Journal of Advanced Research in Applied Sciences and Engineering Technology 52, Issue 1 (2025) 192-208

SEMARAK ILMU
PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Analysing the Performance of Large-Scale Rooftop Solar PV System Using Heliscope, PVsyst and PV*SOL Photovoltaic Simulation Software: As a Renewable Energy Strategy

Logeswaran Govindarajan[1,*], Mohd Faizal Mohideen Batcha[2], Suzairin Md Seri[2] Mohammad Kamil Abdullah[2], Juntakan Taweekun[3]

[1] Faculty of Mechanical and Manufacturing Engineering, University Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor, Malaysia
[2] Center for Energy and Industrial Environment Studies (CEIES), University Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor, Malaysia
[3] Faculty of Engineering, Prince of Songkhla University, Thailand

ARTICLE INFO

Article history:
Received 3 March 2024
Received in revised form 20 August 2024
Accepted 28 August 2024
Available online 1 October 2024

Keywords:
Photovoltaic energy yield; performance analysis; simulation software PVsysts; Heliscope; PV*SOL

ABSTRACT

In Malaysia, government initiatives and policymakers play significant role in creating effective strategies aiming at enhancing the usage of residential, industrial and commercial solar PV systems. However, the most significant barrier to the widespread adoption of photovoltaic (PV) systems is their high installation costs; as a result, numerous studies on PV system modification are now being conducted. Several simulation tools are available for the efficient and extensive integration of solar energy. To predict energy output using climate data and assess performance ration in accordance, such software can be optimized in terms of parameters like PV module number, inverter, tilt angle, and module design structure. The accuracy of these figures fluctuates, though, because climate factors affect how productive photovoltaic systems are. In this current paper, the simulation and design of a 6.9 MW solar power plant in University Tun Hussein Onn Malaysia, have been investigated using three popular software PVsyst v5.06, Heliscope and PV*SOL. This study's main objective is to assess the potential of solar renewable energy sources to produce electrical energy under the Supply Agreement of Renewable Energy (SARE) program using flexible solar system design modelling tools, PVsyst, Heliscope, and PV*SOL. The comparison results showed that Heliscope and PVsyst are considered to be the most dependable software. PVsyst appraised the definite energy production cost with lowermost relative error of 0.12 % and Heliscope estimated performance ratio with lowest relative error of 4.74%. In terms of energy losses, environmental element contributing to the most energy losses where PVsysts recorded 11.1% photovoltaic (PV) loss caused by irradiation and temperature changes. Whereby Helioscope clearly shows that environmental power loss of 8.4% represents the largest portion caused by irradiation and temperature changes. PV*SOL recorded an energy loss of 7.3% due to shading, temperature and reflection on module interface.

* *Corresponding author.*
E-mail address: logeskvi@gmail.com

https://doi.org/10.37934/araset.52.1.192208

1. Introduction

The energy is recognized as one of the key building blocks for economic growth, and maintaining the security of the power generation is essential to a nation's ongoing economic progress. With annual growth rate of 0.2 per cent, Malaysia's need for energy is always rising, but the supply is not sustaining up. Recent trends in electricity supply and demand indicate that the nation's reserve buffer will run out within the coming years [1]. Malaysia has to encourage investment, scientific studies, and research in its energy market in order to fulfill this constantly rising energy demand. In addition, Malaysia has long relied on coal to produce energy throughout the country. Tenaga Nasional Bhd (TNB) generated over 67.4% of the electricity used in the peninsula as of 2020 from imported coal, compared to the meager 7.7% coal provided in 1997 [2].

The Malaysian government must immediately hasten efforts to transform the away from a reliance on fossil fuels in the energy sector that generate greenhouse gases, in order to reduce the country's dependency on coal as an energy source and ensure energy security [3].

By 2030, Malaysia has pledged to use energy that is cleaner, more sustainable, and renewable in an effort to reduce the GDP intensity of its greenhouse gas emissions by up to 45% (RE). Without include hydropower, Malaysia plans to increase the proportion of renewable energy in its electrical mix to 20% by 2025 [4]. Malaysia is expected to boost its capacity for renewable energy as part of the process from 6 to 14 GW, increasing its proportion of the generation mix from 18 to 30%.

The goal of Yaakob *et al.,* [5] research work is to build a stable floating buoy as a wave energy harvester for the Malaysian coastal area as a potential source of ocean-based electricity. Given that its metacentric height is higher than its center of gravity and that it is feasible in the coastal region of Peninsular Malaysia, the floating buoy exhibits a noteworthy result for stability under static settings. A point absorber's advantage is that it can gather energy from waves coming from all directions at one marine area, making it very suitable for use in Malaysia's energy harvesting system.

Given that wind energy possesses the qualities of a clean energy source, through the use of computer simulation, Didane *et al.,* [6] the results of simulations and performance studies of a counter-rotating vertical axis wind turbine (VAWT) based on the Savonius S-type rotor. Based on the K-omega shear stress transfer (SST) turbulence model, 3D simulations were run. The findings indicate that when compared to a wind turbine with a single rotor, the counter-rotating model performs better in terms of torque, power, and their respective coefficients. When compared to a single-rotor wind turbine (SRWT), the new CRWT technology produced a maximum output that was more than twice as high. Furthermore, because of the top rotor's faster rotating speed, its output was greater than that of the bottom rotor.

Among the various renewable energy sources discussed earlier, Due to its Sunbelt location and average daily solar radiation of 4500 kWh m-2, Malaysia also has the advantages in developing its solar energy. It receives at least 10 hours of sunlight every day [7]. Institutions and businesses are profoundly investing in the development of green energy. technologies as a result of this desire. Ilham *et al.,* [8] research, aims to identify potential renewable energy resources that can be beneficial to Malaysia by utilizing the Analytic Hierarchy Process (AHP) as an analytical technique to analyze the results of Focus Group Discussions (FGD). The conclusion, taking into account carbon production, recommended that Malaysia strategically concentrate on solar energy. With 33.69% of the total priority vector, solar energy is thought to have the most potential of all the renewable energy sources that Malaysia may employ.

Researchers are interested in photovoltaic energy because it offers a chance for the effective and environmentally friendly method development for transforming this infinite energy using photovoltaic principles, independent energy can be converted to electrical energy. As a result, research is constantly being done to broaden, enhance, and maximize the practice of solar systems. To have a high energy production, it is optimized built on the criterion of scalability and boosting the power produced. Research done by Liang *et al.,* [9] created a four-wheeled base automatic solar tracking robot that can follow a light source. The robot automatically follows the sun's movement to maximize solar radiation, increasing the efficiency of the solar photovoltaic (PV) module. By computing the average resistance value between four light-dependent resistors (LDR) and servo motors that rotate the panel either vertically or horizontally, the robot was trained to detect light sources. DC motors rotated to move the robot in search of a new light source when the solar PV module was shaded. The robot was evaluated on how well and precisely it could sense light. With a 93.33% tracking accuracy, the robot demonstrated its ability to track light. By contrasting the output power of the solar tracking robot with that of a fixed panel, the performance of the robot was also examined. The results show that the solar tracking robot outperformed the fixed panel in terms of solar energy conversion efficiency, increasing it by 10.4/7%. The need for energy harvesting in the most economical manner is being urgently researched.

The most significant barrier to the widespread use of photovoltaic (PV) systems, however, is their high implementation and maintenance costs; as a result, numerous studies on the improvement of PV systems are now being conducted. Frontini *et al.,* [10] compared several simulation technologies in order to highlight alterations and resemblances instead than just comparing numerical replies. A simulated inspection was performed on a building integrated photovoltaic (BIPV) system installed on the sloping roof of a low-energy residence in Bergamo. The 30 modules are positioned on the roof plane with a 15° inclination and a 45° azimuth. The outcome demonstrates mismatch in energy production are influenced by PV panel thermal models as well as electronic power parameter definitions. The energy output production disparities over the course of the year are around 5% between ESPr and PVsyst and between PVsyst and TRNSYS is 11%.

The architecture, modelling, and financial research of a grid-connected 90 kW PV system with nine subsystems, each having a 10-kW capacity, were demonstrated by Dey and Bidyadhar [11]. PVsyst 6.70 application is used for the modelling to properly design the entire system, including defining the solar azimuth, inverter, inclination angle of the PV panels, shading calculation, effectiveness, and technical evaluation. As a result of the simulation, for each 10 kW GCPV system, it was determined that there was 15.55 MWh of annual energy available at inverter output, which is around 3% less than the data on actual energy generation. According to the experimental result, there will be 1,10,03,463 INR in savings over 30 years and a decrease in CO2 emissions of 2200 tons over a 20-year period.

A presentation was given by Mahmoud [12] on the software tools that are frequently used in the design and simulation of solar PV energy systems. SAM, HOMER, PVsyst, PV*SOL, RETScreen, Solar Pro, and PV F-Chart are the programs evaluated in this research. The free software tools and those with a 30-day free trial are the main topics of this chapter. The current work aims to demonstrate these software's capabilities and the kinds of analysis that may be provided. A variety of assessments, including technical, financial, sensitivity, optimization, economic, environmental, shading, and performance characteristics, can be provided using the software tools. Research investigations revealed that all of these software solutions had good yearly agreement with actual measurements. However, depending on monthly computations compared to real data, the error of simulation findings could differ dramatically. According to research, PVsyst exhibit good agreement with real outcomes.

Othman *et al.,* [13] presented a solar PV system structure and cost assessment performance analysis at UiTM Pulau Pinang in Malaysia. On a guardhouse in UiTM Pulau Pinang, Malaysia, a PV system was built to generate power. It runs continuously for 24 hours with a daily load of 9 kWH.

Using HOMER, it is possible to predict the dual-tariff PV system's projected budget. Total investment, maintenance, operational, service, and salvages all have energy costs that are determined to be $31,600, $15,425, $15,851, and -$4,769, respectively. According to the predicted cost breakdown, the system should pay for itself in 25 years. The energy savings can be calculated using this cost analysis, which is especially beneficial for dual-tariff electricity bills that employ PV panels to offset daytime loads and low-tariff electricity at night.

The planning and simulation of a 12.4 kWp rooftop solar system were explored by Prasad *et al.,* [14]. This research investigates the performance ratio, which is 83.2%, and energy output. Additionally, it shows the potential of a certain solar module in addition to other features like tilt angle correction, peak power loss Sankey diagram development, and PVsyst graphing of the power and temperature distribution of the photovoltaic system.

The research conducted in 2023 by Arif *et al.,* [15] at assessed the efficient and economical method of producing electricity in rural areas. Using the existing process, a PV stand-alone energy source is created. The chosen location's solar irradiation is 6.16 kWh/m2/day, but the village's projected total electric load is 64.259 kWh. The Hybrid Optimization Model for Electric Renewable (HOMER) uses the location's solar irradiance and electric load to develop and assess the stand-alone PV system's techno-economic viability in order to satisfy load needs. The HOMER analysis yielded a total Net Present Cost (NPC) of $0.511 M and a Cost of Electricity (COE) of 2.26$/unit for the study. The system is feasible based on the results, producing 30,078 kWh of electricity year with a $0.434 million initial capital investment. Through a comparison of the system performance, this analysis demonstrated that meeting the village's entire electricity needs with a 7.2-year payback period is both technically and economically feasible.

Al Mehadi *et al.,* [16] constructed and assessed a solar PV plant for the rooftop of a university apartment using PVsyst, PV*SOL, and the System Advisor model (SAM). The findings led to an 18.4% reduction in the university house's annual energy use.

PV systems can be improved based on factors like tilt angle, number of Photovoltaic panels, type of modules, design of the modules, inverter, and storage group capacity. PV systems are designed using a variety of user-friendly software in the most effective manner. This type of software uses climate data to estimate energy output and gives economic data in line with that estimate. The accuracy of these figures fluctuates, though, because climate factors affect how productive photovoltaic systems are. This study intends to assess the performance of software commonly used in the solar energy industry, including PVsyst, Helioscope, and PV*SOL, and to identify which software is better at predicting actual energy production data under the climatic circumstances of UTHM, Johor Malaysia.

1.1 Description of the Grid Connected PV System Under Supply Agreement for Renewable Energy (SARE) Agreement Program

TNB and UTHM have formed a cutting-edge relationship when it comes to renewable energy through the SELCO Scheme using the SARE contract [17]. The setting up of a solar PV system with a 6.9 MWp installed capacity at UTHM in Batu Pahat, Johor, marked the completion of this project's alignment with Malaysia's net zero emission by 2050 target and the 2016-2025 Asian Plan of Action for Energy Cooperation [18], which seeks to upsurge the contribution of by 2025, the whole energy mix will include 23% more renewable energy. The system, which has been used since November 12, 2021, was provided to UTHM at no upfront cost. It is charged a fixed rate for energy generated that is less expensive than the grid tariff, and it is paid for running costs and maintenance during the duration of the contract. The UTHM campus in Parit Raja has a 25-building solar system installation that comprises academic faculties, auditoriums, a walkway, and a solar parking lot [19]. The system comprises PV technology: monocrystalline JINKO solar and 3-phase based inverter, Huawei model SUN2000-100KTL-M1, which was next sent straight to the state grid and was utilized to conversion of alternating current (AC) from direct current (DC). It is put on the flat and tilted rooftop of each building at coordinates of 1° 51'32"N 103° 5'8"E and it is divided into 26 sub-structures, as shown Fig.

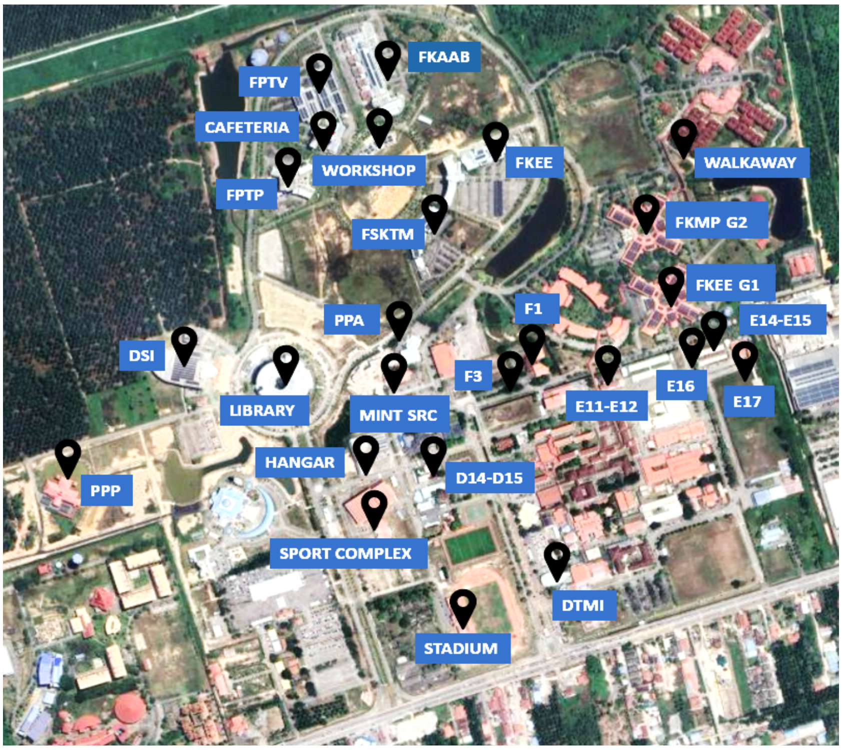


Fig. 1. A 6.9 MWp solar PV system at UTHM comprises 25 subsystems

567 monocrystalline silicon cells and a 300 Wp power rating solar module were employed. With the help of a three-phase Huawei SUN2000-33KTL inverter with a 30-kW rated output power, the grid connection and DC/AC conversion were completed as shown in Figure 2. The PV module and inverter's technical specifications are provided in Table 1. Since the PV system's installation, continuous data on its energy output has been collected, averaged at 5-minute intervals, and kept in a cloud database by FusionSolar. The data used in this study's analysis is taken from January 2022 to December 2022. A local LAN or the internet can be used to quickly access the FusionSolar's built-in web server and on-site data storage.

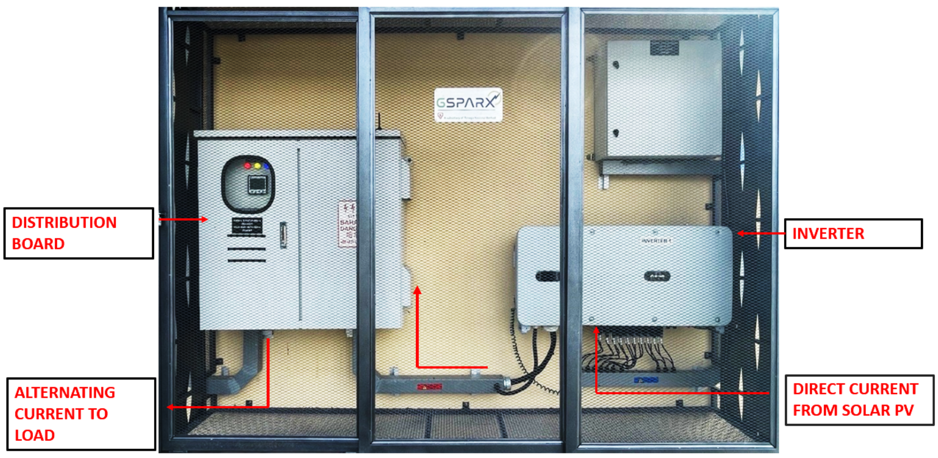


Fig. 2. Inverters (DC) input / output (AC)

Table 1
Specifications for PV and inverter

PV Module		Inverter	
Parameter	Specification	Parameter	Specification
Format of Module	Mono-crystalline silicon	Model	SUN2000-60KTL-M0
P_{max}	315 Wp	Input (DC)	
I_{mp}	9 A	Nominal power, W	200-1000
V_{mp}	35 V	Voltage range, V	1100
I_{sc}	8.68 A	Nominal current, A	
V_{dc}	43 V	Maximum current, A	22
Temperature Coefficient	-0.4 %/℃	Output (AC)	
Efficiency	14 %	Voltage range, V (3-phase)	480
		Nominal current, A	79.4

2. Methodology

2.1 PVsyst Photovoltaic System Simulation

Using the software tool PVsyst, the model can be tested of a grid-connected solar is technically examined; Inverters, PV panels and a utility network interface make up this modelled system [20]. The results of the simulation of photovoltaic systems using a 6.9 MWp PV system simulation model is examined. It is possible to produce a specific amount, mainly in terms of energy losses, performance ratio, and electrical generation. The simulation approach's steps, which were used for the analysis, are as follows:

i. The geological region and weather data for the present site were specified in the design menu.
ii. To configure the PV system appropriately, the PVsyst database, this includes the photovoltaic panel's orientation (Figure 3), its model, and the type of inverter used (Figure 4).

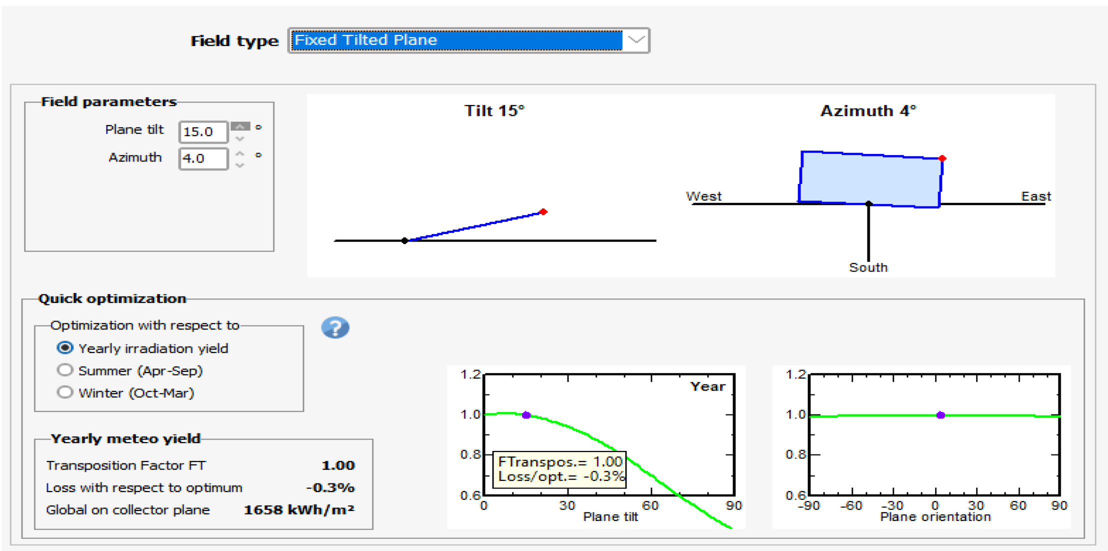


Fig. 3. Tilt angle and plane orientation performance curve

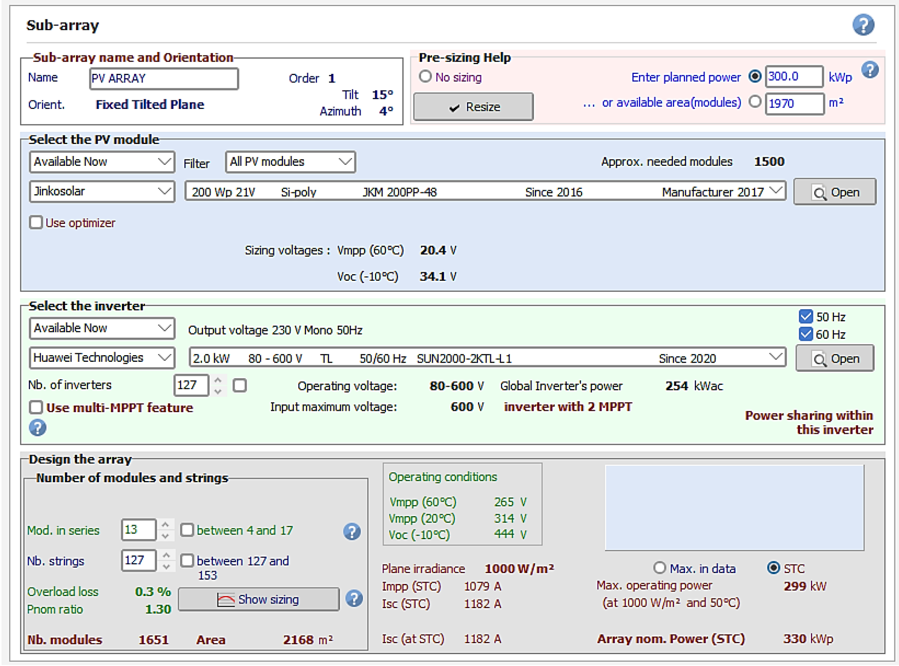


Fig. 4. Identifies the PV module and inverter parameters for 25 subarrays

Figure 5 presents the modeling of the solar horizon for UTHM. The PV panels are facing true south and inclined by 15° according to the simulation, which is conducted under the assumption that the solar azimuth is always 4 and the tilting angle is 15 [21]. On March 20 and September 23, the sun is highest in the sky, while it is at its lowest point on December 22.

For this study, the estimated global incident energy is 1639.8 kWh/m2, the estimated global irradiance is 1663.6 kWh/m2, and the estimated global operational irradiance is 1592.0 kWh/m2 as shown in Figure 6. The 6.9 MWp produces 8928.833 MWh/year of total annual energy, commonly known as generated energy. With this effective irradiance, the annual DC energy is 8539.959 MWh. Additionally, the PV system's performance ratio in the simulated study for the UTHM PV system installed is quite near to 81.1%.

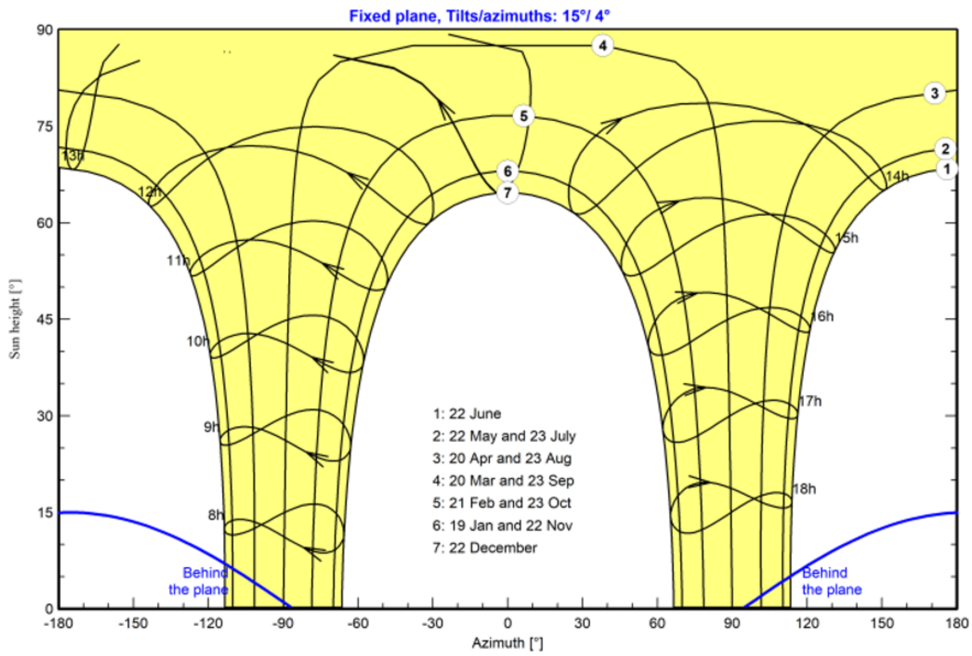


Fig. 5. Modelling of the solar horizon for UTHM

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	138.9	64.80	25.10	150.2	146.5	814442	780413	0.809
February	146.2	60.50	25.40	153.9	150.4	831164	798820	0.809
March	156.9	71.30	25.80	155.5	151.6	841013	806614	0.808
April	146.1	66.90	26.20	137.5	133.2	746246	713833	0.809
May	141.7	64.50	26.10	127.3	122.5	694071	661960	0.810
June	132.3	59.70	25.80	116.3	111.7	637276	607199	0.813
July	133.3	62.90	25.40	118.8	114.2	651158	620212	0.813
August	134.2	67.30	25.50	125.0	120.9	685954	654323	0.815
September	135.9	69.00	25.60	132.7	128.9	726109	694073	0.815
October	141.7	69.40	25.90	145.8	142.1	797356	763724	0.816
November	130.2	63.90	25.80	139.3	135.9	752672	720262	0.806
December	126.2	63.20	25.29	137.4	134.1	751371	718527	0.814
Year	1663.6	783.40	25.66	1639.8	1592.0	8928833	8539959	0.811

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Fig. 6. Solar PV modelling output for UTHM, Johor

The loss diagram in Fig. was derived from the PVsyst simulation, and it allows for the analysis of the numerous losses incurred during the installation of the photovoltaic installation. Information on the various losses in the system is provided below: Every hour over the course of a year, the global horizontal radiation, a mix of the world's diffuse radiation and its direct radiation is computed for a horizontal surface, is shown in the first section of this diagram. Our PV system's value is -1.4%. AMI Overall Factor: The greater loss results from a higher incidence angle which is dependent on where the sun is located. It is roughly 2.9%.

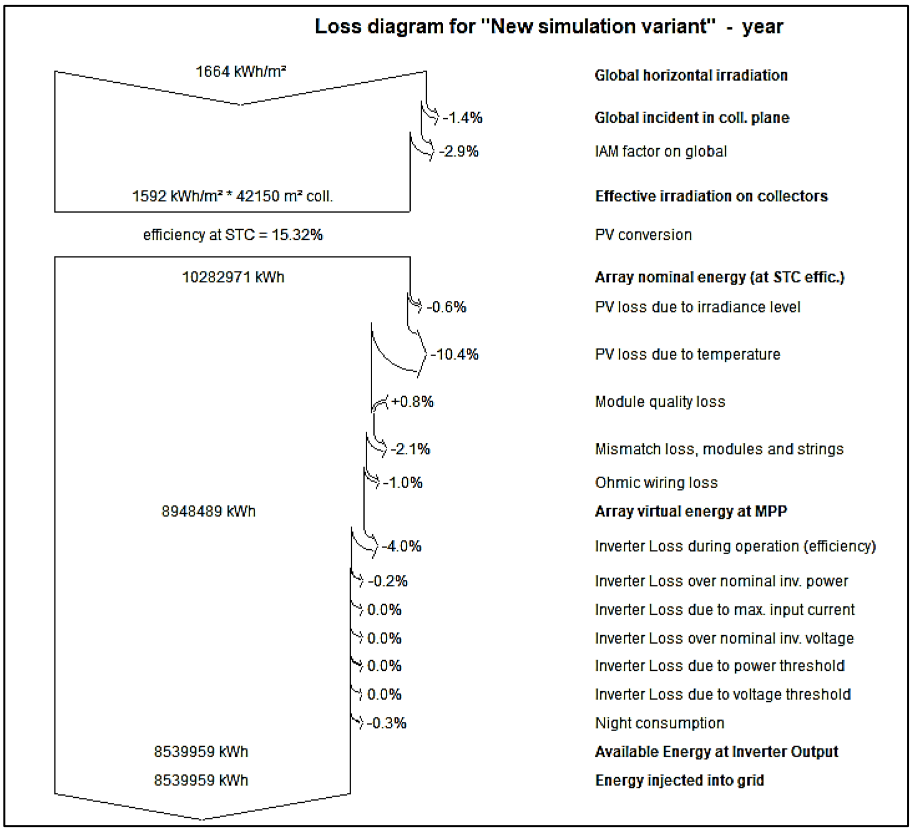
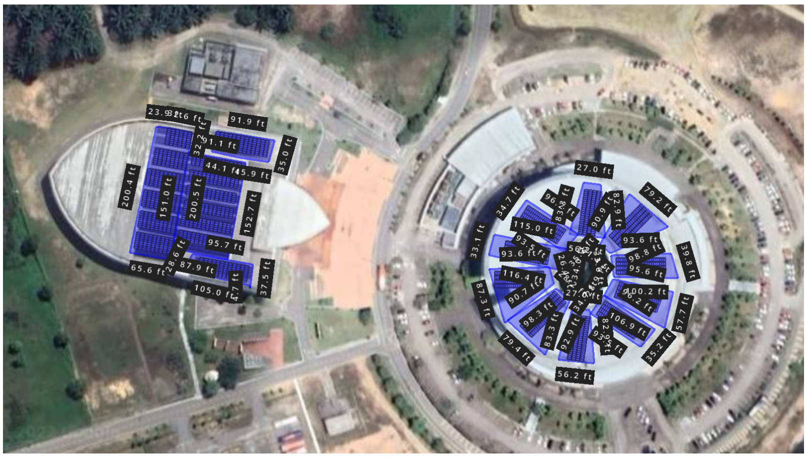


Fig. 7. The loss diagram from the PVsyst simulation

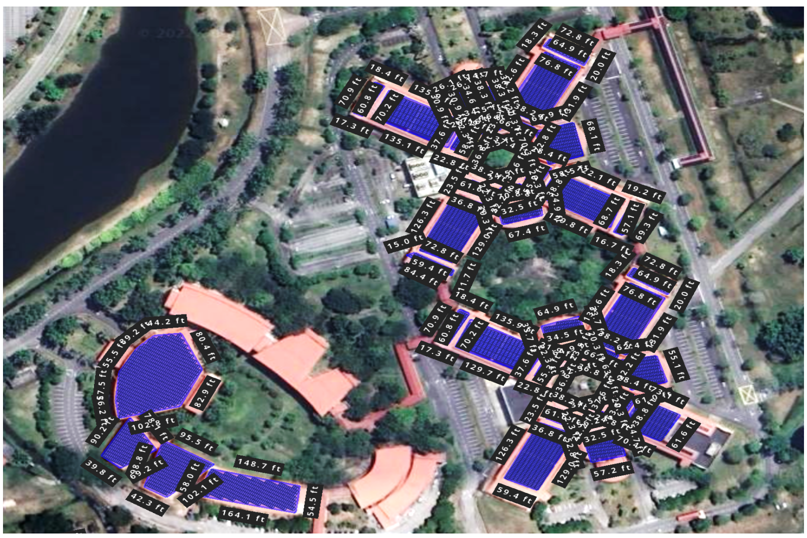
As listed all types of PV system losses in the second section, including the 0.6% PV loss caused by irradiation. The 10.5% PV loss because of temperature variations is what lowers the performance of the module. The module's quality loss is 0.75%. Module mismatches loss accounts for 2.1% of the system's energy loss. 1.0% of wiring loss is ohmic. For PV systems, the inverter efficiency, which measures the inverter's DC to AC conversion efficiency weighted by the change in power stages over the course of the year, is 4.0%.

2.2 Simulation of Photovoltaic System with Helioscope

For the 6.9 MWp solar PV system that was installed, Helioscope was selected as the additional piece of software to run the simulation and calculate the energy generation. As HelioScope provides significant images of the globe, the PV array can be constructed easily. Also, this software is able to generate a thorough solar report based on the site's location and current weather information. The ability to rapidly and simply select different PV layouts, PV modules, and inverters using user-friendly tools is one of the key benefits of using this software to study numerous modeling scenarios and ultimately select the best PV architecture. This software's mechanical design tool aids in module layout. Compared to PV Syst near shadings, this is simpler. It enabled the creation of distinct field segments, allowing for the proper electrical wiring of each inverter, as seen in Figures 8(a) and (b).



(a)



(b)

Fig. 8. Design simulation rooftop of study area (a) Area 1 (b) Area 2

The system losses determined from the modeling program HelioScope are shown in Figure 9. In order to examine the losses throughout a year, a pattern must be formed, and certain criteria, such as losses resulting from de-rating factors, must be taken into account. It is clear that shading power loss represents the largest portion whereas the clipping losses are undoubtedly the smallest. The temperature, irradiance, inverter and reflection losses are 7.5%, 0.9%, 2.1% and 3.3 % respectively. Losses due to soiling are negligible because they make up a small fraction of 2.2% of the total losses and overall plant installed on rooftop and not majorly effect the required energy demand for UTHM. Overall, the environmental element was to responsibility for the bulk of losses.

Figure 10 shows the monthly energy production for modelling software. In January, the radiant intensity is 721.604 MWh, while in March, it is at its peak, 766.268 MWh. Solar radiation declines during the course of the months, reaching 650.923 MWh in June. August sees a second peak to 677.733 MWh, which is once more swiftly followed by a decline to the lowest value of 598.936 MWh in November 2022. The 6.9 MWp roofstop photovoltaic performance measured with helioscope simulation of annual production, performance ratio which is 8.146 GWh and 73.6% respectively as shown in Figure 11.

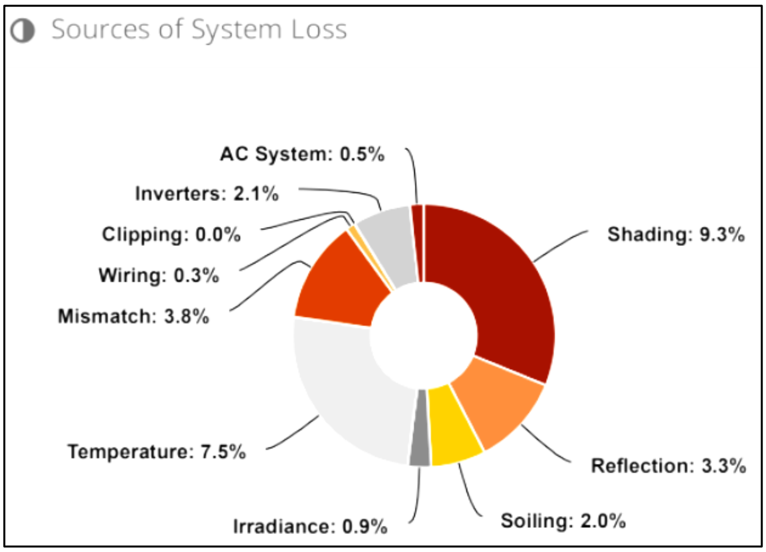


Fig. 9. Shading report for Heliscope modelling software

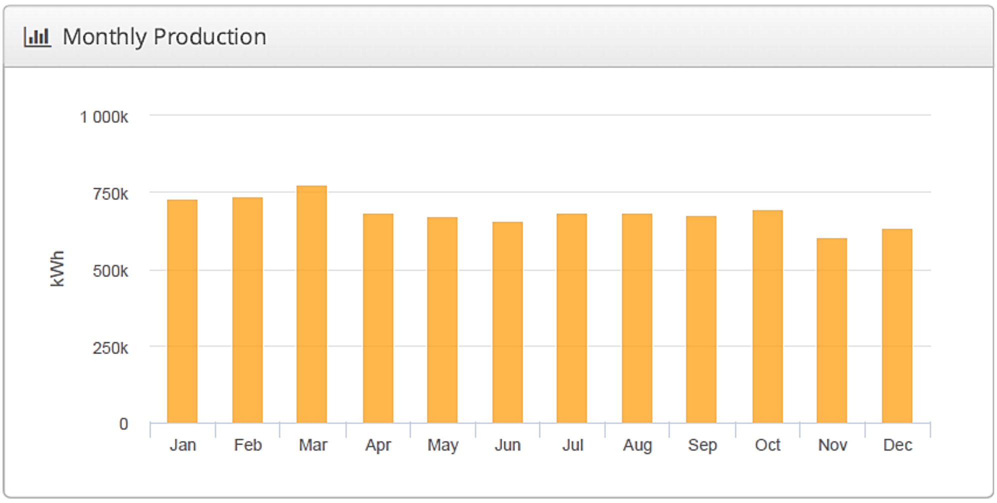


Fig. 10. Monthly energy production for Heliscope modelling software

System Metrics

Design	Design 1
Module DC Nameplate	6.91 MW
Inverter AC Nameplate	5.53 MW Load Ratio: 1.25
Annual Production	8.146 GWh
Performance Ratio	73.6%
kWh/kWp	1,179.4
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	6827cc4bc4-fc8205f29a-cddb18cb01-e6a648b615

Fig. 11. Annual production and performance ratio of the modelling software

*2.3 PV*SOL Photovoltaic System Simulation*

Depending on the system type, PV system design in PV*SOL is typically done in six stages: "Project Data," "System Type, Climate, and Grid," "3D Design," "Cables," "Financial Analysis," and "Results." The project's project number, project designer, and customer information are all entered in the section titled "Project Data." The kind of PV system (on the grid, off-grid, etc.) is chosen, the installation location is chosen, and network-related definitions are established in the System kind, Climate, and Grid section. Many prefabricated building types and shading elements, including trees or chimneys, are accessible as modelling aids in the 3D Design area. Own structures can be imported or developed. Campus building elements are displayed in PV*SOL in Figure 12.

Fig. 12. Campus building elements are displayed in PV*SOL

The annual output forecast, system performance, and performance report from the PV*SOL simulation are shown in the table below. The simulation's outcomes depicts that the Photovoltaic system can produce 6,306 kWh annually. Figure 13 illustrates the results, which reveal that January and February are the months with the highest production. A measurement of the system's specific power in relation to its rated capacity is the performance ratio variation shown in Figure 14. The yearly performance ratio for this PV system is 82.35%, as illustrated in Table 2.

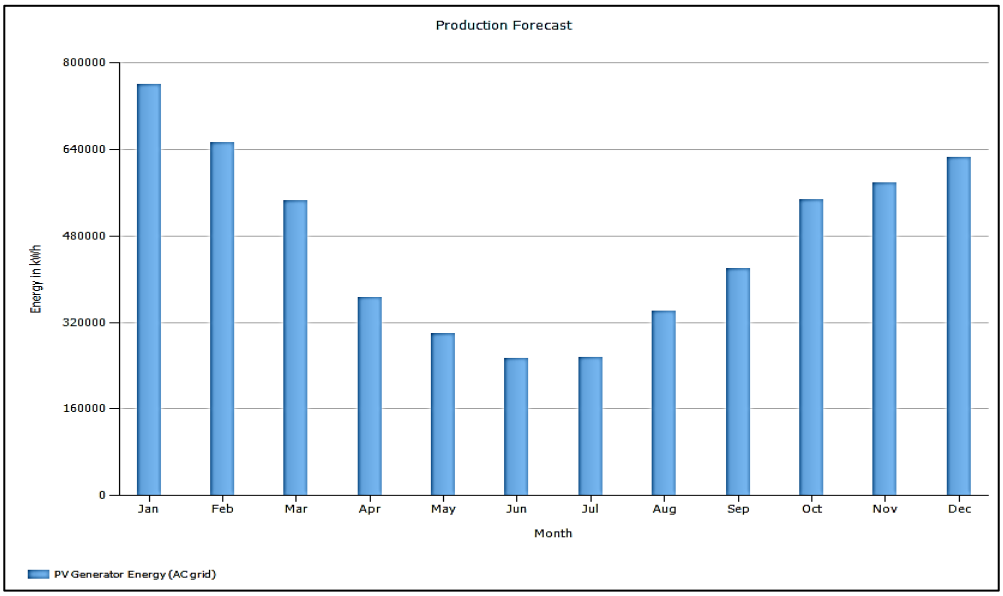


Fig. 13. Annual energy estimation of generation for PV*SOL

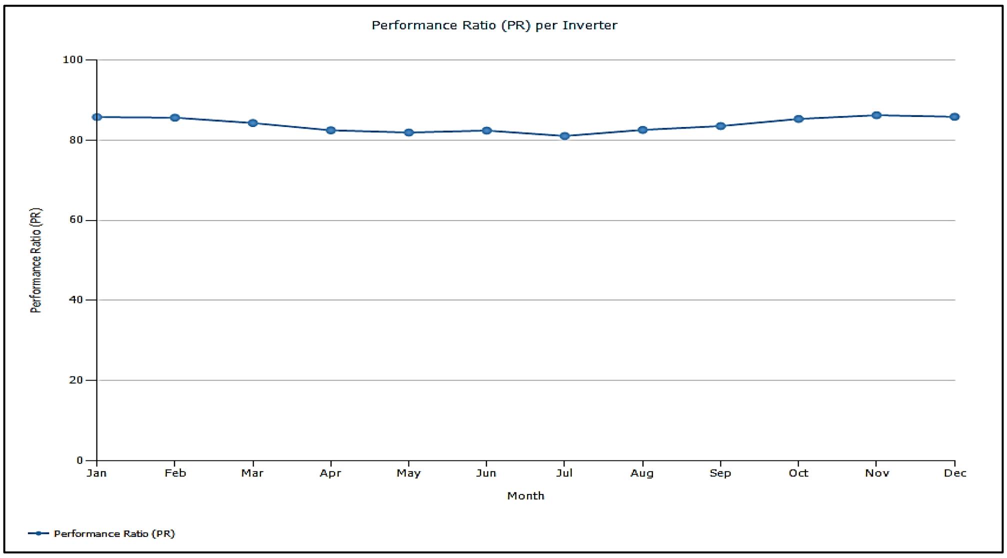


Fig. 14. Average performance ratio according to months

Table 2
Result obtained from the software simulation

PV generator output	6.9MWp
Annual yield specified	1236,55 kWh/kWp
Performance ratio	82.35%
Grid Input	7,935,614- kWh/Year
Grid feed-in during the first year, taking module degradation into account	7,935,614- kWh/Year
Consumption while standby (Inverter)	15,670 kWh/year
reduction of CO2 emissions	2,710,300 kg/year

3. Results

The outcomes of the present study are relevant for the specified location and areas with similar weather patterns, as meteorological parameters have a significant impact on the operations of PV systems. However, it cannot be stated that variations in simulation results from experimental results will be the same for other locations worldwide, nor that PV tools will be applicable in other situations. As a result, this study offers an abundant amount of knowledge about the most widely used PV instruments and offers insightful information about the functioning of PV systems in particular climatic zones as revealed by experiments and simulations.

Table 3 compares and reports the technical performance simulation data of the PV system with actual data. The table shows that the software used in this study's estimations is quite accurate at predicting the outcomes. The 6.9 MW solar power plant in UTHM that is being considered produces 8529.60 MWh yearly. The months of March (889 MWh), August (809 MWh), and April are when power production peaks (509 MWh). The months of December (618 MWh), November (646 MWh), and October saw the lowest energy production (651 MWh) as shown in Figure 15. It is seen in the table 3 that the estimations made by the software examined in this study, are very close to the real results.

The month of November, which has a low solar irradiation of 115.67 kWh/m2, has the highest performance ratio (81.03%), and the month of June, which has the lowest PR (74.67%), has the maximum solar irradiation of 126.89 kWh/m2 as shown in Figure 16. The PR value decreased because solar PV plants lost more energy in the months with higher sun irradiation.

Table 3
Comparison of result obtained from the software simulation and empirical data

Performance parameter	PV*SOL	PVsysts	Helioscope	Real data
Annual PV energy	7935.614	8539.958	8146.00	8529.60
Accuracy	6.96%	0.12 %	4.50%	
PR	82.35%	81.1%	73.6%	77.26%
Accuracy	6.59%	4.97%	4.74%	

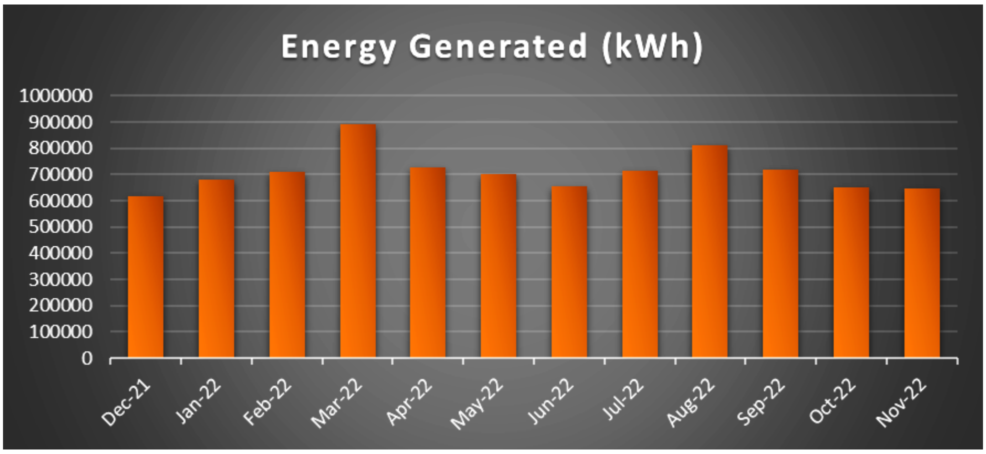


Fig. 15. Actual solar power production (kWh)

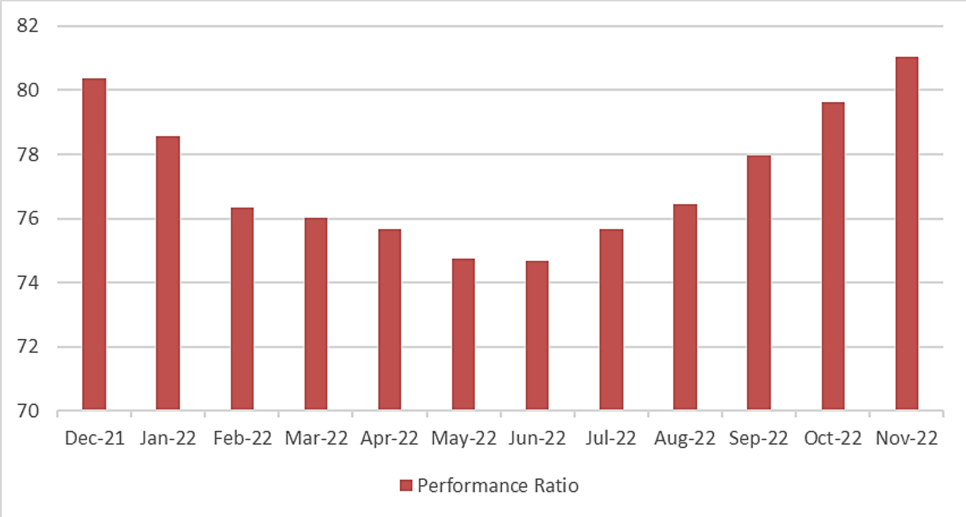


Fig. 16. Monthly variation of performance ratio

From Eq. (1), the relative error parameter in Table 3 is derived.

$$\text{Relative error} = \frac{|\text{Simulated data} - \text{Real data}|}{\text{Real data}} \times 100\% \quad (1)$$

PVsysts provided the most accurate estimate of energy production, with a relative inaccuracy of 0.12%. The ratio between actual and theoretically feasible energy outputs is known as the performance ratio. In terms of nominal installed power and incident energy, it is also described as the overall system efficiency. The best performance ratio estimation has been made by Helioscope with 4.74% relative error. In terms of energy losses, environmental element contributing to the most energy losses where PVsysts recorded 11.1% PV loss caused by irradiation and temperature changes. Whereby Helioscope clearly shows that environmental power loss of 8.4% represents the largest portion caused by irradiation and temperature changes. PV*SOL recorded an energy loss of 7.3% due to shading, temperature, and reflection on module interface.

Review of the monthly data revealed that Heliscope and PVSyst models overestimated energy production in November, December, and January (when solar radiation and daylight hours are lowest), while underestimating results in the summer, which balanced the variation throughout the year. Certain specialized tools are included in the software that are helpful when working with solar energy systems. Examples of these tools include solar geometry parameters, irradiation under a clear day model, PV-array behavior under partial shade, and tables and graphs of Meteonorm data. The 3D models produced by Helioscope can be exported straight to 3D modeling programs like SketchUp for additional analysis, such as shadow analysis or the incorporation of location terrains for geotechnical study. Because Helioscope can simulate at a granular size, it can produce an accurate estimation of energy production, just like PVSyst. The program utilizes the same cutting-edge mathematical models that are implemented in a comparable manner.

4. Conclusion

In the solar energy sector, a variety of software tools are used to build and analyze PV systems in the most effective way. These programs use meteorological data to produce a variety of forecasts about the energy output and financial benefits of PV systems. Since climatic circumstances vary so often, it is challenging to produce reliable forecasts. Meteorological variables directly affect how well

PV systems function. PV*SOL, PVsyst, and Helioscope software are used in this work to simulate the 6.9 MWp solar PV system at University Tun Hussein Onn Malaysia (UTHM). In terms of annual PV Energy Production and Performance Ratio criteria, the simulation results are compared to the actual data. The comparative findings showed that Heliscope and PVsyst are the most dependable software. The performance ratio was assessed by Heliscope with the lowest relative error of 4.74% and the actual energy production value was estimated by PVsyst with the lowest relative error of 0.12%. Utilizing PVsyst, Heliscope, and PV*SOL allowed for the effective design of a grid-connected system. In the case of PVsyst, there is a slight mismatch with the empirical data. The solar PV modelling program Heliscope and PVsyst has proven to be quite accurate, comprehensive, free, simple to use, and easy to install. It also includes a good deal of modelling flexibility and a variety of reporting and analysis options.

Acknowledgments
The authors would like to acknowledge that there are no conflicts of interest associated with this publication. University Tun Hussein Onn Malaysia (UTHM) funded this research through Research Enhancement- Graduate Grant, RE-GG (vot No. 083.).

References
[1] Aleluia, J., P. Tharakan, A. P. Chikkatur, G. Shrimali, and X. Chen. "Accelerating a clean energy transition in Southeast Asia: Role of governments and public policy." *Renewable and Sustainable Energy Reviews* 159 (2022): 112226. https://doi.org/10.1016/j.rser.2022.112226
[2] Chatri, Fatemeh, Masoud Yahoo, and Jamal Othman. "The economic effects of renewable energy expansion in the electricity sector: a CGE analysis for Malaysia." *Renewable and Sustainable Energy Reviews* 95 (2018): 203-216. https://doi.org/10.1016/j.rser.2018.07.022
[3] Abdul Latif, Siti Norasyiqin, Meng Soon Chiong, Srithar Rajoo, Asako Takada, Yoon-Young Chun, Kiyotaka Tahara, and Yasuyuki Ikegami. "The trend and status of energy resources and greenhouse gas emissions in the Malaysia power generation mix." *Energies* 14, no. 8 (2021): 2200. https://doi.org/10.3390/en14082200
[4] Aziz, PD. Abd., Wahid, S. S.A., Yanuar Z. Arief, and N. Ab Aziz. "Evaluation of solar energy potential in Malaysia." *Trends in Bioinformatics* (2017). https://doi.org/10.3923/tb.2016.35.43
[5] Yaakob, Yusli, Mahamad Hisyam Mahamad Basri, Muhammad Farhan Bardzan, Noor Iswadi Ismail, Azli Abd Razak, and Muhammad Arif Ab Hamid Pahmi. "The Stability Analysis Of Floating Buoy As A Wave Energy Harvester For Malaysian Coastal Area." *Journal of Advanced Research in Applied Mechanics* 96, no. 1 (2022): 1-6. https://doi.org/10.37934/aram.96.1.16
[6] Didane, Djamal Hissein, Muhammad Amir Zafran Saipul Anuar, Mohd Faizal Mohideen Batcha, Kamil Abdullah, Mas Fawzi Mohd Ali, and Akmal Nizam Mohammed. "Simulation study on the performance of a counter-rotating savonius vertical axis wind turbine." *CFD Letters* 12, no. 4 (2020): 1-11. https://doi.org/10.37934/cfdl.12.4.111
[7] Khairi, Nor Hazlina Md, Yutaro Akimoto, and Keiichi Okajima. "Suitability of rooftop solar photovoltaic at educational building towards energy sustainability in Malaysia." *Sustainable Horizons* 4 (2022): 100032. https://doi.org/10.1016/j.horiz.2022.100032
[8] Ilham, Zul, Nur Aida izzaty Saad, Wan Abd Al Qadr Imad Wan-Mohtar, and Adi Ainurzaman Jamaludin. "Multi-criteria decision analysis for evaluation of potential renewable energy resources in Malaysia." *Progress in Energy and Environment* 21 (2022): 8-18. https://doi.org/10.37934/progee.21.1.818
[9] Ahmad, Nur Irwany, Vernon Yeoh Sheng Liang, Diyya Hidayah Abd Rahman, Aimi Athirah Hazwani Zaidi, Saidatul Shema Saad, Nazrul Azril Nazlan, Habibah Mokhtaruddin, and Baseemah Mat Jalaluddin. "Development of solar tracking robot for improving solar photovoltaic (PV) module efficiency." *Journal of Advanced Research in Applied Mechanics* 61, no. 1 (2019): 13-24.
[10] Frontini, Francesco, Matteo Marzoli, and Narghes Doust. "Investigation of different simulation tools for solar photovoltaic modules." In *Proceedings of BSA Conference 2013: 1st Conference of IBSPA*, p. 89-94. 2013.
[11] Dey, Diptiman, and Bidyadhar Subudhi. "Design, simulation and economic evaluation of 90 kW grid connected Photovoltaic system." *Energy Reports* 6 (2020): 1778-1787. https://doi.org/10.1016/j.egyr.2020.04.027
[12] Mahmoud, Montaser, Enas Taha Sayed, Mohammad Ali Abdelkareem, Malek Kamal Hussien Rabaia, and Abdul Ghani Olabi. "Modeling and simulation of solar photovoltaic energy systems." In *Renewable Energy-Volume 1:*

Solar, Wind, and Hydropower, p. 281-295. Academic Press, 2023. https://doi.org/10.1016/B978-0-323-99568-9.00017-0
[13] Othman, N. A., N. S. Damanhuri, I. R. Ibrahim, R. Radzali, and M. N. Mohd. "Automated monitoring system for small scale dual-tariff solar PV plant in UiTM Pulau Pinang." In *Proceedings of the World Congress on Engineering* 2, p. 945-947. 2010.
[14] Prasad, B. Kailash Krishna, K. Prahlada Reddy, K. Rajesh, and P. Viswanath Reddy. "Design and simulation analysis of 12.4 kWp grid connected photovoltaic system by using PVSYST software." *The International Journal of Recent Technology and Engineering* 8, no. 5 (2020): 2859-2864. https://doi.org/10.35940/ijrte.E6243.018520
[15] Arif, Saba, Juntakan Taweekun, Hafiz Muhammad Ali, Abrar Ahmed, and Aqeel Ahmed Bhutto. "Building Resilient communities: Techno-economic assessment of standalone off-grid PV powered net zero energy (NZE) villages." *Heliyon* 9, no. 11 (2023). https://doi.org/10.1016/j.heliyon.2023.e21426
[16] Al Mehadi, Abdullah, Misbahul Alam Chowdhury, Mirza Muntasir Nishat, Fahim Faisal, and Md Minhajul Islam. "Design, simulation and analysis of monofacial solar pv panel based energy system for university residence: a case study." In *IOP Conference Series: Materials Science and Engineering*, vol. 1045, no. 1, p. 012011. IOP Publishing, 2021. https://doi.org/10.1088/1757-899X/1045/1/012011
[17] Ali, Mohamad Fakrie Mohamad, and Mohd Noor Abdullah. "Feasibility Study of the Technical and Economic Performance of Grid-Connected PV System for Selected Rooftops in UTHM." *Journal of Electronic Voltage and Application* 2, no. 2 (2021): 45-56. https://doi.org/10.30880/jeva.2021.02.02.005
[18] Qureshi, Misbah Hameed, and Shujaat Farooq. "Oil Price Shocks and Renewable Energy: A policy overview of asian economies." *Perennial Journal of History* 4, no. 1 (2023): 96-118. https://doi.org/10.52700/pjh.v4i1.143
[19] Roslan, Ahmad Azfar, and Zainal Abidin Akasah. "The implementation of solar photovoltaic installation on the rooftop of UTHM buildings." In *3rd Undergraduate Seminar on Built Environment and Technology,* p. 462-466. 2018.
[20] Kadir, N. A., A. Z. Abdullah, and NN Mohd Hussin. "Modeling and simulation of a 16.20 kWp on-grid solar Photovoltaic System (PV) using PVSyst at Malaysia." In *Journal of Physics: Conference Series*, vol. 2550, no. 1, p. 012005. IOP Publishing, 2023. https://doi.org/10.1088/1742-6596/2550/1/012005
[21] Patkó, István, András Szeder, and Csilla Patkó. "Evaluation the impact tilt angle on the sun collectors." *Energy Procedia* 32 (2013): 222-231. https://doi.org/10.1016/j.egypro.2013.05.029