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Techno-Economic Analysis Utilization of On-Grid Solar Photovoltaic Systems in Improving Energy Efficiency in Manufacturing Industries

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Abstract
Energy efficiency is a critical factor in the success of the manufacturing industry in the era of globalization and increasing competition. One alternative to reduce dependence on conventional energy sources is to utilize Solar Power Plants. This research focuses on the analysis of the techno-economic utilization of on-grid solar photovoltaic (PV) systems in improving energy efficiency in manufacturing industries using Homer Pro software. The study utilizes data on electricity consumption before and after the use of PV panels on a low voltage 33 kVA customer grid for one year. The results show that after the use of On-Grid Photovoltaic System, electricity costs decreased by 16.935.541 IDR or about 15%. The percentage of On-Grid Photovoltaic System usage reached 15.6%, while the grid usage reached 84.4%. Therefore, this study recommends the use of on-grid solar photovoltaic systems as an alternative energy-saving solution in manufacturing industries. However, in designing On-Grid Photovoltaic System, it is crucial to consider the power of the grid and the loads that will be backed up by On-Grid Photovoltaic System.

Keywords:
Energy Efficiency;
Homer Pro;
Manufacturing Industries;
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INTRODUCTION

In the era of Industry 4.0, the demand for energy is increasing rapidly in line with population and industrial growth. One of the industrial sectors that requires a large amount of energy is the manufacturing industry. In addition, energy costs are one of the biggest factors in the manufacturing process. The larger the energy consumption in the industry, the higher the cost incurred by industry players. In addition, the average energy needs are currently met using fossil fuels which have a negative impact on climate change. Therefore, renewable alternative energy sources are needed to save the environment from greenhouse effects. One such energy source that can be utilized is solar power generation. The photovoltaic system is one of the alternatives for environmentally friendly energy [1, 2, 3].

One alternative to fossil fuel energy is by utilizing solar radiation, where energy from the sun is converted into electrical energy. Some elements of solar radiation, fluid, and heat transfer can be engineered to become sources of energy. The design and analysis of solar energy utilization schemes are approached from a systems-analysis perspective, which combines technical design with techno-economic analysis. There is no single correct solution

to energy management tasks other than utilizing solar energy. Additionally, each problem must be analyzed separately from basic principles to ensure efficiency in energy use [4, 5, 6].

Therefore, innovation is needed in utilizing renewable energy by harnessing solar energy through photovoltaic technology that can provide economic benefits for industries. One way to achieve this is by connecting the solar photovoltaic system to the main electricity grid (on-grid) so that excess energy generated can be utilized and sold back to the grid owned by the State Electricity Company (PLN). Thus, this research aims to analyze the utilization of technology and economic aspects by using on-grid photovoltaics, and to compare the electricity bill costs before and after the use of on-grid solar photovoltaic system using Homer Pro software. By using on-grid photovoltaic systems, it is expected that companies can save on electricity costs and even generate income from selling energy back to the grid.

MATERIAL AND METHODS

On-Grid Photovoltaic System

On-Grid Photovoltaic System is a renewable electricity utilization system that utilizes photovoltaic technology and is connected to the main electricity grid owned by the electricity service provider [7, 8, 9]. On-Grid Photovoltaic System consists of several components, including solar panels consisting of several photovoltaic modules, an inverter that converts direct current (DC) into alternating current (AC) that can be used by electrical equipment, an electric meter to measure the production and consumption of electricity, and other components such as protection equipment. On-Grid Photovoltaic System works by generating electricity from solar energy through solar panels and supplying it to electrical equipment inside the building. When the electricity production from the solar panels is greater than the electricity consumption, the excess electricity will be directed to the main electricity grid [10][11]. Conversely, if the electricity consumption is greater than the electricity production, the additional electricity needs will be supplied from the main electricity grid. For the On-Grid PV system, please refer to Figure 1.

The advantage of the On-Grid Photovoltaic system is that it can maximize the use of electricity generated by solar panels and reduce dependence on fossil energy sources that can produce greenhouse gas emissions. Furthermore, the system can generate additional income through the sale of electricity to the main electricity grid. Additionally, the On-Grid Photovoltaic System is relatively easy to operate and can be integrated with an automated control system (SCADA) to monitor and regulate system performance in real-time.

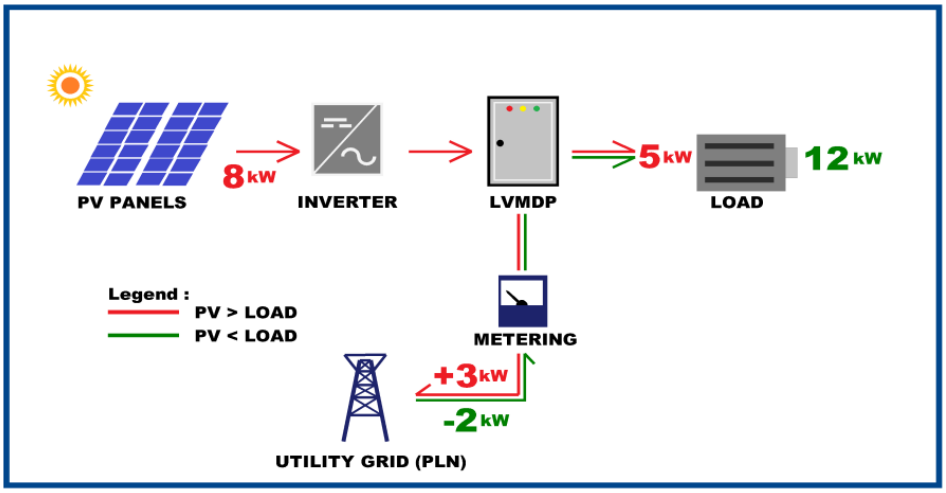

Figure 1. On-Grid PV System

However, there are some disadvantages of the On-Grid Photovoltaic System, such as dependence on the availability of the main electricity grid, which can cause problems if there is a disruption in the main electricity grid. In addition, the high initial investment cost is also a challenge in implementing the On-Grid Photovoltaic System [12, 13, 14, 15].

Methods

The research method used in this study includes several stages, starting with site survey to determine the suitability of installing the On-Grid Photovoltaic System in the industrial area. Then, an analysis of electrical loads is conducted, which includes the electricity usage and usage time of electrical equipment in the industry. Next, an optimal design of the system is created to meet the energy needs of the industry. The performance of the system and operational costs are then estimated through simulation using Homer Pro software [16, 17, 18, 19, 20]. Based on the analysis and simulation results, it is concluded that the implementation of the On-Grid system is highly effective in improving energy efficiency and reducing operational costs in the manufacturing industry. Figure 2 presents a research flowchart.

Study Area

In the study, the research was conducted at PT Bisma Belis located in the Indoporlen industrial area in South Tambun, Bekasi Regency, precisely at coordinates 6°15'09.5"S 107°02'30.0"E. The planning location can be seen in Figure 3.

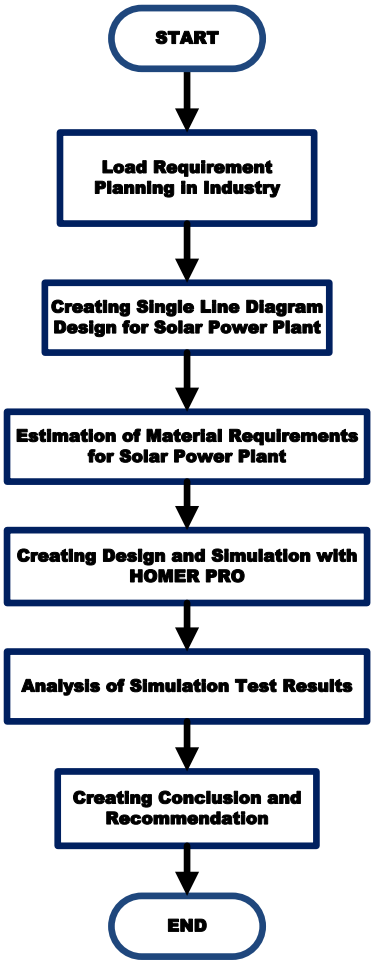

Figure 2. Research Flowchart

Figure 3. PV Planning Location

The company operates in the manufacturing industry, specifically in the assembly of electrical panels and repair of distribution transformers. The power source comes from the Tambun Main Substation and is distributed through a portal substation with a capacity of 33 kVA. The charged is 1444.5 IDR/kWh, which is relatively high for small-scale industries. Therefore, a On-Grid Photovoltaic System is needed to improve energy efficiency.

RESULTS AND DISCUSSION

Load Data

In designing an On-Grid Solar PV system, a classification of the loads is necessary so that the material requirements for the PV system can be estimated. Table 1 shows the load requirements with a total load of 26.47 kW. The data on the loads will be used as a reference for designing and simulating the system using Homer Pro.

Table 1. Load Data in Industry

Load	kW	Pcs	Total (kW)
Office Area			
Computer	0.25	5	1.25
AC 2 PK	1.92	2	3.84
Refrigerator	0.2	1	0.2
Electric Stove	1.2	1	1.2
Barret Lamp	0.032	4	0.128
Incandescent Light Bulb	0.006	1	0.006
Dispenser	0.42	2	0.84
TL 1X18	0.018	4	0.072
TL 2X18	0.032	2	0.064
Printer	0.0068	4	0.0272
Attendance Machine	0.01	1	0.01
Work Shop Area			
Hoist 6 Ton	0.75	2	1.5
Compressor	1.8	1	1.8
Bench Drill	0.75	3	2.25
Hydraulic Bending Busbar	0.2	1	0.2
Welding Transformer	2	1	2
Grinding Machine	0.85	3	2.55
Incandescent Light Bulb	0.006	2	0.012
Cutting Machine	1.65	4	6.6
Dispenser	0.42	2	0.84
TL 1X18	0.018	5	0.09
TL 2X18	0.032	6	0.192
Industrial Lamp	0.1	8	0.8
Total Load			26.4712

Solar Energy Source Data

In designing a solar power system, solar radiation data is needed as a reference to estimate the amount of energy used. In this research, the researcher obtained the data from the official NASA website. Then, the researcher placed the map coordinates for the Bekasi Regency area in West Java, where the average solar radiation level reaches 6.73 kWh/m²/days with an average temperature of 30.48 °C. This natural resource potential needs to be developed, considering that Bekasi is an industrial area. This is a significant potential for utilizing solar energy. The data source can be seen in Table 2.

Component Cost Budget Planning

When designing a system, attention must be paid to the materials used and predicting the budget plan that will be used in designing the solar power system. In the location, there is already an existing LVMDP panel. The highest load is typically during the day, but the load at night only reaches 6.06 kW. Because the main network still depends on PLN, the solar power system is only needed to back up energy at night. With a battery capacity that lasts up to 5 hours, a solar power system with a capacity of 8 kW is needed. Therefore, in planning the solar power system, only 550 WP Solar Panel, Joint Box, Control Panel with batteries, and an 8 kW Inverter are needed. The Control Panel is connected to the existing LVMDP network still supplied by the PLN network. For the price details, please refer to Table 3.

Design and Simulation of On-Grid Photovoltaic System

When designing and simulating a On-Grid Photovoltaic System using Homer Pro, it is necessary to identify the energy needs. Then, select the necessary components to build the On-Grid Photovoltaic System, such as solar panels, batteries, power converters (inverters), and other equipment.

Table 2. Temperature & Solar Radiation Data in Bekasi

Month	Temperature (C°)	kWh/m²/days
January	29.9	7.21
February	29.53	7.27
March	30.36	7.13
April	30.4	6.67
May	30.54	6.08
June	30.38	5.8
July	30.11	5.98
August	30.48	6.35
September	31	6,9
October	31.78	7.07
November	30.64	7.14
December	30.66	7.11
Average	**30.48**	**6.73**

Table 3. Initial investment cost as well as operational

Material	Qty	Price
Solar Panel 550 Wp	2 ea	14.928.000 IDR
Inverter 4 kW	2 ea	8.500.000 IDR
Control Panel with Battery	1 ea	25.000.000 IDR
NYY 4x2,5mm	15 m'	560.000 IDR
Auxiliary Material	1 Lot	1.000.000 IDR
Grand Total		49.988.000 IDR

Next, configure the system where the user must determine how to configure the system to be efficient and reliable. The next step is to simulate the system to provide important information about efficiency, cost savings, and system performance when using On-Grid Photovoltaic System to achieve cost efficiency due to the high electricity cost from PLN. The schematic diagram of the system design can be seen in Figure 4.

After that, input the load data that exists in the company and it can be seen through Homer Pro software. The results can be seen in Figure 5 where the average load reaches 9.01 kW with a peak load of 26.21 kW and the average daily energy consumption reaches 216.65 kWh/d. The figure shows a large power consumption especially during the morning to afternoon hours.

Electricity Production Simulation Results When Using PV

From the simulation results, it is shown that the use of PV panels can reduce the electricity consumption up to 12.472 kWh/year with a usage percentage of 15.6%, while the electricity usage from the grid (PLN) reaches 67.267 kWh/year with a usage percentage of 84.4%. The monthly production can be seen in Figure 6, with the total main load per year reaching 78,975 kWh/year. The estimated electricity sales are around 0.127%, and the excess usage reaches 97.9 kWh/year. Table 4 listed the percentage of electricity production in 1 year.

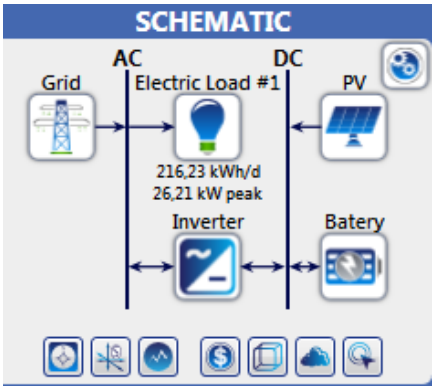

Figure 4. Schematic Diagram PV

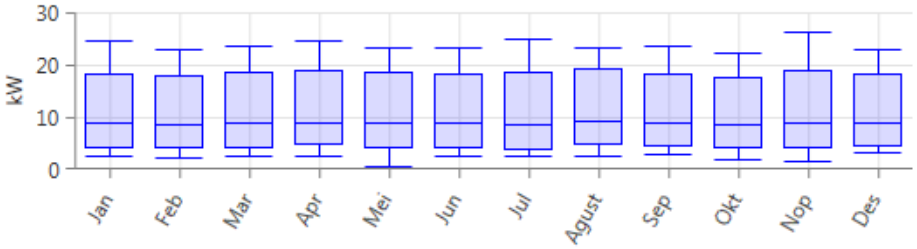

Figure 5. Seasonal Profile Load

Table 4. Percentage of Electricity Production in 1 Year

Description	kWh/year	%
Generic PV	12.472	15.6
Grid Purchases	67.267	84.4
AC Primary Load	78.975	99.9
Grid Sales	100	0.127
Excess Electricity	97.9	0.123

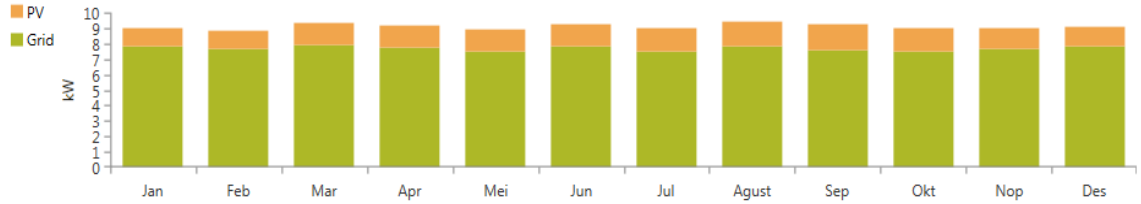

Figure 6. Monthly Average Electric Production

Energy Charge Before PV Installation

Based on the data presented in Homer Pro software, as listed in Table 5, it can be concluded that prior to the installation of PV panels, the electricity consumption was heavily dependent on PLN as the energy source and was relatively expensive. In a year, the total payment for electricity was quite substantial, reaching 114.022.477 IDR. However, by installing PV panels, it is expected to reduce dependence on PLN and also reduce the cost of electricity payments. Furthermore, the peak load data of 26.21 kW can be used as a reference for selecting the type and capacity of PV panels to be installed. The energy consumption from the grid (PLN) can be seen in Figure 7.

Energy Charge After PV Installation

After the installation of Grid-Tied PV system, where the energy sold to the grid (PLN) reached 97.086.936 IDR in one year, this had a significant impact on the efficiency of electricity use and the reduction of carbon emissions from fossil fuel power plants, as refer to Table 6. The average energy sold to the grid (PLN) per month was 8.33 kWh, which is very economically beneficial compared to not using PV panels.

Table 5. Energy Charge Before PV Installation

Month	Energy Purchased (kWh)	Peak Demand (kW)	Energy Charge (IDR)
January	6638.73	24.63	9.590.972 IDR
February	5885.86	22.98	8.503.303 IDR
March	6862.17	23.81	9.913.781 IDR
April	6538.63	24.69	9.446.359 IDR
May	6582.76	23.21	9.510.117 IDR
June	6577.83	23.41	9.502.984 IDR
July	6634.74	25.03	9.585.203 IDR
August	6924.27	23.30	10.003.490 IDR
September	6551.62	23.43	9.465.122 IDR
October	6608.71	22.39	9.547.605 IDR
November	6410.59	26.21	9.261.385 IDR
December	6708.77	22.86	9.692.154 IDR
Annual	78924.67	26.21	114.022.477 IDR

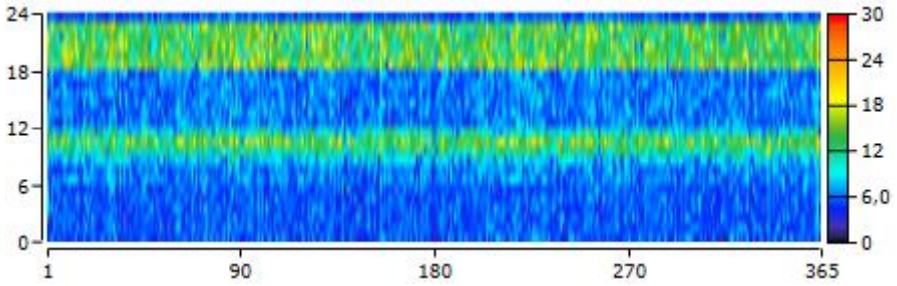

Figure 7. Energy Purchased From Grid Before Installation PV

Table 6. Energy Charge After PV Installation

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Peak Demand (kW)	Energy Charge (IDR)
January	5794.14	15.07	24.63	8.356.650 IDR
February	5115.12	7.13	22.98	7.383.122 IDR
March	5886.60	5.72	23.81	8.498.997 IDR
April	5558.00	5.67	24.69	8.024.312 IDR
May	5574.69	11.63	23.21	8.042.834 IDR
June	5604.35	9.44	23.41	8.087.735 IDR
July	5581.90	8.17	25.03	8.056.494 IDR
August	5819.23	10.97	23.30	8.396.737 IDR
September	5460.29	7.66	23.43	7.881.283 IDR
October	5546.13	6.93	22.39	8.005.984 IDR
November	5514.09	5.62	26.21	7.960.930 IDR
December	5812.62	6.01	22.86	8.391.856 IDR
Annual	67267.16	100.03	26.21	97.086.936 IDR

Therefore, the industrial sector needs to adopt renewable energy to make production costs more efficient. Purchases of energy from the grid can be seen in Figure 8, and the energy sold from the PV panels can be seen in Figure 9.

Analysis of Simulation Test Results

After conducting a simulation with Homer Pro, it was found that there was a price difference of around 16.935.541 IDR in electricity purchases from the grid (PLN) before and after the use of PV panels, with only an investment of 49.988.000 IDR. This resulted in significant energy savings. Figure 10 shows this for a comparison graph. The operational cost is much cheaper compared to using diesel-powered generators. Maintenance is also cheaper and less complicated, making the use of solar energy cells a necessary alternative for energy conservation [21][22].

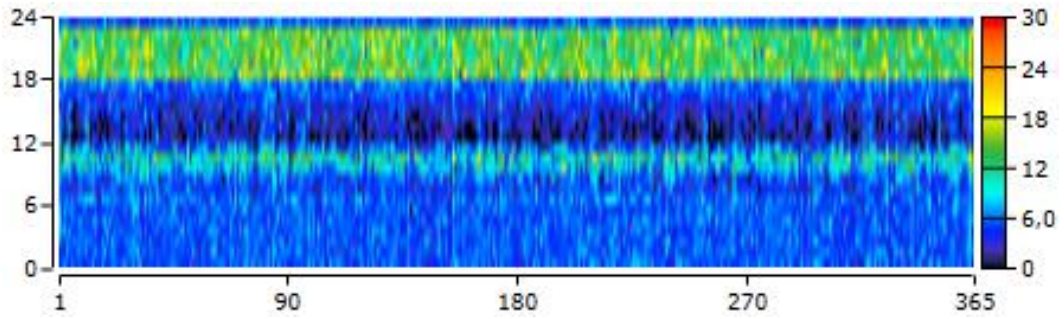

Figure 8. Energy Purchased From Grid After Installation PV

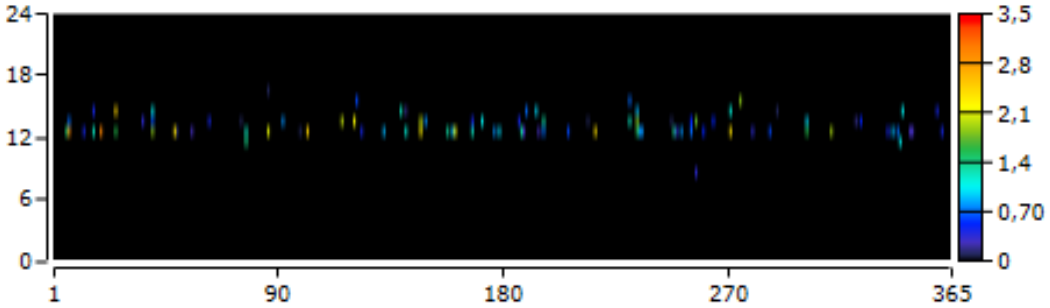

Figure 9. Energy Sold To Grid

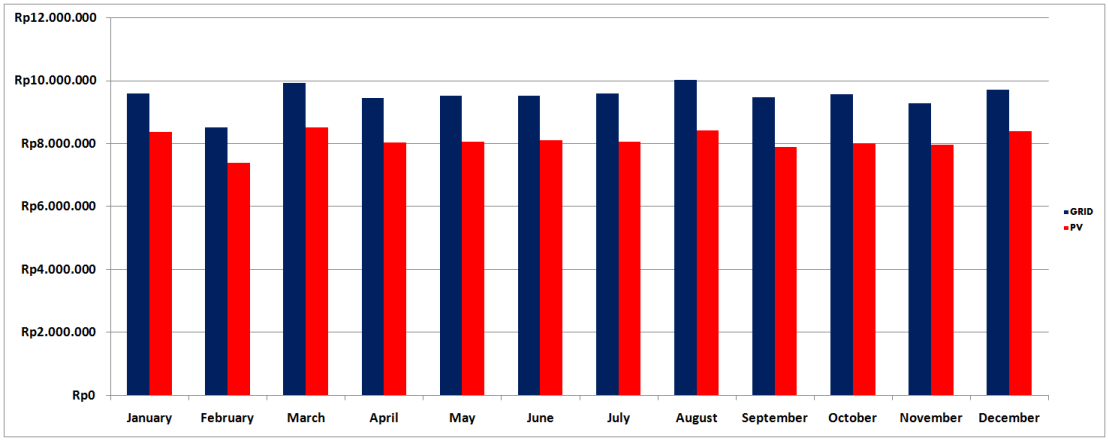

Figure 10. Comparison of Costs Before and After PV Installation

CONCLUSIONS

Based on the Techno-Economic Analysis of Utilizing On-Grid Solar Photovoltaic (PV) System to Improve Energy Efficiency in the Manufacturing Industry, it can be concluded that the use of Homer Pro software in a low-voltage customer electricity network with a capacity of 33 kVA resulted in an energy consumption of 216.23 kWh/day and a peak load of 26.21 kW/year. Prior to implementing the Solar Photovoltaic (PV) system, the electricity cost amounted to 114.022.477 IDR. However, after implementing the PV system, the electricity cost was successfully reduced to 97.086.936 IDR, resulting in savings of 84.4% compared to the previous electricity cost. Furthermore, the PV system also achieved a cost utilization efficiency of 15.6%.

Suggestions that can be taken from the simulation test results are as follows. In future research, it can be combined with Diesel Power Plants (DPP) and wind power generators as an alternative solution to Solar Photovoltaic systems. In designing the On-Grid PV system, it is necessary to pay attention to the power of the grid and the loads that will be backed up by the PV system. Furthermore, this research can serve as a reference for future studies.

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