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Planning of Solar Power Plant SMA LabSchool UPGRIS with PV*SOL

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ABSTRACT

The increase in the use of electrical energy is increasing in the development of technology at this time. At present in Indonesia, power plants still use non-renewable energy sources that will eventually run out. The purpose of this study is to provide a source of electricity with solar energy sources, so that dependence on PLN electricity can be reduced. The method used is planning and simulating using PV*SOL software. The planned location for the installation of Solar Power Plant (SPP) is in the Gayamsari District, Semarang City, Central Java. The location of the SMA Building has an area of 1773 m2 with coordinates of Latitude -6.9830564° N, 110.4494686 ° E. In the planning, the stages are determining the location of the PLTS, identifying solar radiation intensity data, identifying electrical load data, determining solar panel capacity, determining battery capacity, determining inverter capacity, and determining the capacity of the Solar Charge Controller (SCC). The planned SPP operates in an off-grid system. In carrying out this planning with stages. The results of the study showed that the amount of daily electricity consumption was 18,402 Wh and the electricity consumption for one month was 552,060 Wh. The simulation showed that solar panels effectively produced an average of 1300 kWh of electricity. The production of large solar panels occurred from April to October, with an average energy of 130 kWh. The results of the study showed that the amount of electricity consumption was large but could be served by solar power plants.

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1. INTRODUCTION

The increase in the use of electrical energy is increasing in the development of technology at this time. At present in Indonesia, power plants still use non-renewable energy sources that will eventually run out. Indonesia is a country that has very abundant renewable energy sources. One of the most abundant renewable energy sources in Indonesia is solar energy. This type of renewable energy source is most suitable for use to meet electrical energy needs, especially electrical energy needs in housing or residential homes, school buildings, government buildings, and industry. The use of solar energy as a source of electricity in homes or school buildings can reduce dependence on PLN electricity which still uses non-renewable energy.

The development of solar energy use with solar panels is not only installed on the roof of the building which is better known as rooftop Solar Power Plant, but also installed on the surface of the water which is known as floating Solar Power Plant. This method is usually used for solar panels on a large scale. To increase the generation of electrical energy with solar panels, a change in direction is made to the south, east or west, in order to obtain maximum output [1]. Furthermore, researchers [2] designed a solar panel module with a new configuration, so that large output can be produced even if there is heat or damage to the solar panels. Usually solar panel modules only have a terminal connection box from several circuits. The proposed module design has two junction boxes located at the top and bottom. Researchers [3] proposed the design and optimization of solar panel installations with panel surface variables, weather data, solar panel models. Usually in the design of solar panel installations, the focus is on identifying the roof surface or geographical conditions of an area. Researchers [4] focused more on micro-inverters connected to solar panels with current decoupling. The purpose of the study was to obtain the maximum power point of solar panels without using large capacitors. With this method, the current decoupling on the micro-inverter can overcome the difference in current from the solar panel and the DC current from the utility grid that has been rectified. Researchers [5] proposed an optimization method in designing a power plant with solar panels. This is due to geographical changes, meteorological changes, and the addition or reduction of the available area that can affect the size of the inverter and the type of solar panels. Furthermore, to improve the solar panel system connected to the utility grid, an optimal design of solar panels and inverters with an integrated design process is proposed. The study was conducted by comparing separate and integrated arrangements on solar panels and inverters [6]. In the study conducted [7] aims to improve solar panels with benchmark analysis. This is because the location, orientation, and angle of the solar panel installation significantly affect its performance and shorten its durability. The study was conducted using two different panel positions with PSIM and Matlab simulations. Researchers [8] proposed a volt-watt and volt-VAR control design for high integration of solar energy with the aim of reducing voltage drops and distributing electrical energy evenly to all loads. With the increasing public interest in the use of solar panels, research was conducted on the impact of very high penetration of solar panel generation [9]. Researchers predict the impact of increasing the generation rate of solar panels when reaching a very high penetration rate and voltage fluctuations occur. In the use of solar panels, they are usually equipped with battery energy storage, which is connected to a DC inverter link to restore solar panel energy. Researchers [10] used a DC-DC converter that functions as a controller of the maximum power point of the solar panel output and a DC link controller. With this configuration, excess power can be stored in the battery and supplied to the utility grid. To design a Solar Power Plant (SPP), researchers [11] used PVsyst at PT.Industri Gula Glenmore. In the planning with PVsyst, a 4 MWp rooftop SPP model installation was produced which was installed on an area of 2 hectares. In the planning using 330 Wp solar panels, with a total of 12,121 units, 22 on-grid model inverters with a capacity of 150 kW. Based on the simulation, the electrical energy produced was 902.7 kWh/year.

To determine the performance of microgrids for housing, researchers [12] designed a DC microgrid with a centralized power system using solar panels and batteries. The microgrid operates in an off-grid system. In this arrangement, an outseal PLC is used. The proposed strategy is able to produce DC bus voltage stability with fluctuations of around 10%. Furthermore, the DC microgrid was developed with a new DC/AC coupling configuration [13]. The study was simulated using MATLAB simulink. In this study, two PV arrays, two multi-batteries, and connected to the utility grid were used. The DC microgrid was controlled from each DC-DC converter by sending a reference signal to the converter control. The simulation results showed a DC bus voltage stability of 48 V. In addition, the development of solar panels can be done by developing a DC-DC converter configuration with Proportional Integral (PI) control in a stand-alone system [14]. The design was carried out using Matlab simulation. The proposed method is able to overcome DC bus voltage fluctuations when there are changes in solar panel output and load. The strategy for increasing the power source is improved using fuzzy logic to regulate the power flow at the solar panel/battery source and at the load [15]. The regulation strategy is carried out using coordinated control on the microgrid system with an AC coupling configuration. The provision of renewable energy sources is carried out with several solar array panels and several batteries connected to the DC bus. The proposed strategy is able to increase load services with a THD of around 10%. Another method to increase solar panel output is using a Fuzzy-PID controller on a solar charge controller device with the Maximum Power Point Tracking (MPPT) algorithm [16]. Testing was carried out on residential loads. The test results with Fuzzy-PID produced solar panel output at the optimum point when compared to MPPT in general, with an efficiency of 95.79%. Furthermore, to increase the availability of battery energy, coordinated control is used to regulate the energy flow of several batteries using a fuzzy logic controller, so that the DC bus voltage is stable. This method is used in microgrids with a DC coupling configuration [17]. The results of the study showed lower voltage and power deviations when compared to using a proportional integral (PI) controller. Researchers [18] conducted an optimal design of a low-voltage distribution network for rural electrification by calculating solar panels and battery energy storage for a period of 30 years. The aim is to obtain an optimal topology in a low-voltage distribution system, by determining the location.

Next, researchers [19] conducted off-grid minigrid planning by providing rural electrification. Planning was carried out by considering equipment size and resource allocation, distribution network location, and reliability cost-benefit analysis. Optimization was carried out to minimize customer electricity costs and maintain the targeted reliability level. The results of the study showed that reliability ranged from 18% to 130% for reliability probabilities from 10% to 100%. Researchers [20] conducted the design, analysis, and implementation of a DC microgrid architecture with an off-grid system using widespread solar panels and suitable for rural electrification in developing countries. The proposed architecture has advantages for rural electrification in terms of generation and storage scalability, higher distribution efficiency, the ability to provide electricity for larger communal loads without requiring large and special generation by utilizing the diversity of use, and the controller uses a hysteresis-based voltage droop control method, so that no central controller is needed. Finally, researchers [21] conducted optimal planning and design of microgrid energy system management for rural electrification. This research focuses on the optimal utilization of biomass potential by considering the specifications of the bio generator (BG). The microgrid system uses BG, solar panels, wind turbines, and batteries. The purpose of the research is to minimize the current net total cost, energy costs and greenhouse gas (GHG) emissions.

Based on previous research, it is proposed to plan a Solar Power Plant (SPP) in a school environment, namely SMA LabSchool UPGRIS Semarang. In the study, a centralized controller is used to regulate the flow of energy. The purpose of this study is to provide a source of electricity with solar energy sources, so that dependence on PLN electricity can be reduced. In this planning, identification of potential solar irradiation, identification of loads, calculating the needs of solar panels, batteries, inverters, and solar charge controllers (SCC) are carried out.

2. METHOD

In the study, a design of a Solar Power Plant was carried out as a source of electricity for the activities of SMA Labschool UPGRIS Semarang. The design and simulation were carried out using PV*SOL software. This software is used to help predict the generation of solar panels in the Solar Power Plant system. In addition, this software also helps the performance of the inverter and battery. This study also shows the intensity of solar radiation and environmental temperature, so that the suitability of the location is one of the important requirements. The planned Solar Power Plant operates in an off-grid system. In carrying out this planning with the following stages:

a. Determine the location of the Solar Power Plant.
b. Identify solar radiation intensity data.
c. Identify electrical load data.
d. Determine the capacity of the solar panels.
e. Determine the battery capacity.
f. Determine the inverter capacity.
g. Determine the capacity of the Solar Charge Controller (SCC).

When all data has been determined in the PV*SOL software, the Solar Power Plant simulation can show the solar panel generation and load energy consumption.

2.1. Solar Power Plant Locations

The planned location for the installation of PLTS is in the Gayamsari District, Semarang City, Central Java. The location is shown in Figure 1. The location of the SMA Building has an area of 1773 m2 with coordinates of Latitude -6.9830564° N, 110.4494686° E.

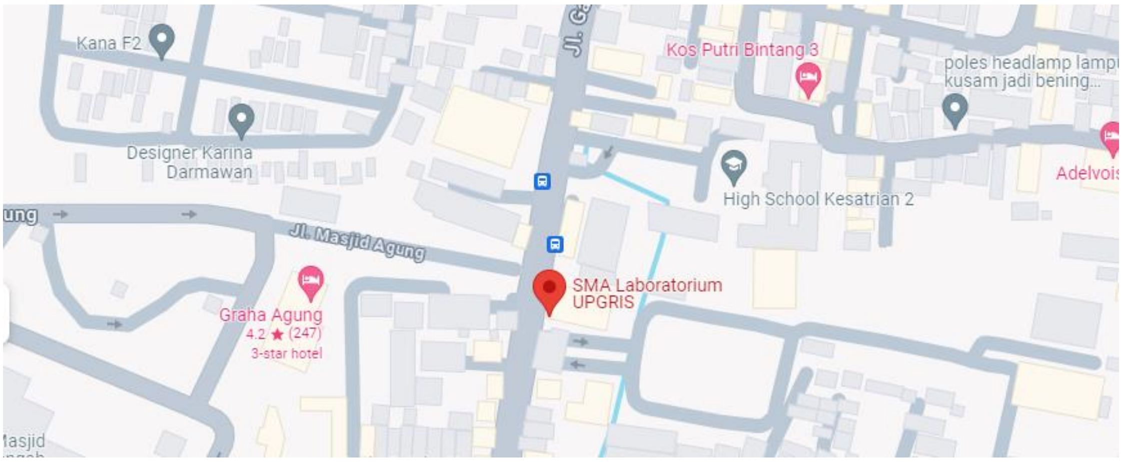

Figure 1. Location of Solar Power Plant planning.

Meanwhile, in Figure 2, it shows the solar azimuth which shows the angle at the horizontal position in the north direction in the location of the Solar Power Plant planning. This image shows the geographical conditions of the location where the Solar Power Plant will be installed. Solar azimuth is useful for placing solar panels according to the radiation of the solar.

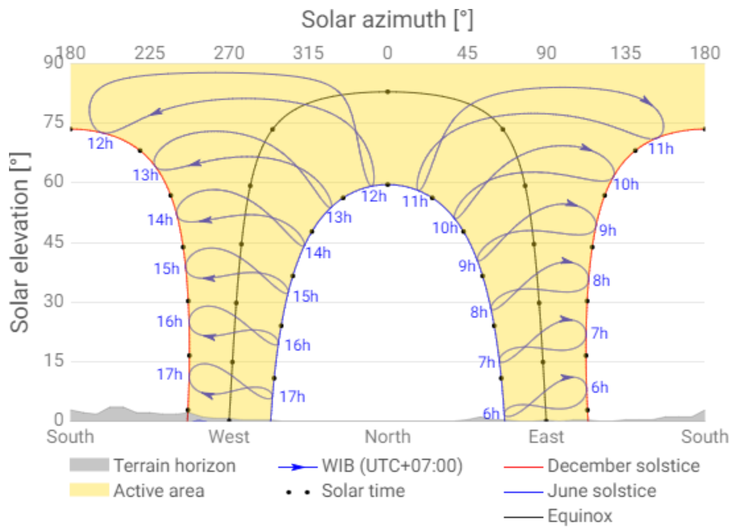

Figure 2. Solar azimuth location planning for Solar Power Plant.

2.2. Solar Irradiation Intensity

The location in the study has an annual irradiation intensity (2023) of 1920.7 kWh/m2 as shown in Figure 3. In the figure, the highest irradiation intensity is seen in October, at 190 kWh/m2 or 6.3 kWh/m2 per day. The ambient temperature in that month was 29 ºC, which is the highest temperature compared to other months. While the lowest irradiation intensity occurred in January at 130 kWh/m2 or 4.3 kWh/m2 per day. However, the irradiation potential in January is still quite large for solar panels and this shows that the research location has the potential for using solar panels to meet electricity needs.

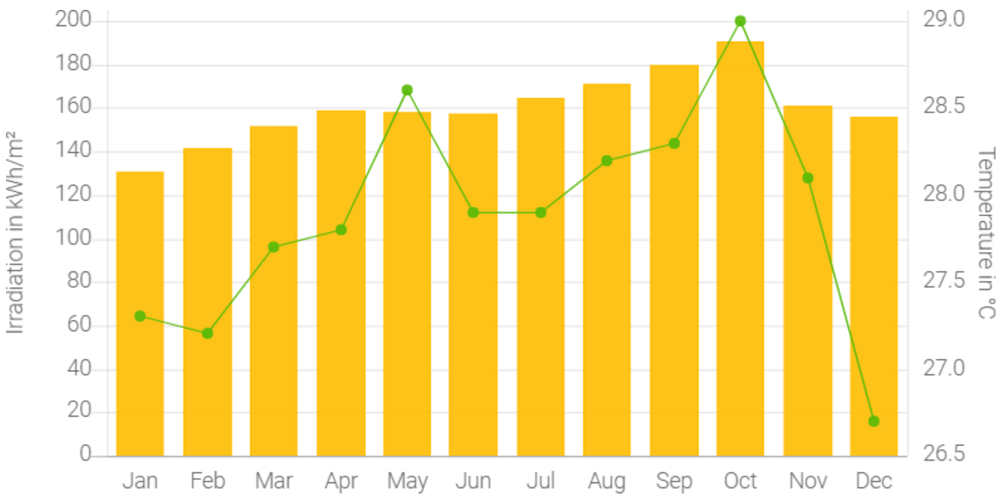

Figure 3. Intensity of solar irradiation.

2.3. Electrical Load

Identification of electrical loads is shown in Table 1, with the largest use of AC loads of 8,880 Wh. The amount of electrical energy consumption per day is 18,402 Wh and electrical energy consumption for one month is 552,060 Wh. The daily electrical energy consumption is shown in Table 1, with loads of lights, fans, AC, and water pumps. These loads are the electrical loads used every day at school.

Table 1. Load energy consumption.

Load	Quantity	Time (hour)	Power (W)	Energy (Wh)
LED Lamp	15	12	18	3240
LED Lamp	20	12	12	2880
Fan	6	8	44	2112
Air Conditioner	2	6	740	8880
Water Pump	1	6	215	1290

2.4. Solar Panel

The need for solar panels in planning is determined based on the consumption of electrical energy and the duration of effective irradiation intensity. For the average intensity duration in Indonesia for 5 hours, so the number of solar panels is determined by the following equation

$$PV = \frac{E_b}{I_r \times P_k} \quad (1)$$

In equation (1) P_V represents the number of solar panels, E_b represents the amount of energy in the load, I_r represents the duration of effective intensity, P_k represents the capacity of the solar panels used.

2.5. Battery

The battery in this planning is used to store excess electrical energy during the day and used at night or when the weather is rainy. The battery in this planning uses VRLA 1 200 Ah. For the number of batteries used based on the equation below

$$B = \frac{E_b}{V_b \times B_k} \quad (2)$$

In equation (2) B represents the number of batteries, E_b represents the amount of energy in the load, V_b represents the battery voltage, and B_k represents the capacity of the batteries used.

2.6. Inverter

The inverter is used to convert the DC output voltage of the solar panel and battery into 220 V AC voltage. The inverter in this planning uses the Eversol TL3000 (Ever-Solar). The capacity of the inverter used is greater than the load, with a capacity of 30% exceeding the power on the load.

2.7. Solar Charge Controller (SCC)

SCC in the planning of power plants with solar panels is used to regulate the charging and discharging process of batteries and the distribution of solar panel output to the inverter. The planned SCC is of the PWM type, while its capacity is calculated using the following equation

$$K_{SCC} = PV_{Isc} \times N_{PV} \quad (3)$$

In equation (3) K_{SCC} represents the SCC capacity used, PV_{Isc} represents the short circuit current of the solar panels, and N_{PV} represents the number of solar panels.

3. RESULTS AND DISCUSSION

In this planning based on equation (1) 12 300 Wp solar panels are used, while for battery needs based on equation (2) 8 200 Ah panels are needed. In load needs, an inverter with a capacity of 5Kw is used, and for SCC capacity based on equation (3) an SCC with a capacity of 150 A is needed. The calculation results are simulated using PV*SOL.

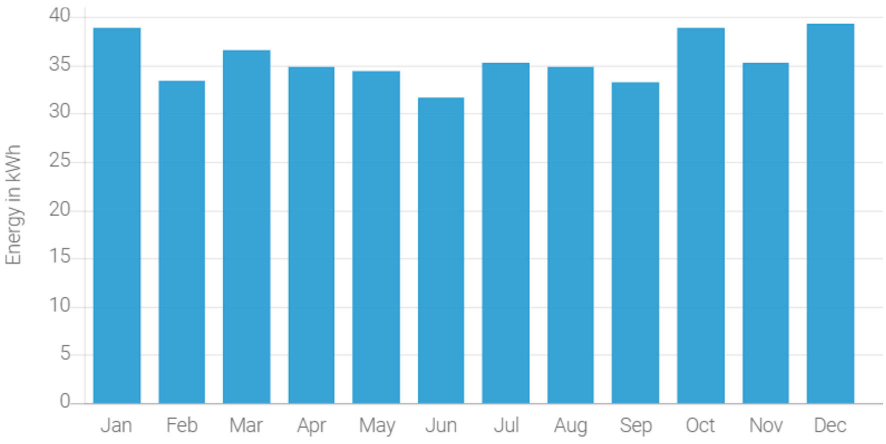

Figure 4. Electrical energy consumption.

Figure 4 shows the electricity load consumption in the school building each month simulated by PV*SOL software. The increase in load occurred in January, October, and December. This shows that in those months there was an increase in activities, so that all electricity loads were used a lot.

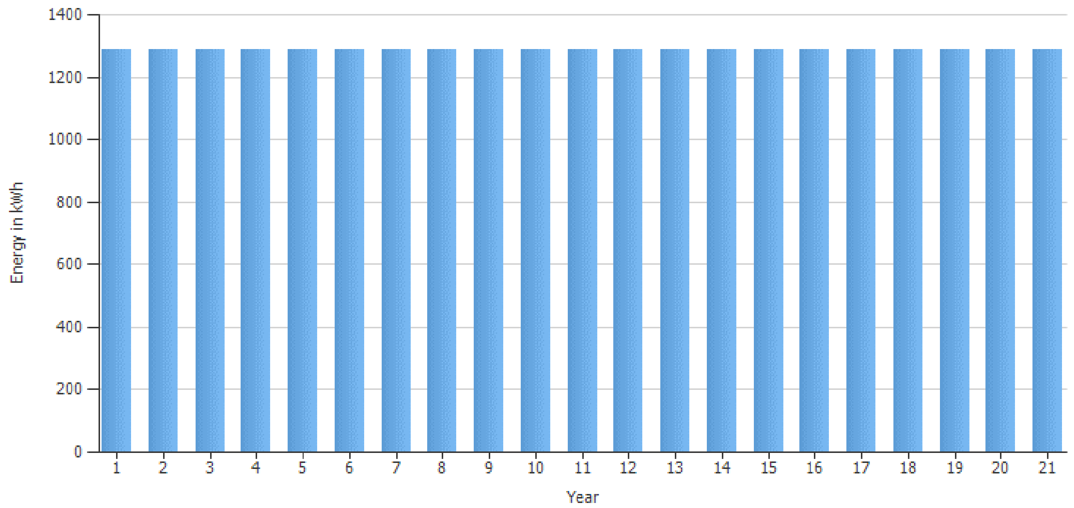

Figure 5. PV Energy.

Figure 5 shows the energy produced by solar panels for 21 years, it can be seen that solar panels effectively produce an average of 1300 kWh of electrical energy. This shows that solar panels are effectively used as a source of electricity in the community.

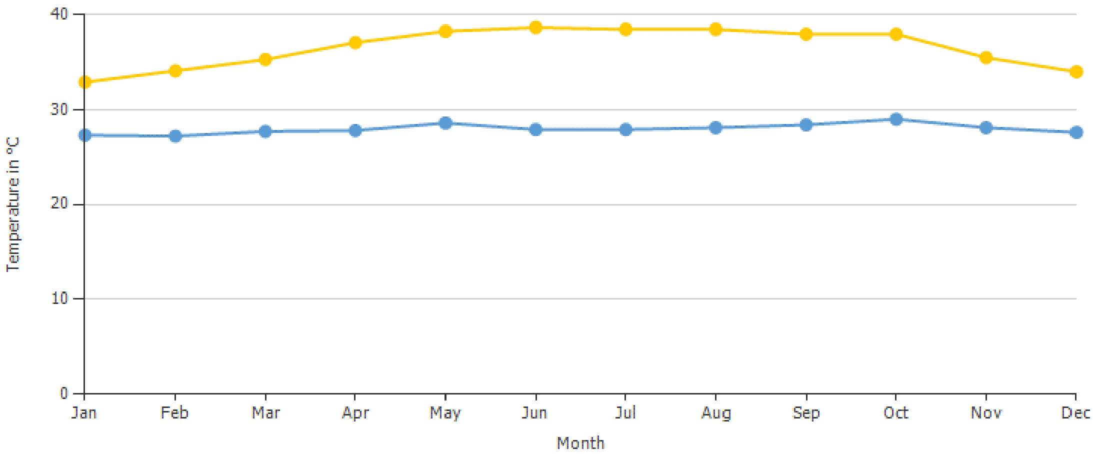

Figure 6. Temperature on solar panel module.

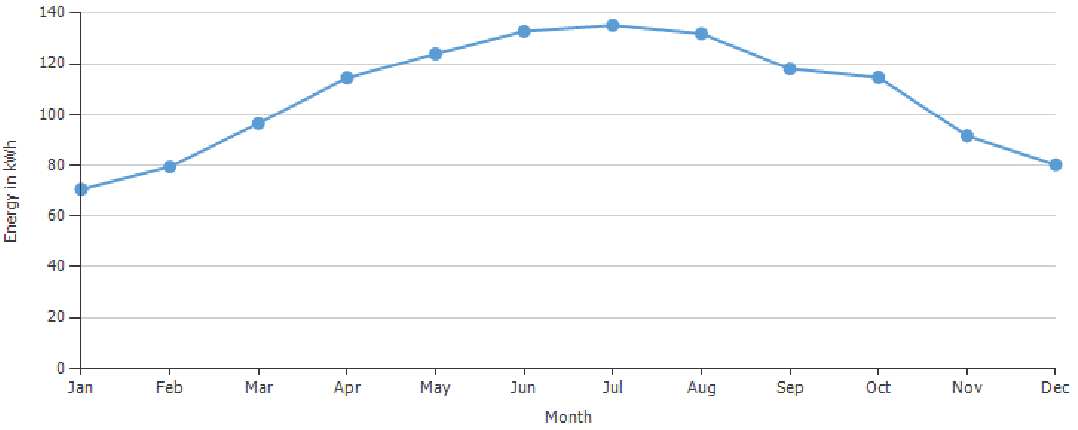

Figure 7. Inverter energy prediction.

Figure 6 shows the temperature changes in the solar panel module area, with a yellow line. The figure shows that the temperature from April to October is quite high, with an average temperature of 38 ºC. While the blue line shows the temperature outside the solar panel area, with an average temperature of 28 ºC. Figure 7 shows the predicted inverter output energy. Based on Figure 7, the largest inverter energy output occurs in July, with an average electrical energy of 135 kWh. While the smallest inverter energy output occurs in January, with an average electrical energy of 70 kWh. This shows that the largest load occurs in July and the lowest load occurs in January.

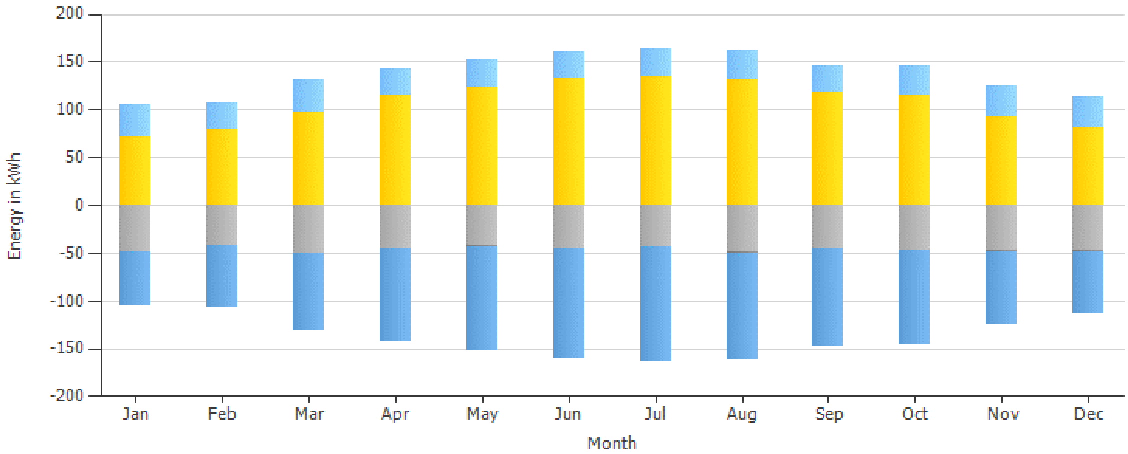

Figure 8. Output of solar power generation system.

Figure 8 shows the final simulation based on the planning that has been done at the location of the Labschool High School Building, Universitas PGRI Semarang (UPGRIS). The figure shows the predicted energy output from solar panels, batteries, equipment loads, and utility grids. The yellow line shows the production of electrical energy from solar panels, while the black line shows the equipment load used. In the figure, the dark blue line shows the production of electrical energy from the battery, while the light blue line shows the contribution of the utility grid source. The production of solar panels with a large category occurs from April to October, with an average energy of 130 kWh. Figure 8 shows the large production of solar panels and batteries so that they are able to supply the load without interruption, while the contribution of the utility grid source is very low and is needed when the weather is rainy or the battery production is interrupted.

4. CONCLUSION

Increased electricity consumption can be served by solar panels and batteries in a solar power generation system. Integration with batteries is used to supply the load at night and when the solar panel output is disconnected. The simulation shows that solar panels effectively produce an average of 1300 kWh of electricity. Large-scale solar panel production occurs from April to October, with an average energy of 130 kWh. The increase in load is due to the many activities in January, October, and December, so that all electrical loads are widely used. This research can be implemented and developed with a coordinated control strategy in areas that are not covered by PLN electricity sources.

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