

Comparative Analysis of Photovoltaic Simulation Software with Actual Conditions of 93.6 kWp On-Grid Photovoltaic System

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Abstract - The Indonesian government encourages an increase in the energy mix, especially renewable energy such as on-grid rooftop PV, which has an intermittent nature and high investment costs, so the development of rooftop PV must be carefully calculated by considering system reliability. Thus, PV systems can be optimised in terms of tilt angle, number of PV modules, module type, module support structure, and inverter. Many simulation tools are currently used to design PV systems using climate data. These simulation tools estimate energy production and provide corresponding economic data. However, the reliability of these data varies because the system productivity of the photovoltaic system productivity depends on the climatic conditions of the photovoltaic system depends on the climatic conditions. Therefore, in this study, two simulation tools, namely helioscope and RETScreen, will be evaluated in comparison with the actual conditions in the field of 93.6 kWp on-grid PV system. Based on the comparison results, Helioscope and RETScreen are reliable simulation tools because the results obtained are closest to the actual energy value.

Keywords: Photovoltaic, Performance Ratio, On-Grid, Helioscope, RETScreen.

I. INTRODUCTION

Energy is very important in all aspects of human needs because it relates to needs such as for transport, health education and many more[1]. Along with the increase in the human population in the world, it results in an increasing need for energy so that the emissions produced will also be proportional to the amount of energy released, especially the fossil energy sector [2]. Currently, the world's awareness of climate change is increasing, especially the demand for renewable energy sources to reduce global warming below 2°C [3], [4] then low-carbon energy production must dominate [5], in Indonesia, the government has set a target to achieve an energy mix of 23% of energy sourced from renewable energy [6], One of the renewable energy sources based on the net zero

emission roadmap in Indonesia is one of the potential of solar energy [7]. The potential of solar energy in Indonesia is 4-5.8 kWh/m²/day [8] with an average solar radiation intensity value of 4.8 kWh/m²/day [9].

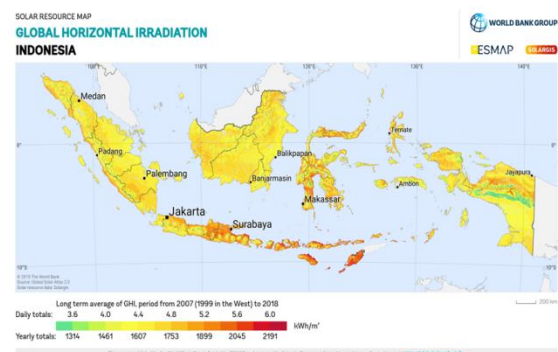


Figure 1: Solar PV power potential map of Indonesia

In planning the implementation of photovoltaic (PV) systems, it is better to use modelling or tools in the form of software used to analyse and optimise PV systems and the desired cost analysis [10], [11]. These modelling tools vary in scale and complexity, as well as the inputs that the software requires to produce the desired output [12], common input data such as location data and weather information, system components such as solar modules, inverters and batteries to be used, electricity tariffs, and electricity loads [13]. Some modelling includes input data on financial parameters such as the cost of the components of the system such as module and inverter costs, construction, taxes and financial parameters such as inflation and discount rate [14], system degradation rate [15]. Therefore, this study was conducted to see the difference in simulation results from the two-software used, namely Helioscope and RETScreen, the simulation results will be compared with the actual system at the location of Building 625 which has an on-grid PV system installed with a capacity of 93.6 kWp so that in planning the PV system implementation project, the tolerance value of the simulation results is obtained which will be included in the project proposal.

Helioscope Developed by Folsom Labs, Helioscope is a non-installed software that uses a subscription system to design PV systems and quickly analyze design decisions [16]. Helioscope can generate system layouts of solar system layouts and energy production estimates. Helioscope provides CAD-like tools, but it is specifically made for solar power, so users can quickly design a system that can be used to calculate each simulated component in the array. However, this software is limited to systems under 5 MW. The software focuses only on solar PV and cannot model other renewable technologies [17]. RETScreen is an energy modelling software that simulates the comparison between a base case, usually a conventional technology or measure and a proposed case, which is a clean energy technology [18]. The software can evaluate the benefits of clean energy production from power generation projects and savings through energy efficiency projects, considering project costs, emission reductions, and financial risks [18]. Input data from the user is general information about the facility, type of analysis, and location. Other inputs include fuel type or electricity base rate. In addition, several spreadsheets are provided to evaluate designs, energy models, and emission reductions [18].

II. METHODOLOGY

Case study

Building 625 is in the PUSPIPTEK area, Setu, South Tangerang, Indonesia. The solar energy system is connected to the electricity grid without using batteries, so electrical energy is generated to the electricity grid during the daytime. The on-grid PV system was installed on the rooftop area of Building 625, which started operating in November 2018. This system converts direct Current (DC) from solar modules into Alternating Current (AC) using an inverter. In the system used in this building, the required energy is utilised, and the excess is exported to the interconnected system with the same frequency and voltage as the grid with a decoupling system. In the power plant installation, energy is transmitted directly to the grid. Energy production data from the PV system and weather information from the weather station are monitored online in the SCADA system.

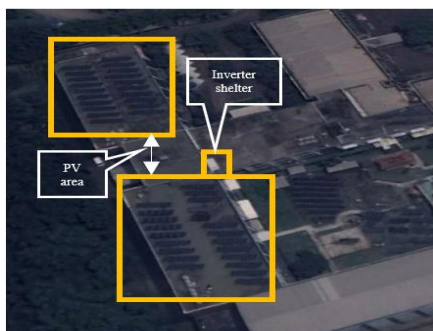


Figure 2: PV System Location

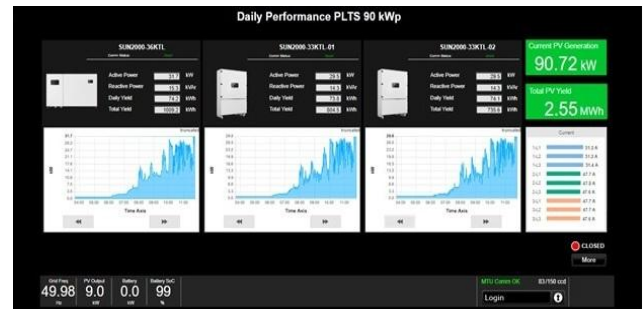


Figure 3: System Data Acquisition Equipment

Table 1 provides technical information on the PV modules used. The arrays consist of 3 arrays, each containing six strings containing 16 solar modules connected in series. Three inverters are used, and their specifications are shown in Table -2.

The real energy production and weather data of the 93.6 kW PV system can be downloaded through the SCADA system available in the field, as shown in Figure. The results of the photovoltaic system are illustrated in Table 3. The energy data used is 2019 because it is a full year of data obtained when the system operates for a year from the start of operation. The energy produced by the system in one year was 128,895kwh. The largest production in October was 11,988 kWh, the minimum energy production was 9,401kwh in January, and the average monthly energy production was 10,741 kWh.

Table 1: Specification of Solar Modules

Manufacturer	Canadian Solar
Type	CS6U-325P
Peak Watt Rating	325 Wp
Optimum operating voltage (Vmp)	37 VDC
Optimum operating current (Imp)	8.78 A
Efficiency	16.72 %

Table 2: Specification of Inverter

Technical Specifications	SUN2000-33KTL-A
Max. Efficiency	98.60%
European Efficiency	98.40%
Input	
Max. DC Usable Power	30,600 W
Max. Input Voltage	1100V
Max. Current per MPPT	22A
Max. Short Circuit Current per MPPT	30A
Full Power MPPT Voltage Range	480 V ~ 800 V
Rated Input Voltage	620 V
Number of MPP Trackers	4
Output	
Rated AC Active Power	30,000 W
Max. AC Apparent Power	33,000 VA

Rated Output Voltage	230V / 400V, default 3W+N+PE;
Rated AC Grid Frequency	50 Hz / 60 Hz
Max. Output Current (@400V)	48 A
Adjustable Power Factor	0.8 LG ... 0.8 LD
Max. Total Harmonic Distortion	<3%

Table 3: PV Production and Daily Solar Radiation Actual Conditions

No	Month	Inverter 1	Inverter 2	Inverter 3	Total Energy (kWh)	Daily Solar Radiation kWh/m ²
		(kWh)	(kWh)	(kWh)		
1	January	3192	3177	3032	9401	3.75
2	February	3386	3321	3364	10071	4.29
3	March	3600	3583	3575	10758	3.94
4	April	3893	3881	3864	11638	4.54
5	May	3586	3571	3533	10690	4.13
6	June	3238	3154	3285	9677	4.13
7	July	3761	3741	3743	11245	4.17
8	August	3789	3767	3764	11319	3.88
9	September	3881	3880	3867	11628	4.27
10	October	4001	4003	3984	11988	4.59
11	November	3654	3642	3402	10698	3.65
12	December	3374	3355	3053	9782	4.08



Figure 4: Helioscope Shading Simulation Result

Table 4: Helioscope Simulation Results PV Production and Daily Solar Radiation

Month	Helioscope (kWh)	Daily Solar Radiation kWh/m ²
January	7541	3.43
February	8447	3.94
March	11022	4.64
April	11545	4.83
May	12045	4.71
June	11848	4.65
July	12381	4.75
August	12268	4.89
September	12513	5.38
October	10927	4.75
November	9102	4.18
December	9298	4.35

3.2 Simulation of Photovoltaic System with helioscope

Steps in using helioscope software are as follows: Fill in the formula consisting of the project name, address, and description and enter the coordinate map of the place where you want to design the PV system. After determining the location, create a building according to actual conditions with visual 3D images. Next, enter the description and type for the PV design that will be used after selecting the solar panel layout page; this stage will segment the selected roof plane and angle so that the solar module will fill the selected area. However, it is necessary to change the parameters to get the desired design. For example, the roof does not face the North direction perfectly. So, adjusting the azimuth according to the actual conditions at the location to be compared is necessary. The next step is to select the specifications and location of the inverter and the cable to be used. After the above stages have been completed, start to simulate and simulation report results in PDF format that can be downloaded.

The shading simulation results obtained shading of 1%, in addition to the helioscope shading results, also display monthly and annual production estimates. The 93.6 kWp PV design can produce 128,936 kWh annually, or an average monthly production of 10,745 kWh. The largest production in September was 12,513 kWh, while the minimum energy production was 7,541 kWh in January. For more details, it is shown in Table 4.

3.3 Simulation of Photovoltaic System with RETScreen

Similar to the simulation using a helioscope, the initial step of using RETScreen software is to enter location information for daily solar radiation data, earth temperature, wind speed, and others that can also be downloaded so that it matches the year to be compared, namely 2019. Then, enter the energy menu and determine the type of solar tracking, slope and azimuth as shown in Figure, then select the desired solar module and inverter in the RETScreen simulation to enter losses of 15% [19]. For more details can be seen in Figure. Simulation results using RETScreen, the annual PV system produces 130,974 kWh of electrical energy with a monthly average of 10,915 kWh. The maximum energy production was found in August at 12,396 kWh, while the minimum in January was 9,134 kWh.

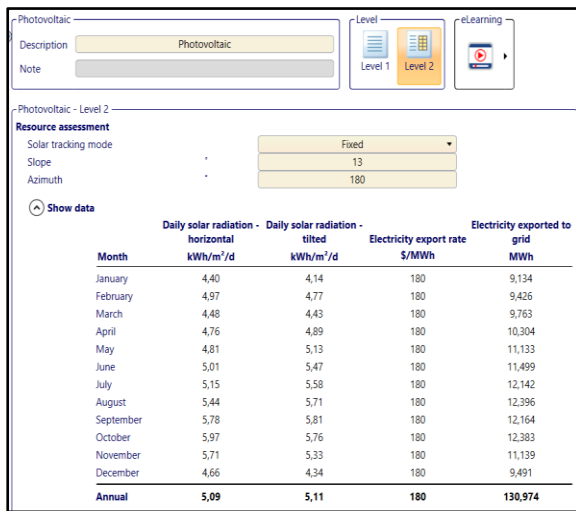


Figure 5: Resource Assessment

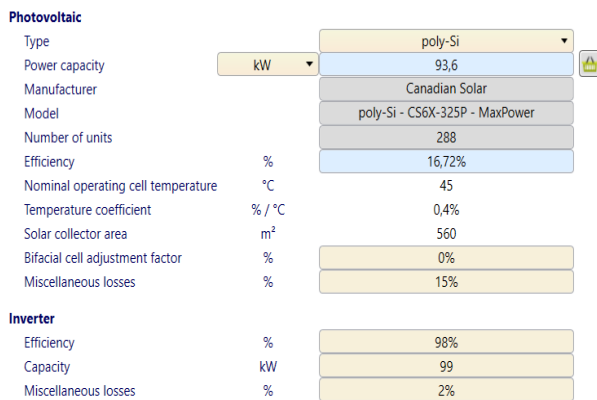


Figure 6: RETScreen Input on Solar Modules and Inverter

III. RESULTS AND DISCUSSIONS

The simulated data of the PV system and the actual field data are compared in Table 5. It can be seen in the table that the estimated annual energy production simulated by the software are both very close to the real results. However, the best energy production estimation or the closest to the actual value in the field is the helioscope with an accuracy value of 100.03% or greater than the actual value by 0.03% while the accuracy value of the RETScreen simulation is 101.61% or greater than the actual value by 1.61% The accuracy parameters in Table 5. are calculated from Equation 1.

$$Accuracy \% = \frac{Simulated\ Data}{Actual\ Data} \times 100 \quad (1)$$

The performance ratio is the ratio of the actual and actual energy output and the theoretically possible energy output. It is also defined as the global system efficiency with respect to the nominal installed power and incoming energy and is given in Equation 2.

$$Performance\ Ratio\ (PR) = \frac{Y_f}{Y_r} \quad (2)$$

Equation 3 describes Y_f which is defined as the ratio of the PV system's actual energy output to its nominal capacity power while Y_r is the ratio between the total in-plane radiation to the PV reference radiation. The reference irradiance of PV in STC condition is equal to 1000W/m² in this study using Y_r value of 1,689.8 kWh/m² from helioscope simulation.

$$Y_f = \frac{Annual\ Energy\ Output\ (kWh)}{Nominal\ Power\ (kWp)} \quad (3)$$

$$Y_r = \frac{Total\ Inplane\ Irradiance\ (kWh/m^2)}{PV\ Ref.\ Irradiance\ (kW/m^2)} \quad (4)$$

PR is an important indicator that reflects the performance in the field which depends on the system parameters as well as climatic parameters[20]. in this study, it shows a fairly good performance ratio of 81.49% for the year under study. The actual performance ratio is lower than the simulated values observed in two different software. The PR values by Helioscope and RETScreen were 81.52 and 82.81% respectively.

Table 5: Comparison analysis results

Paramater	Actual	Helioscope	RETScreen
Annual Energy (kWh)	128,895	128,936	130,974
Accuracy (%)	100.00	100.03	101.61
Specific Annual Yield (kWh/kWp)	1377.0	1377.5	1399.2
Performance Ratio (%)	81.49	81.52	82.81

Figure shows the observed variation in the actual solar radiation at the site compared to the potential solar radiation from the two simulation tools. Figure shows that the solar radiation values derived from the simulations are higher than those recorded at the site. The maximum solar radiation recorded at the site was 4.59 kWh/m²/day in October. The minimum was 3.75 kWh/m²/day in January. Overall, the annual average solar radiation at the site was 4.12 kWh/m². Helioscope predicted an average monthly solar radiation of 4.54 kWh/m², while RETScreen was 5.10 kWh/m².

Figure energy production results are the same as those of solar radiation, whose values vary with actual conditions, but the pattern is the same in January. Next month, energy production will be higher and will start to drop when December is the rainy season. High energy production is around July to October, and annual energy production is close to actual conditions in the field.

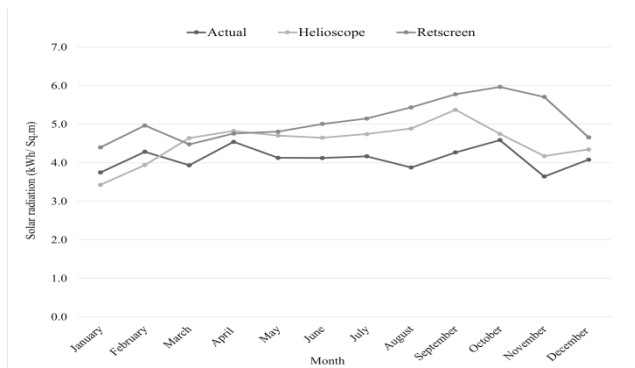


Figure 7: Monthly Solar Radiation

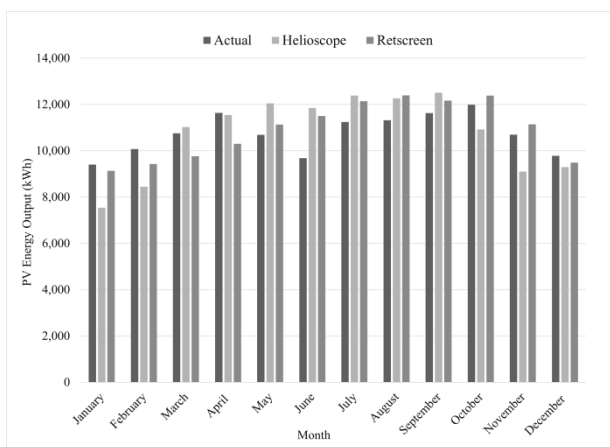


Figure 8: Monthly PV Energy Output

IV. CONCLUSION

This study demonstrates the application of simulation tools such as Helioscope and RETScreen, which are compared with the performance feasibility assessment of a 93.6kWp photovoltaic power plant installed on the roof of Building 620, Banten, Indonesia. The simulation results were compared with actual field data regarding monthly and annual PV Energy Production criteria, solar radiation, and Performance Ratio. Based on the comparison results, it is concluded that Helioscope and RETScreen are the most reliable software. Although the predictions of solar radiation and monthly production differ from the actual conditions of annual energy production, they are very close to the results in the field. Helioscope predicted the value of energy production compared to actual conditions with an accuracy value of 100.03% or greater than the actual value of 0.03%. In comparison, the accuracy of the RETScreen simulation was 101.61% or greater than the actual value of 1.61%. This study shows a fairly good performance ratio of 81.49% for the year under study. The actual performance ratio is lower than the simulated value observed in two different software. The PR values by Helioscope and RETScreen were 81.52 and 82.81% respectively.

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