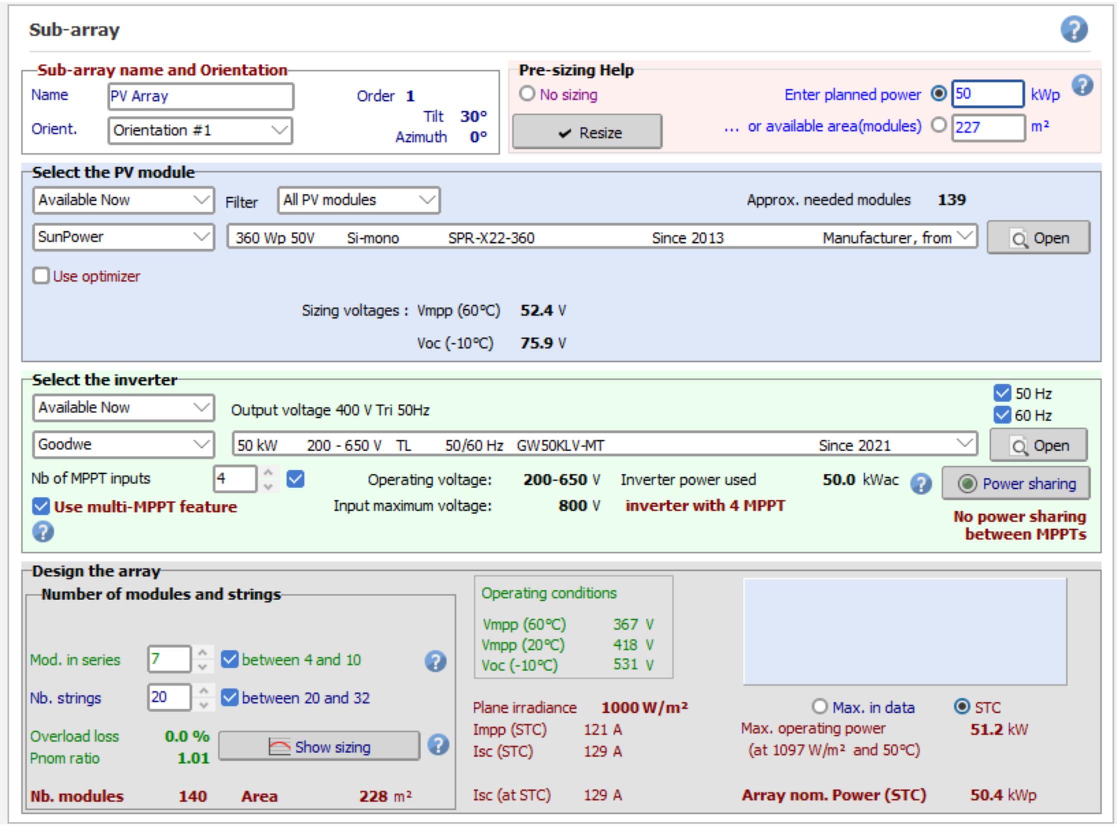

Sub-array
Sub-array name and Orientation
Name: PV Array
Order 1
Orient.: Orientation #1
Tilt 30°
Azimuth 0°
Pre-sizing Help
○ No sizing
Enter planned power ● 50 kWp
… or available area(modules) ○ 227 m²
Select the PV module
Available Now
Filter: All PV modules
Approx. needed modules 139
SunPower
360 Wp 50V Si-mono SPR-X22-360 Since 2013 Manufacturer, from
☐ Use optimizer
Sizing voltages : Vmpp (60°C) 52.4 V
Voc (-10°C) 75.9 V
Select the inverter
Available Now
Output voltage 400 V Tri 50Hz
☑ 50 Hz
☑ 60 Hz
Goodwe
50 kW 200 - 650 V TL 50/60 Hz GW50KLV-MT Since 2021
Nb of MPPT inputs 4 ☑
Operating voltage: 200-650 V
Input maximum voltage: 800 V
Inverter power used 50.0 kWac
inverter with 4 MPPT
☑ Use multi-MPPT feature
No power sharing between MPPTs
Design the array
Number of modules and strings
Mod. in series 7 ☑ between 4 and 10
Nb. strings 20 ☑ between 20 and 32
Overload loss 0.0 %
Pnom ratio 1.01
Nb. modules 140
Area 228 m²
Operating conditions
Vmpp (60°C) 367 V
Vmpp (20°C) 418 V
Voc (-10°C) 531 V
Plane irradiance 1000 W/m²
○ Max. in data ● STC
Impp (STC) 121 A
Isc (STC) 129 A
Max. operating power 51.2 kW
(at 1097 W/m² and 50°C)
Isc (at STC) 129 A
Array nom. Power (STC) 50.4 kWp

Figure 6: Sizing and system applied in PVSys

2.5. *Arrangement of Solar Panels*

The spacing between the solar panels is an essential factor in the design of solar photovoltaic systems, as shown in Fig. 7. The rationale behind providing adequate space was to ensure that there is proper ventilation and air flow around the panels. This aids to keep the panel cool, subsequently enhances performance.

Minimizing shading is imperative, it can significantly reduce the output of photovoltaic systems. Therefore, by leaving space between panels, can mitigate the risk of shading, which occurs when one panel casts a shadow on another panel.

The accumulation of dust or debris can also degrade the panel's performance [11]. Therefore, leaving space between panels is essential, providing convenient for maintenance and cleaning. Overall, allocating sufficient space for solar panels is vital, ensuring optimal performance, power efficiency, and longevity of solar photovoltaic systems.

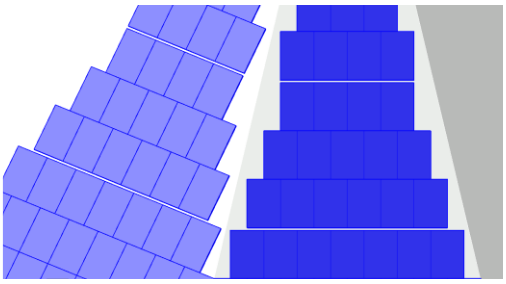


Figure 7: Spacing between Solar panels

2.6. *Budget of the project*

An expenditure of 911,192 dollars, equivalent to RM 4,309,026.97, as shown in Table 1, was anticipated for the acquisition of PV panels and solar inverters utilized in this project.

Table 1: Total cost of material

Product	Model	Total unit	Single unit price (dollar)	Total price of all units (dollar)
PV panel	SunPower X22-360	1,120	800	896,000
Solar inverter	Goodwe GW50KLV-MT	8	1,899	15,192
Total				911,192

3. RESULT AND DISCUSSIONS

3.1. *PVsyst Analysis*

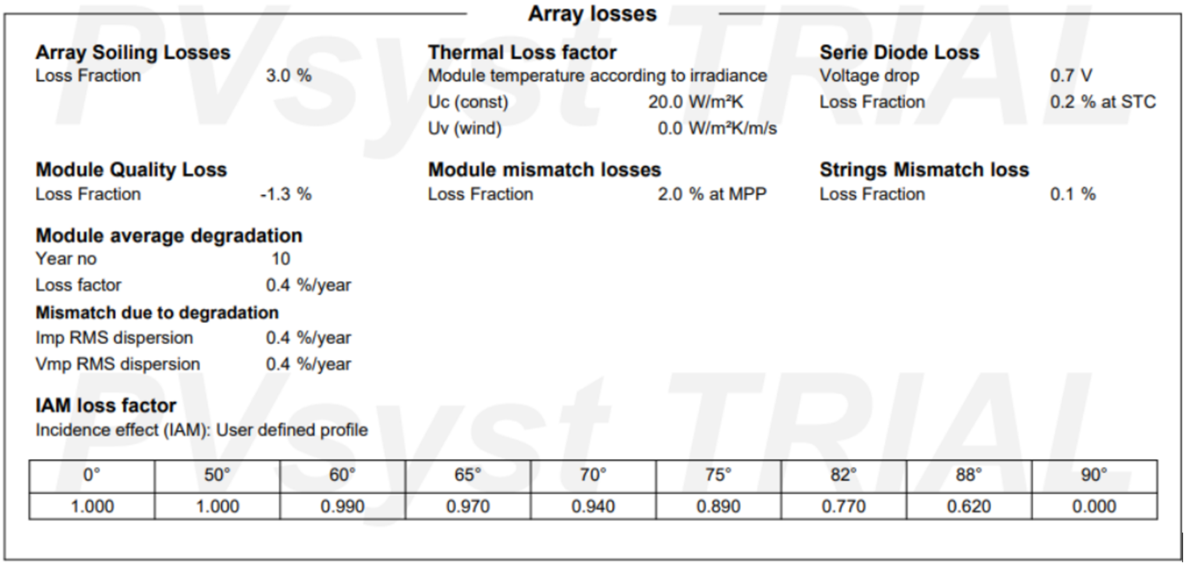
The array loss analysis simulated by PVSyst software as outlined in Fig. 8. The series diode typically exhibits a default voltage drop of 0.7 V. Concurrently, ohmic losses emerge from the resistance in wires and connectors, contributing to a potential decline in the solar system's output power.

To quantify these losses within the subfield, the loss fraction was specified as STC which is 2%. In this scenario, the solar system achieves a total power output of 400 kW at STC and ohmic losses are stipulated at 2%, the resultant power loss due to ohmic factors amounts to 2 kW.

Apart from that, the yearly soiling loss factor indicates the decrease in solar panel energy production caused by dust and dirt accumulation on the surface. It varies depending on the location and environmental conditions of the solar panel installation such as rainfall frequency, wind patterns, and proximity to dust sources can affect the rate of soiling. The annual soiling loss factor was found to be 3% analysed by PVSyst software, reducing solar panel's performance. This outcome can be used to determine the cleaning frequency needed to ensure the solar panel performing optimally.

The PVSyst module analysis revealed an average degradation of 0.4% per year with a 10-year loss factor. This indicates that the module's efficiency is expected to decrease by 0.4% each year over the course of 10 years.

The analysis also revealed a mismatch due to degradation and resulting in Root Mean Square of Current (Imp RMS) and Root Mean Square of Voltage (Vmp RMS) dispersions of 0.4% per year. Owing to the degradation of the panels, the current and voltage output from the solar panels will experience slight deviations over time. These findings highlighted the importance of regular maintenance and monitoring of the solar panels to ensure optimal performance and efficiency over the long-term.



Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

Serie Diode Loss
Voltage drop 0.7 V
Loss Fraction 0.2 % at STC

Module Quality Loss
Loss Fraction -1.3 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

Module average degradation
Year no 10
Loss factor 0.4 %/year

Mismatch due to degradation
Imp RMS dispersion 0.4 %/year
Vmp RMS dispersion 0.4 %/year

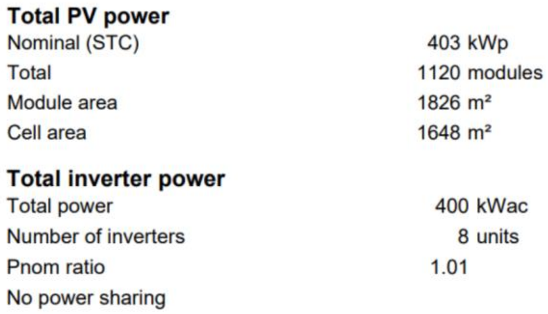
IAM loss factor
Incidence effect (IAM): User defined profile

0°	50°	60°	65°	70°	75°	82°	88°	90°
1.000	1.000	0.990	0.970	0.940	0.890	0.770	0.620	0.000

Figure 8: Array Loss analysis

Within the total PV power characteristic, the total number of utilized PV modules is 1,120, generating a nominal (STC) output of 403 kWp as shown in Fig. 9, which is consistent with the calculated value. The covered module area and unit area are 1,826m^2 and 1,648 m^2 respectively.

The total power of the inverters that have converted was 400kWac and the number of the converter used is 8 units. The ratio of PV to inverter power is measured as the DC/AC ratio whereby ideal value is 1.25. Nevertheless, the simulation analysis indicates the power nominal (Pnom) ratio is 1.01, falling short of the recommended healthy ratio for the PV system.



Total PV power	
Nominal (STC)	403 kWp
Total	1120 modules
Module area	1826 m²
Cell area	1648 m²
Total inverter power	
Total power	400 kWac
Number of inverters	8 units
Pnom ratio	1.01
No power sharing	

Figure 9: Total PV power and inverter power

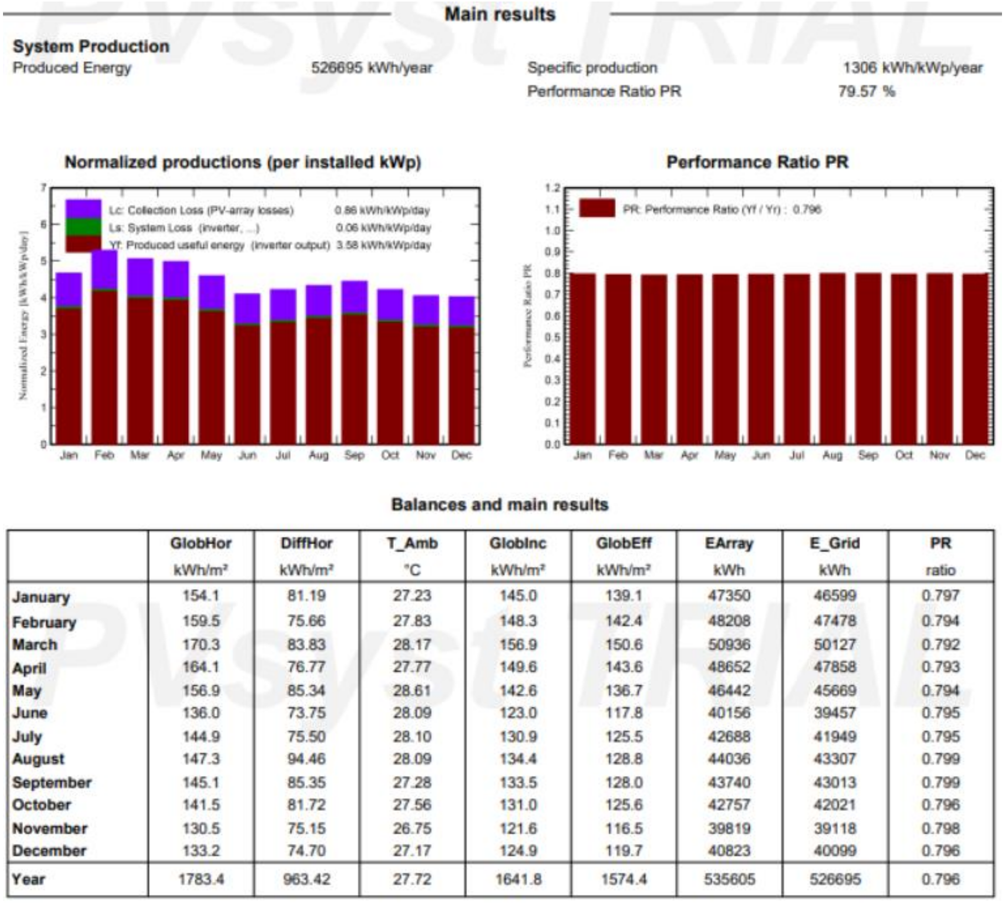
In Fig. 10, it shows the total global horizontal irradiation (GlobHor) for the given area was found to be 1,783.4 kWh/m^2, whereas the total horizontal diffuse irradiation (DiffHor) was calculated to be 963.42 kWh/m^2. During this period, the average ambient temperature (T_Amb) was 27.72℃. The total global incidence in coll. plane (Globinc) was calculated to be 1,641.8 kWh/m^2, indicating a reduction in the total energy incident on the module due to the tilt angle and orientation.

According to the PVSyst analysis the obtained results affirm that the PV system was performing well in terms of energy production. The high specific production or high output of 1,306 kWh/kWp/year indicates that the system was well-designed and well-maintained, which was a positive sign. In addition, the total energy injected into the 526,695kWh grid indicated a critical commitment to the overall electricity supply on site.

The analysis of the results indicates that, in the given location, the PV module tilt point and the degree of inclination are not optimally configured. This was reflected in the comparatively lower value of Globinc in comparison to GlobHor.

By focusing on the DiffHor value of 963.42 kWh/m2, the location of the PV system is not highly shaded, which was a positive factor for energy production. The average ambient temperature during the study period of 27.72°C was considered within the cycle and is also within the ideal temperature range for photovoltaic system performance.

Apart from that, the average performance ratio (PR) that indicates the efficiency of the system in converting the solar energy into electrical energy was calculated to be 0.796, equivalent to 79%, which is close to 80%. Nevertheless, for the year 2010 is found to be between ~70 and ~90% and shows a median PR of 84%. However, the analysis shows that it does not getting 84% the PV system due to the imperfection of tilts. To solve this problem, it is recommended to add an adjustable mounting system for optimal tilt and performance [12].



Main results

System Production

Produced Energy	526695 kWh/year	Specific production	1306 kWh/kWp/year
		Performance Ratio PR	79.57 %

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	154.1	81.19	27.23	145.0	139.1	47350	46599	0.797
February	159.5	75.66	27.83	148.3	142.4	48208	47478	0.794
March	170.3	83.83	28.17	156.9	150.6	50936	50127	0.792
April	164.1	76.77	27.77	149.6	143.6	48652	47858	0.793
May	156.9	85.34	28.61	142.6	136.7	46442	45669	0.794
June	136.0	73.75	28.09	123.0	117.8	40156	39457	0.795
July	144.9	75.50	28.10	130.9	125.5	42688	41949	0.795
August	147.3	94.46	28.09	134.4	128.8	44036	43307	0.799
September	145.1	85.35	27.28	133.5	128.0	43740	43013	0.799
October	141.5	81.72	27.56	131.0	125.6	42757	42021	0.796
November	130.5	75.15	26.75	121.6	116.5	39819	39118	0.798
December	133.2	74.70	27.17	124.9	119.7	40823	40099	0.796
Year	1783.4	963.42	27.72	1641.8	1574.4	535605	526695	0.796

Figure 10: Balance and main results

In this study, the efficiency of the PV system has comprehended by the system output power distribution graph as shown in Fig. 11. The graph shows that the system operates at optimum efficiency, with a peak energy injection of 9 MWh/class of 2.5 kW, corresponding to a power injection of 240 kW. Notably, the majority of the energy injected into the grid falls within a stable range of 5 to 7 MWh/class of 2.5 kW, suggesting efficient and consistent operation. The distribution graph provides useful insights into the system's performance that can be used to find potential areas for development and optimize the functioning of the PV system. By knowing the power levels at which the system produces the most energy, the system can be operated to maximize energy output at these power levels.

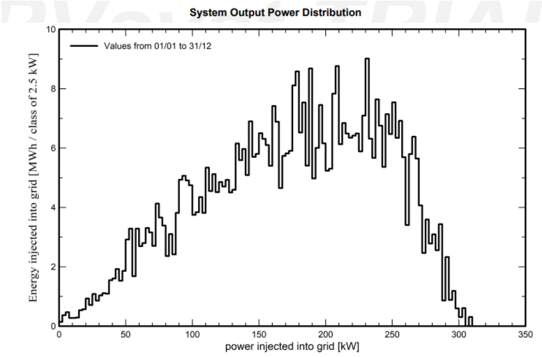


Figure 11: Power distribution graph

3.2. *Estimate Cost Saving, Breakeven point and Return of Investment (ROI)*

According to the analysis, 526.70 MWH can be generated throughout the year, with an average of 43.891 MWH per month. The electricity bill is calculated using the formula provided by Tenaga National Berhad (TNB), as shown below:

Electricity Bill = (Consumed electricity x First 200 kWh rate) + (Consumed electricity x Next 100 kWh rate) + (Consumed electricity x Next 300 kWh rate) + (Consumed electricity x Next 300 kWh rate) + (Consumed electricity x Next 901 kWh onwards per month) *(6% tax)

Table 2: Year of the ROI

	Electricity Bill
Per Month	RM 28,146.24
Per Year	RM 339,306.98

Through the calculation, user can save minimum up to RM 28,146.24 per month and RM 339,306.98 per year as shown in Table 2. Besides, the use of electricity from the solar panels are prioritised instead of using electricity from the TNB grid whereby surplus electricity will not be wasted and exported back to TNB.

$$ROI = \frac{Net\ profit}{Cost\ of\ Investment} \times 100$$

$$Year\ 1 = \frac{RM339{,}307 - RM4{,}350k}{RM4{,}350k} \times 100$$
$$= -92\%$$

Table 3: Year of the ROI

Year	ROI = (Net profit / cost of investment) x 100
1	-92%
2	-84.4%
3	-76.6%
4	-68.8%
5	- 61%
6	-53.2%
7	-45.4%
8	-37.6%
9	-29.8%
10	-22%
11	-14.2%
12	-6.4%
13	1.4%
14	9.2%

Breakeven point (in year)
= Fixed Costs / Gross Profit Margin
= RM 4,309,026.97/ RM 339,306.98
= 12.69 year

At the beginning of the investment, it resulted in a net loss and no returns due to the high upfront cost of the system which is RM 4,309,026.97 [13]. In Year 13, the ROI has become positive after 12 years as shown in Table 3. Beyond the 13th year, it is expected to be in a profit-making state, where the saving from the electrical bill exceeds the total cost of panels ordered. Regarding the breakeven point analysis, it shows this project needs to take 12.69 year which is almost 13 years to reach the breakeven point.

4. CONCLUSION

This study examines the potential of installing a solar photovoltaic (PV) system at a small, tall building in Malaysia. The analysis considers factors such as the building's energy demand, available space, and the financial feasibility of the proposal. The findings of the analysis reveal that a 403-kW solar PV system has the capacity to generate approximately 526695 kWh of electricity and helps to save up to RM 339,306.98 per year which can satisfy the building's power requirements.

Apart from cost saving and power supply, the performance of PV systems is not optimal. In order to take full advantage of the potential capabilities of the system and reduce performance differences, key recommendations for the future include the adoption of adjustable mounting systems. This technology facilitates dynamic tilt regulation, ensuring optimal alignment of photovoltaic panels with incoming sunlight, thereby improving overall energy conversion efficiency. However, the calculation of the ROI and the breakeven point shows it takes 13 years to reach profit-making state with no expenses. This is because of the upfront cost of the system is high to begin with.

5. ACKNOWLEDGE

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

1. M. Alsulaiman and N. Mohammadi, “Optimal Pitch Distance and Tilt Angle of PV Power Plant for Different Climate,” 2020.
2. S. I. Mustapa, L. Y. Peng, and A. H. Hashim, “Issues and challenges of renewable energy development: A Malaysian experience,” in Proceedings of the International Conference on Energy and Sustainable Development: Issues and Strategies, ESD 2010, IEEE Computer Society, 2010.
3. F. Chien, L. Huang, and W. Zhao, “The influence of sustainable energy demands on energy efficiency: Evidence from China,” *Journal of Innovation and Knowledge*, vol. 8, no. 1, Jan. 2023.
4. W. S. W. Abdullah, M. Osman, M. Z. A. A. Kadir, and R. Verayiah, “The potential and status of renewable

energy development in Malaysia," Energies (Basel), vol. 12, no. 12, 2019.
5. F. Reil, I. Baumann, J. Althaus, and S. Gebhard, "Evaluation of current standards and practices for the simulation of wind-blown sands and their applicability as accelerated ageing tests for PV modules," in Conference Record of the IEEE Photovoltaic Specialists Conference, Institute of Electrical and Electronics Engineers Inc., 2013, pp. 1537–1541.
6. "MT G2 Series User Manual Grid-Tied PV Inverter." [Online]. Available: www.goodwe.com
7. T. Bravo Mahachi and A. Johan Rix, "Energy yield analysis and evaluation of solar irradiance models for a utility scale solar PV plant in South Africa," 2018.
8. A. Eric El Obeid, "BEST-PRACTICES GUIDELINES AND LESSONS LEARNT FOR ON-GRID AND PV-DIESEL HYBRID SYSTEMS." [Online]. Available: www.lb.undp.org/DREG
9. "MALAYSIAN STANDARD Installation of grid-connected photovoltaic (PV) system (Second revision) DEPARTMENT OF STANDARDS MALAYSIA DEVELOPMENT OF MALAYSIAN STANDARDS," 2018, [Online]. Available: http://www.sirim.my
10. C. Marketing, "THHN/THWN-2 600V CT RoHS CABLE." [Online]. Available: www.nexans.co
11. F. Saeed and A. Zohaib, "Quantification of Losses in a Photovoltaic System: A Review †," Engineering Proceedings, vol. 11, no. 1, 2021.
12. N. H. Reich, B. Mueller, A. Armbruster, W. G. J. H. M. Van Sark, K. Kiefer, and C. Reise, "Performance ratio revisited: Is PR > 90% realistic?," in Progress in Photovoltaics: Research and Applications, Sep. 2012, pp. 717–726.
13. C. Houston, S. Gooberman-Hill, R. Mathie, A. Kennedy, Y. Li, and P. Baiz, "Case study for the return on investment of internet of things using agent-based modelling and data science," Systems, vol. 5, no. 1, Mar. 2017.

Authors Introduction

Mr. Wei Kang Lai

He is currently pursuing Bachelor of Electrical and Electronics Engineering as final year student in Faculty of Engineering, Technology and Build Environment, UCSI University, Malaysia. His research interests are electrical and solar system design.

Ms. Zhi Ying Yeoh

She is currently pursuing Bachelor of Engineering Electrical and Electronics with Honors as final year student in Faculty of Engineering, Technology and Built Environment, UCSI University, Malaysia. Her research interests are electrical and power electronics.

Ms. Jia Wei Tan

She is currently pursuing Bachelor of Engineering Communication and Electronics with Honors as final year student in Faculty of Engineering, Technology and Built Environment, UCSI University, Malaysia. Her research interests are communication and antenna design.

Dr. Sew Sun Tiang

She is an Assistant Professor in Faculty of Engineering at UCSI University in Malaysia. She received her PhD in Electrical and Electronic Engineering from Universiti Sains Malaysia in 2014. Her research interests are optimization and antenna design.

Dr. Kim Soon Choong

He obtained his B.Eng., M.S., and Ph.D. degrees in electrical and electronic engineering from Universiti Kebangsaan Malaysia in 2012, 2015, and 2019, respectively. He currently serves as an Assistant Professor in the Department of Computer Engineering (Artificial Intelligence) within the Faculty of Engineering Technology and Built Environment at UCSI Kuala Lumpur. His research focuses on areas such as medical signal processing and instrumentation.

Dr. Mohammad Arif Bin Ilyas

He received his PhD in Electrical Engineering from Universiti Tun Hussein Onn Malaysia in 2020. He also earned his bachelor's degree in electronic engineering at the same university. Currently, he is a lecturer in the Faculty of Engineering, Technology, and Built Environment at UCSI University. His main areas of research interest are machine learning, artificial intelligence, etc.