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Performance Evaluation of 600 kWp On-Grid Solar Power Plant on Gili Trawangan

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ABSTRACT — Indonesia is one of the countries that remains reliant on the utilization of fossil energy. The increasing demand for fossil energy is causing a decrease in the availability of fossil energy, consequently leading to an increase in fossil fuel prices. Therefore, one of the efforts that can be undertaken involves establishing new renewable energy (NRE) plants to diminish reliance on the use of fossil-fueled plants. One of the NRE plants built by the government is the 600 kWp Gili Trawangan on-grid solar power plant. After ten years of operation, an evaluation of the 600 kWp Gili Trawangan on-grid solar plant is necessary to assess its performance in meeting electricity load requirements. The power and electrical energy generated by a solar power plant can be evaluated by comparing its current power and energy production with the potential power and energy that should be generated. To determine the current power and energy production generated by the solar power plant, the measurement results from the PLN. Additionally, to ascertain the potential power and energy that the solar power plant should be capable of producing at this time, simulation results from Homer software were employed. The results demonstrate that the power and energy measured by PLN are lower than the potential power and energy that should be achievable using Homer software for solar power plants. According to PLN measurement, the average power production and energy were 196.72 kW and 765.92 kWh, respectively. Meanwhile, based on the simulation results were 207.10 kW and 840.39 kWh.

KEYWORDS — Solar Power Plant, Output Power, Output Energy, Gili Trawangan, Homer Software.

I. INTRODUCTION

Up to 95% of Indonesia's energy requirements are currently met by fossil fuels [1]. It indicates that Indonesia still relies relatively heavily on fossil energy. Due to the increasing demand for fossil energy, the availability of fossil energy will decrease [2]. It will impact fossil fuel prices, causing an increase. Furthermore, the sustained combustion of fossil fuels results in elevated levels of greenhouse gas emissions [3]. The power generation sector accounts for the largest increase in greenhouse gas emissions, reaching a percentage of 33% [4]. Thus, one of the Indonesian government's endeavors, facilitated by the Ministry of Energy and Mineral Resources (Kementerian Energi dan Sumber Daya Mineral, ESDM) and the Ministry of Finance, is dedicated to constructing new renewable energy (NRE) infrastructure. This initiative is part of the government's broader strategy to facilitate an energy transition, aiming to diminish reliance on fossil fuel-based power plants [5]. It is also an effort to meet the target contributions of NRE power plants, aiming for 23% by 2025 and 31% by 2050 in the national energy mix [6].

One tangible form of the Indonesian government's commitment to the development of NRE infrastructure is the construction of solar power plants throughout Indonesia. It is also supported by the potential for high solar irradiation intensity in Indonesia, with an average of 4.8 kWh/m^2 [7].

The Gili Trawangan 600kWP on-grid solar power plant is one of the projects contributing to the construction of NRE power plants in Indonesia. The 600 kWp on-grid solar power plant located in Gili Trawangan consists of two components: a 200 kWp and a 400 kWp solar power plants. Those solar power plants were built in 2011 and 2012. They are directly interconnected with the National Electricity Company (Perusahaan Listrik Negara, PLN) mesh network through an undersea cable transmission line [8]. The presence of the undersea cable transmission line led to the termination of the Gili Trawangan diesel power plant's role in supplying electricity to the island, as the transmission line now fulfills the island's electricity needs more effectively." The role of the Gili Trawangan diesel power plant was subsequently replaced by supply from the Lombok electrical system through a 20 kV submarine cable transmission line, assisted by the presence of solar power plants in Gili Trawangan, which operate during the day [9]. It is clear evidence of the government's commitment to making an energy transition, specifically by reducing dependence on fossil-fueled plants in Indonesia, including in the Gili Trawangan region.

Since its construction in 2011 and 2012, Gili Trawangan's 200 kWp and 400 kWp on-grid solar power plants have been operating and serving the needs of electricity load for approximately ten years. It needs to be a concern for related parties because solar power plants that have been in operation for a long time need evaluation to determine their performance in meeting electricity load requirements. Therefore, a study is necessary to assess the performance of the solar power plant system in meeting the requirements of electrical loads.

In general, numerous previous studies have discussed and analyzed the performance of solar power plants [10]–[17]. Reference [10] conducted an analysis of the 500 kWp solar power plant performance in Mae Hong Son Province, Thailand. Performance analysis was conducted on the components of the solar power plant, specifically focusing on photovoltaics (PV) and power conditioning units. The analysis was based on factors such as power output to the grid, system efficiency, and reliability. The results showed that the energy produced was 383,274 kWh. The efficiency of the PV array system ranged from 9% to 12%, while the efficiency of the power conditioning unit ranged from 92% to 98%. Additionally, the working ratio ranged from 0.70 to 0.90.

Reference [11] conducted a performance analysis of a 5 MW solar power plant in Kupang, East Nusa Tenggara Province. The evaluation of the solar power plant performance was carried out based on the results of calculating the work ratio using existing data from March 2016 to December 2019. The results showed that the solar power plant generated 25.3 GWh of energy and had a daily performance ratio ranging between 0.7 and 0.9.

Reference [12] conducted a performance analysis of the Gili Trawangan 600 kWp solar power plant. The analysis was conducted by comparing the solar power plant output obtained from the calculation results based on the specification data with the solar power plant output derived from the calculation results based on the measurement data. The selected objects were the Gili Trawangan 200 kWp and 400 kWp on-grid solar power plant. The results showed that the calculated values based on the measurement data were smaller than those based on the specification data. It occurred because the calculation results, based on the measurement data, depended on the weather conditions during the measurement, which could influence the intensity value of solar irradiation. Conversely, calculations based on the specification data were conducted under the assumption of standard testing conditions (STC), with an irradiation level of 1,000 W/m^2.

Meanwhile, the analysis of solar power plant performance has also been conducted by comparing the real-time electricity production from solar power plants with the potential energy that should be achievable using various software tools [13]–[17]. Reference [13] chose to use PVSysyt and PV-Gis in its research. This research was conducted at the 10 MW SOLAR POWER PLANTS in India. The results indicated that based on the monitoring data, the total energy output achievable by the solar power plant was 15,605.908 MWh. Additionally, using PvSyst and PV-Gis resulted in energy outputs of 16,047 MWh and 16,043 MWh, respectively.

Meanwhile, PVSyst was used in the subsequent three studies [14]–[16]. Reference [14] examined a 50 kWp on-grid solar power plant in UPDL Makassar. The comparison process involved utilizing real data on electrical energy production from the solar panel and simulating the results using software based on data from the National Aeronautics and Space Administration - Surface Meteorology and Solar Energy (NASA-SSE) and Meteonorm 7.3. The results showed that, based on data from Meteonorm 7.3, the actual energy production of the solar panel was 70.51 MWh/year, with an optimal potential of 72.65 MWh/year. Additionally, according to NASA-SSE data, the actual energy production was 91.65 MWh/year. Meanwhile, based on the simulation results in PVSyst with Meteonorm 7.3 data, the energy produced was 73.1 MWh/year. One cause of the disparity in results is the shadow effect surrounding the solar power plant site, which impacts the production of its electricity.

Reference [15] analyzed the performance of the Sengkol 7 MWp solar power plant. In this study, real data produced by the solar power plant were obtained from measurements carried out over 30 days in March 2020. The results showed that the real-time production of electrical energy amounted to 461.6 MWh, whereas the simulated production using PVSyst yielded a slightly smaller value of 448.9 MWh. It occurred because the simulation neglected the account for shading and loss factors.

Reference [16] conducted a performance analysis of on-grid solar power plant systems in Rajasthan, India, with capacities of 100 kWp, 300 kWp, and 2 MW, utilizing polycrystalline PV modules. The results showed that among the three solar power plants, the 300 kWp solar power plant had the highest work ratio value, at 79.34%, compared to the 100 kWp and 2 MW solar power plants, which had work ratio values of 72.64% and 74.3% respectively. Meanwhile, using PV-SYST, 100 kWp, 300 kWp, and 2 MW solar power plants produced a working ratio of 83.72%, 76.85%, and 80.9%, respectively.

Furthermore, an analysis has been conducted on the performance of the 26.4 kWp solar power plant within the microgrid system of Udayana University (UNUD) [17]. In this study, the energy produced by the solar power plant was compared with the potential energy calculated using Helioscope software. The analysis results revealed that the actual energy production from the solar power plant for one year amounted to 39,948 kWh, whereas the simulated electrical energy production stood at 43,055 kWh. The difference in these results is influenced by the shading or shadow cast by the trees surrounding the solar power plant, which affects its energy production.

In this study, the evaluation and analysis of the performance of the solar power plant system were carried out, following methodologies established in previous studies [10]–[17]. The selected system under evaluation is the 600 kWp on-grid solar power plant located at Gili Trawangan, which corresponds to the system evaluated in [12]. The Gili Trawangan 600 kWp on-grid solar power plant was selected as the subject of research due to its extensive operational history in fulfilling electrical load requirements. Therefore, an evaluation is necessary to determine the performance of the solar power plants system in meeting these needs. The evaluation conducted in this study was similar to that of previous research [13]–[17], which involved comparing the actual output of a solar power plant with the expected output based on existing potential, utilizing software assistance. Homer software was selected for this study. In addition to not having been used in previous studies, Homer is also capable of displaying the electrical power that can be generated by a solar power plant. These matters have not been done in previous studies [13]–[17]. Thus, alongside comparing the energy that can be generated by the solar power plant, this study also conducted a power comparison to determine the actual production of power and energy from the current solar power plant, the measurement results of PT PLN West Nusa Tenggara’s Regional Main Unit were used. Simulation results using Homer were used for determining the potential power and energy that the Gili Trawangan 600 KWp on-grid solar power plant should be able to produce.

II. METHODOLOGY

In this study, the performance of the Gili Trawangan 600 kWp on-grid solar power plant was evaluated by comparing its actual power production (kW) and energy output (kWh) with the potential power production (kW) and energy output (kWh) that it could generate. Data on the measurement results provided by PT PLN West Nusa Tenggara’s Regional Main Unit were utilized [18] to determine the current power (kW) and energy (kWh) production of the solar power plant. Measurements were taken daily for one year using Homer

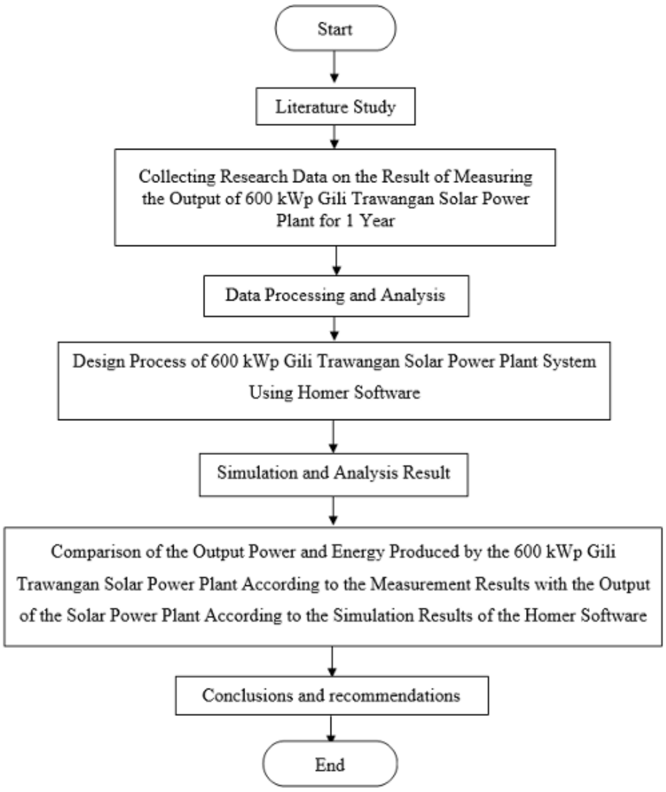

Figure 1. Research flowchart.

software. Measurements were taken during the operational hours of the solar power plant, from 07.00 to 18.00 Indonesia Central Standard Time (Waktu Indonesia Tengah, WITA).

The research flow, as depicted in Figure 1, began with a literature study comprising related research. Subsequently, data collection was conducted to acquire the necessary information for the research process. The data were sourced from PT PLN PT PLN West Nusa Tenggara's Regional Main Unit in the form of daily power and energy output of the solar power plant over one year, along with solar irradiation data obtained by the PV module. Furthermore, the data processing and analysis of the previously obtained data were carried out. It was done to obtain the daily average data for each month over the course of a year. These results were used as data on the average power (kW) and output energy (kWh) of the solar power plant that can be produced by the Gili Trawangan 600 kWp solar power plant at this time, based on the measurement data conducted by PT PLN West Nusa Tenggara's Regional Main Unit. The subsequent step involved designing the Gili Trawangan 600 kWp on-grid solar power plant system using Homer. The solar power system designed for Gili Trawangan was installed and operational, with Homer serving as a crosschecking device. Simulation results obtained using Homer provide crucial data on the expected output of power (in kW) and energy (in kWh) from the Gili Trawangan 600 KWp solar power plant. The next step involved comparing the solar power plant output generated from the measurement data of PT PLN West Nusa Tenggara's Regional Main Unit with the simulation results on Homer, enabling the drawing of conclusions and suggestions.

A. THE MODEL OF THE GILI TRAWANGAN 600 KWP SOLAR POWER PLANT SYSTEM

The Gili Trawangan 600 kWp on-grid solar power plant system, directly interconnected with the PLN network, consists of two solar power plant systems, one with a capacity of 200 kWp (solar power plant) and the other with a capacity of 400 kWp (solar power plant). In a 200 kWp solar power plant, there are 920 PV modules, each with a capacity of 220 Wp. These modules are arranged into four array groups. The plant is equipped with one inverter with a capacity of 250 kW [19]. In a 400 kWp solar power plant, there are 2,240 solar modules, each with a capacity of 180 Wp, arranged into ten array groups. The highest capacity among these array groups is 40.32 kWp. Additionally, there are two inverters, each with a capacity of 250 kW.

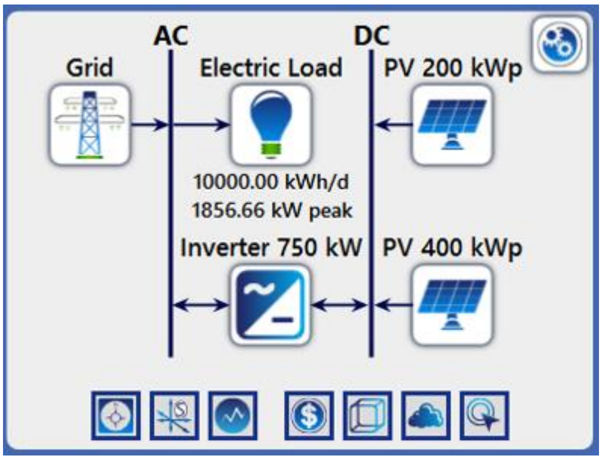

Figure 2. Schematic of the Gili Trawangan 600 kWp on-grid Solar Power System using Homer.

The process of modeling the Gili Trawangan 600 kWp on-grid solar power plant system in the Homer software is depicted in Figure 2. This solar power plant modeling scheme on Homer consisted of a PLN (public utility) grid, an electrical load profile, an inverter, and two PV panels with capacities of 200 kWp and 400 kWp, respectively. After completing the modeling process, the next step was to input the necessary data, including PV component data, inverter component data, electrical load data, and solar irradiation intensity data for Gili Trawangan.

1) PV COMPONENT DATA

The data included in Homer were in the form of PV capacity used amounts, specifically 200 kWp and 400 kWp, along with the data on component replacement costs, as well as operational and maintenance expenses. The cost of replacing PV components can be found on several e-commerce platforms widely available on the internet, which can provide information on the prices of PV components to be used. The price varies on the type and capacity of the PV system. Operational and maintenance costs were estimated using assumed expenses. Operational and maintenance costs may include employee salaries and costs incurred during the operational process. However, data on the initial investment cost or initial purchase cost of PV components were not included. It is because the solar power system in question has already been installed and operational, thus eliminating the need for initial component purchases.

2) INVERTER COMPONENT DATA

The inverter component data included in Homer is in the form of the amount of inverter capacity used in the design process, component replacement cost data, and operational and maintenance cost data. In this study, the solar power plant modeling on Homer software used one inverter with a total installed capacity of 750 kW. This total capacity of 750 kW was achieved by combining three inverters, each with a

TABLE I
RESULTS OF SOLAR POWER PLANTS OUTPUT ACCORDING TO MEASUREMENT DATA OF PT PLN

Month	200 kWp Solar Power Plants			400 kWp Solar Power Plants					
	G1 Inverter			G2 Inverter			G3 Inverter		
	Power (kW)	Energy (kWh)	Solar irradiation (kWh/m^2)	Power (kW)	Energy (kWh)	Solar irradiation (kWh/m^2)	Power (kW)	Energy (kWh)	Solar irradiation (kWh/m^2)
January	77.49	300.46	2.60	38.23	126.94	2.61	40.32	110.22	2.61
February	91.51	383.02	3.16	52.17	196.02	3.14	44.89	140.89	3.17
March	85.28	347.64	2.57	43.92	136.05	2.57	40.72	105.55	2.57
April	106.44	484.34	3.12	54.22	200.46	3.12	54,52	168.13	3.12
May	100.83	453.98	2.96	56.98	180.05	2.88	47.31	149.2	2.96
June	98.12	427.21	2.65	57.44	192.41	2.65	50.3	139.67	3.48
July	87.59	354.8	2.40	49.92	170.22	2.49	43.22	141.06	2.50
August	88.54	408.36	2.77	55.49	220.79	2.77	49.1	177.02	2.77
September	93.67	402.9	3.00	63.52	260.28	3.00	76.55	247.35	4.14
October	132.81	440.27	3.48	59.50	248.77	3.48	54.27	210.72	3.48
November	100.55	528.91	3.57	56.52	258.65	3.58	50.01	188.81	4.47
December	86.75	426.39	6.54	37.78	134.89	7.61	33.95	128.63	7.78
Average	95.80	413.19	3.23	52.14	193.79	3.33	48.76	158.93	3.59

capacity of 250 kW, used in the Gili Trawangan 600 kWp on-grid solar power plants under actual conditions. It was carried out because the number of inverter components in Homer is limited; in each design, only one inverter component can be included. Meanwhile, the data on component replacement costs, as well as operational and maintenance costs, are identical to those of PV components.

3) ELECTRICITY LOAD DATA

The Gili Trawangan electrical load profile data used were those that had been available on Homer. The load profile utilized in this study was of a residential type. This type of electrical load profile was chosen because it shares similarities with the residential load profile available in Homer and Gili Trawangan.

4) SOLAR RADIATION DATA

The solar irradiation intensity data in this study were sourced from NASA, and available on Homer. The data were collected based on the coordinates of the Gili Trawangan solar power plant location. The average solar irradiation intensity in Gili Trawangan is 5.40 kWh/m^2/day.

B. CALCULATION OF SOLAR POWER PLANT OUTPUT RESULTS BASED ON PLN DATA

In this study, the calculation process was carried out using data previously obtained from PT PLN West Nusa Tenggara's Regional Main Unit. These data represent the output of the 600 kWp Gili Trawangan on-grid Solar Power Plant, obtained through real-time measurements conducted by PT PLN West Nusa Tenggara's Regional Main Unit daily over the course of one year. The data consisted of output data from the G1 inverter at 200 kWp solar power plant, and from G2 and G3 inverters at 400 kWp solar power plant. These data include data on power (kW) and energy (kWh) generated by PV as well as solar irradiation intensity (kWh/m^2) data received by PV modules for one year.

Then, from the daily measurement data taken over one year, a data processing procedure was conducted to determine the monthly average values generated by the solar power plant. The resulting data were then utilized to determine the average power (kW) and energy (kWh) achievable by the existing Gili Trawangan 600 kWp on-grid solar power plant, based on measurements conducted by PT PLN West Nusa Tenggara's Regional Main Unit.

C. CALCULATION OF SOLAR POWER PLANT OUTPUT RESULTS IN HOMER SOFTWARE

The output of the solar power plant produced using Homer was the result of simulating the design of the Gili Trawangan 600 kWp on-grid solar power plant system, which had been previously modeled. The simulation produced data on total power output (kW) and total energy output (kWh), capable of producing Gili Trawangan 600 kWp on-grid solar power plant per year. Then, based on these results, the data processing was carried out to obtain the average daily power (kW) and energy (kWh) values that the solar power plant could produce every month. The average daily power value (kW) generated each month can be seen in the time series plot in the simulation results by selecting the time series details analysis and then selecting the inverter power output monthly averages allowing for the display of the average daily power value (kW) for each month. A weighting process was conducted based on the average energy measurement results (in kWh) obtained from PT PLN West Nusa Tenggara's Regional Main Unit to determine the average daily energy value (kWh) produced by the solar power plant each month. It was done because Homer cannot display the average daily energy (kWh) that can be produced by the solar power plant every month.

III. RESULTS

At this stage, the outputs of the Gili Trawangan 600 kWp on-grid Solar Power Plant, comprising a 200 kWp and a 400 kWp solar power plant, were elaborated. The displayed output results were in the form of average power (kW) and energy (kWh) produced by the Gili Trawangan 600 kWp on-grid solar power plant, based on data from PT PLN West Nusa Tenggara's Regional Main Unit's measurement results and the output results obtained from simulation using Homer. Then, the process of comparing these two results was carried out.

A. THE SOLAR POWER PLANT OUTPUT ACCORDING TO DATA FROM PT PLN

Table I presents data on the output of the solar power plant based on the measurement results of PT PLN West Nusa Tenggara's Regional Main Unit. It shows the average daily

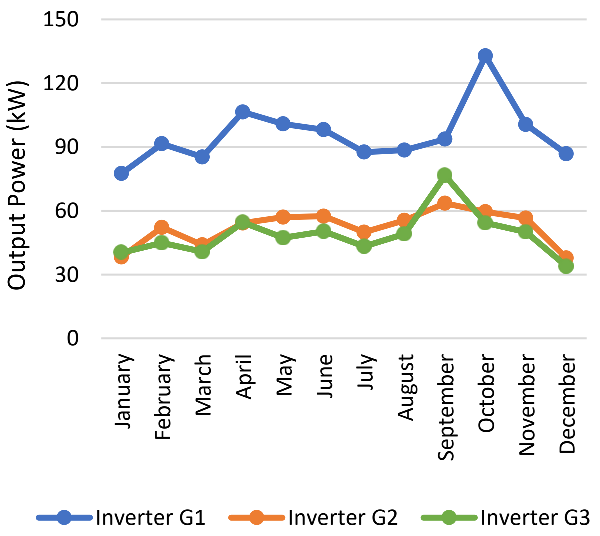

Figure 3. Comparison of average output power of G1, G2, and G3 inverters.

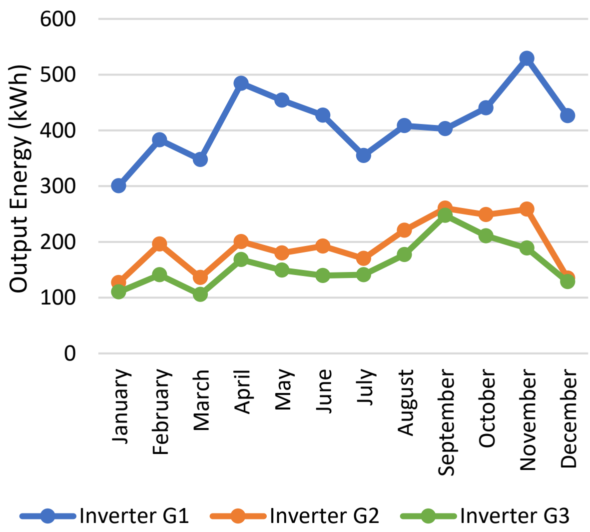

Figure 4. Comparison of the average output energy of G1, G2, and G3 inverters.

power (kW) and energy (kWh) that can be produced by the Gili Trawangan 600 kWp on-grid solar power plant every month. These data consist of the output of the G1 inverter at the 200 kWp solar power plant, the outputs of the G3 and G400 inverters at the 2 kWp solar power plant in Gili Trawangan, as well as data on the solar irradiation intensity (kWh/m^2) in Gili Trawangan.

1) ANALYSIS OF G1 INVERTER OUTPUT RESULTS AT 200 KWP SOLAR POWER PLANT

The average power value (in kW) produced by G1 inverters in a 200 kWp solar power plant with polycrystalline-type PV panels was 95.80 kW (Table I). The lowest average power value (kW) was 77.49 kW, occurring in January, while the highest average value of 132.81 kW happened in October. The average energy output (in kWh) generated by the G1 inverter in a 200 kWp solar power plants system was 413.19 kWh. The lowest average energy output, 300.46 kWh, was recorded in January, while the highest, 528.91 kWh, was observed in November.

2) ANALYSIS OF G2 INVERTER OUTPUT RESULTS AT 400 KWP SOLAR POWER PLANT

Based on Table I, the average power value (kW) that could be produced by G2 inverters at 400 kWp solar power plant with monocrystalline PV type was 52.14 kW. The lowest average power value (37.78 kW) occurred in December, while the highest average power value (63.52 kW) was recorded in September. The average energy output (in kWh) that could be produced by the G2 inverter in a 400 kWp solar power plant was 193.79 kWh. The lowest average energy output was 126.94 kWh, occurring in January, while the highest average was 260.28 kWh, occurring in September.

3) ANALYSIS OF G3 INVERTER OUTPUT RESULTS AT 400 KWP SOLAR POWER PLANT

The average power value (kW) that could be generated by the G3 inverter at the 400 kWp solar power plant with a monocrystalline PV type was 48.76 kW (Table I). The lowest average power (33.95 kW) occurred in December, while the highest average (76.55 kW) was recorded in September. The average energy value (kWh) produced by G2 inverters in a 400 kWp solar power plant was 158.93 kWh. The lowest average energy output (kWh) was 105.55 kWh, observed in March, while the highest average, 247.35 kWh, was recorded in September.

4) COMPARISON ANALYSIS OF THE OUTPUT POWER OF 200 AND 400 KWP SOLAR POWER PLANTS

Based on Table I and Figure 3, the output power (kW) produced by the G1 inverter at the 200 kWp solar power plant with polycrystalline-type PV had an average output power (kW) of 95.80 kW. Meanwhile, the output power generated by the G2 inverter and G3 inverter in the 400 kWp solar power plant with monocrystalline PV type had an average output power of 52.14 kW and 48.76 kW. Based on these results, it is evident that the solar power plant with a capacity of 200 kWp, equipped with polycrystalline PV, produces almost the same output power as the solar power plant with a capacity of 400 kWp, utilizing monocrystalline PV. It shows that the polycrystalline PV used in the Gili Trawangan 200 kWp solar power plant can produce a higher power output compared to the monocrystalline PV used in the Gili Trawangan 400 kWp solar power plant.

These occurrences are attributable to the quality factor of the PV panels utilized in the Gili Trawangan Solar Power Plant. In its use, the monocrystalline PV type in the 400 kWp solar power plant suffered a lot of damage, died completely, and underwent oxidation compared to the PV of the polycrystalline type in the 200 kWp solar power plant [20].

5) ANALYSIS OF THE ENERGY RATIO OF 200 AND 400 KWP SOLAR POWER PLANT OUTPUTS

Based on Table I and Figure 4, the output energy (in kWh) generated by the G1 inverter in a 200 kWp solar power plant with polycrystalline PV type averaged 443.19 kWh. In contrast, the output energy generated by the G2 inverter and G3 inverter in a 400 kWp solar power plant with monocrystalline PV type averaged 193.79 kWh and 158.93 kWh, respectively. Based on these results, it can be concluded that despite having half the capacity of a 400 kWp solar power plant, a 200 kWp solar power plant with polycrystalline PV type can produce better output energy compared to a 400 kWp solar power plant with monocrystalline PV type. It demonstrates that polycrystalline PV panels used in the Gili Trawangan 200 kWp solar power plant can generate a higher energy output compared to monocrystalline PV panels utilized in the Gili Trawangan 400

TABLE II
RESULTS OF 600 KWP SOLAR POWER PLANTS OUTPUT ACCORDING TO MEASUREMENT DATA OF PT PLN

Month	Measurement of PT PLN	
	Output Power (kW)	***Output Energy (kWh)***
January	156.8	537.62
February	187.74	719.93
March	169.52	589.24
April	215.14	852.93
May	204.98	783.23
June	206.14	759.29
July	181.23	666.08
August	193.56	806.17
September	233.21	910.53
October	246.41	899.76
November	207.46	976.37
December	158.45	689.91
Average	196.70	765.92

kWp solar power plant. It is attributed to the PV quality factor employed in the Gili Trawangan solar power plants. In its usage, monocrystalline PV panels in a 400 kWp solar power plant experienced significant damage, complete failure, and oxidation compared to the polycrystalline PV panels in a 200 kWp solar power plant [20].

6) ANALYSIS OF THE POWER AND ENERGY OUTPUT OF THE GILI TRAWANGAN 600 KWP SOLAR POWER PLANT

The power (kW) and energy (kWh) values of the output from the 600 kWp n-grid solaor power plant on Gili Trawangan are shown in Table II. These results represent the average value for each inverter per month, which can be obtained from the data provided in Table I. Equations (1) and (2) outline the steps to find the average values of power (kW) and energy (kWh) for the Gili Trawangan 600 kWp solar power plant.

$$\begin{aligned} \textit{Total average power} \\ &= \textit{average inverter power } G1 \\ &+ \textit{average inverter power } G2 \\ &+ \textit{ inverter power } G3 \end{aligned} \tag{1}$$

$$\textit{Total of average power} = 95.80 + 52.14 + 48.76 = 196.7\ \text{kW}$$

$$\begin{aligned} \textit{Total energy average} \\ &= \textit{average inverter energy } G1 \\ &+ \textit{average inverter energy } G2 \\ &+ \textit{average inverter energy } G3 \end{aligned} \tag{2}$$

$$\textit{Total energy}\ \text{average} = 413.19 + 193.79 + 158.93 = 765.92\ kWh.$$

Based on (1) and (2), the 600 kWp Gili Trawangan on-grid solar power plant was capable of producing an average power output (kW) and average energy output (kWh) of 196.70 kW and 765.92 kWh, respectively. The average power (kW) and energy (kWh) represent the power production and energy output achievable by the 600 kWp Gili Trawangan on-grid solar power plant.

B. THE OUTPUT OF SOLAR POWER PLANTS ACCORDING TO HOMER SIMULATION

Table III presents the output data of the 600 kWp Gili Trawangan on-grid solar power plant, as determined by simulation results using Homer. Output generated in this simulation was in the form of power output (kW) and energy (kWh). Based on Table III, it is evident that the 600 kWp Gili Trawangan on-grid solar power plant has the potential to produce a power output (kW) and energy output (kWh) of 207.10 kW and 840.39 kWh, respectively. The lowest average power value (kW) produced was 177.78 kW, which occurred in January, while the highest average was 234 kW, which was in October. The lowest average energy value (in kWh) that the solar power plant should be capable of producing was 721.40 kWh, occurring in January, while the highest average, 949.54 kWh, was in October.

TABLE III
RESULTS OF 600 KWP SOLAR POWER PLANTS OUTPUT ON THE HOMER

Month	Homer	
	Output Power (kW)	***Output Energy (kWh)***
January	177.78	721.40
February	181.84	737.88
March	202.24	820.66
April	216.54	878.68
May	217.5	882.58
June	202.12	820.17
July	200.6	814.01
August	217.78	883.72
September	233.5	947.51
October	234	949.54
November	209.4	849.71
December	191.94	778.86
Average	207.10	840.39

C. COMPARISON OF SOLAR POWER PLANT OUTPUT RESULTS BASED ON PT PLN MEASUREMENT DATA WITH SIMULATIONS ON HOMER

In this study, an evaluation was conducted on the Gili Trawangan 600 kWp solar power plant system, which has been operational for an extended period, serving the electrical load requirements. Evaluation is carried out to assess the performance of the solar power plant system in meeting electrical load requirements. The performance of a solar power plant can be assessed by its capacity to generate power and electrical energy. The evaluation was conducted by comparing the power and electrical energy produced by the current solar power plant with the potential power and energy that the solar power plant should be able to produce based on its existing potential.

Table IV, Figure 5, and Figure 6 depict a comparison between the output results of the solar power plant based on measurements and simulations. According to the measurement results from PT PLN West Nusa Tenggara's Regional Main Unit, the Gili Trawangan 600 kWp on-grid solar power could produce an average power of 196.70 kW and an average energy output of 765.92 kWh. Meanwhile, according to simulations conducted using Homer, Gili Trawangan's 600 kWp on-grid solar power plant had the capacity to generate an average power of 207.10 kW and an average energy output of 840.39 kWh. Based on these results, it is evident that the average power (kW) and energy (kWh) produced by the Gili Trawangan 600 kWp on-grid solar power plant, according to PT PLN's current measurements, are smaller than the average power (kW) and energy (kWh) that should be able to be produced by the solar power plant based on the existing potential, as per Homer's simulation.

TABLE IV
COMPARISON OF SOLAR POWER PLANT OUTPUT RESULTS ACCORDING TO PLN MEASUREMENT DATA WITH HOMER SIMULATION RESULTS

Month	Measurement of PT PLN		Homer	
	Output Power (kW)	*Output Energy (kWh)*	*Output Power (kW)*	*Output Energy (kWh)*
January	156.8	537.62	177.78	721.40
February	187.74	719.93	181.84	737.88
March	169.52	589.24	202.24	820.66
April	215.14	852.93	216.54	878.68
May	204.98	783.23	217.5	882.58
June	206.14	759.29	202.12	820.17
July	181.23	666.08	200.6	814.01
August	193.56	806.17	217.78	883.72
September	233.21	910.53	233.5	947.51
October	246.41	899.76	234	949.54
November	207.46	976.37	209.4	849.71
December	158.45	689.91	191.94	778.86
Average	196.70	765.92	207.10	840.39

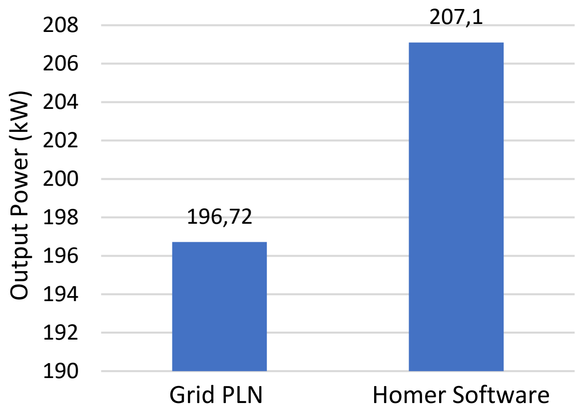

Figure 5. Comparison of the average solar power output of 600 kWp based on the measurement results of PT PLN with the results of the Homer simulation.

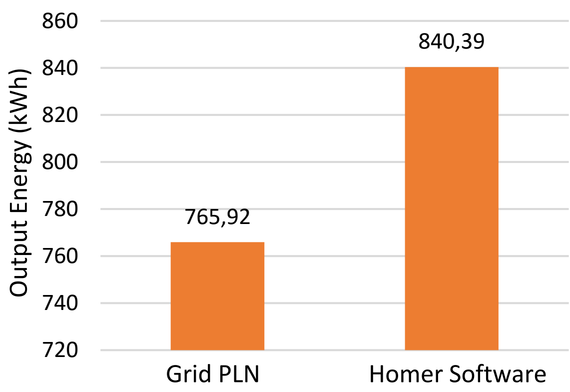

Figure 6. Comparison between the average energy output of a 600 kWp solar power plant, based on the measurement results from PT PLN, and the results obtained from the Homer simulation.

This difference in results occurred because, in the Gili Trawangan 600 kWp on-grid solar power plant system, there was a decrease in performance in its operation, especially in the 400 kWp solar power plant which used monocrystalline PV modules. Monocrystalline PV modules suffered a lot of damage, total shutdown, and oxidation, thus decreasing the performance of Gili Trawangan's 600 kWp on-grid solar power plants [20]. The reason is that monocrystalline PV is not suitable for use in areas that have cloudy or overcast weather, such as the weather in the Gili Trawangan area. In contrast, polycrystalline PV used in 200 kWp solar power plants has a much better performance compared to monocrystalline PV used in 400 kWp solar power plants, even though the installation was done earlier. It happens because polycrystalline PV used in 200 kWp solar power plants has better efficiency and is more stable in producing power and electrical energy Therefore, polycrystalline PV panels are deemed more suitable or preferable for use in regions characterized by cloudy or overcast conditions, such as the Gili Trawangan area [20].

In addition, the intensity of solar irradiation at the 600 kWp Gili Trawangan on-grid solar power plant also impacts the power and energy output. The average solar irradiation in Gili Trawangan, according to the measurement data from PT PLN West Nusa Tenggara's Regional Main Unit, is 3.38 kWh/m^2. Meanwhile, according to NASA data found in Homer, the average potential solar irradiation in Gili Trawangan is 5.40 kWh/m^2. The variance in solar irradiation intensity also influences the quantity of power and energy generated by the Gili Trawangan 600 kWp solar power plant. This occurs because the intensity of solar irradiation directly influences the output current of the PV [21]. The greater the intensity of solar irradiation, the greater the current generated by PV, thereby increasing the power and energy produced by the Gili Trawangan 600 kWp solar power plant.

IV. CONCLUSION

In this study, a performance evaluation of the Gili Trawangan Solar Power Plant with an installed capacity of 600 kWp has been conducted. The average power (kW) and energy (kWh) produced by the solar power plant, according to the measurement data of PT PLN West Nusa Tenggara's Regional Main Unit, are 196.70 kW and 765.92 kWh, respectively. In contrast, the average power (kW) and energy (kWh) that should be produced by the solar power plant, based on the simulation results using Homer, are 207.10 kW and 840.39 kWh. The variation in the resulting value is attributed to the solar power plants system, which has experienced a decrease in performance over time due to prolonged operation. The components of the solar power plant experiencing decreased performance include PV module components, especially those used in the 400 kWp solar power plant with monocrystalline PV, which experienced significant damage, total shutdowns, and oxidation during operation, thus affecting the solar power plant's ability to generate power (kW) and electrical energy (kWh).

The intensity of solar irradiation also affects the power and energy output that solar power plants can produce. This happens because the intensity of solar irradiation affects the PV output current. The greater the intensity of solar irradiation, the greater the current produced, thereby increasing the power and energy generated by the Gili Trawangan 600 kWp solar power plant.

CONFLICTS OF INTEREST

The author asserts that the study titled 'Performance Evaluation of 600 kWp on-grid Solar Power Plant on Gili Trawangan Distribution Network' is free from conflicts of interest, both in terms of writing and compiling the articles

AUTHORS' CONTRIBUTIONS

Conceptualization, Rifky Irawan, and Francisco Danang Wijaya; methodology, Rifky Irawan, and Francisco Danang Wijaya; original drafting, Rifky Irawan, Francisco Danang Wijaya, and Adha Imam Cahyadi; reviewing and editing, Francisco Danang Wijaya, and Adha Imam Cahyadi.

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