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Design of 600 WP Solar Power Plant for Juice Vendors Through Off-Grid System

Fitroh Anugrah Kusuma Yudha[1*], Bambang Riyanta[2], Ikhsan Fakhri Fadullah[3], Aditya Kurniawan[4]
Universitas Muhammadiyah Yogyakarta
Corresponding Author: Fitroh Anugrah Kusuma Yudha
fitroh.anugrah@umy.ac.id

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A B S T R A C T

Solar power plants (PLTS) generate electricity from the energy of solar photons. Solar cells, or solar cells made of crystalline silicon, are examples of solar panels that generate electricity through the photovoltaic effect. Thus, the construction of solar power plants (PLTS) is one of the right choices to save energy. The purpose of this study is to utilize the energy that is owned and to introduce it to the surrounding community. The community has widely used solar power generation (PLTS) technology, one of the main components of solar power plants is solar photovoltaic technology, which is used to operate juice blenders, cup sealers, and energy-efficient lighting. PLTS functions as an alternative energy source to help juice traders. Based on solar energy for this off-grid system, it has a power capacity of 3 x 200 WP. This monocrystalline solar panel also has a 300 Ah VRLA battery, a 2000 W inverter, and a 50 A solar charger controller (SCC). In addition, the PLTS off-grid system for juice traders has blender equipment, cup sealers, and lighting with an average power rating of 600 Watts. With an efficiency calculation of 80%, this system can be fully used to support business operations. This study is to develop and Design a 600-watt peak Solar Power Plant using an off-grid system for juice vendors that costs Rp. 22,000,000, including all essential components and services needed to ensure that the system can operate properly

INTRODUCTION

The need for energy increases along with the growth and development of infrastructure every year [1]. It is possible that the energy reserves on Earth will decrease as a result of the increasing energy needs in Indonesia. Furthermore, this encourages the government to look for alternative energy sources [2]. The goal is to produce a large enough amount of alternative energy with good quality without having a negative impact on the environment. In Indonesia, there are many alternative energy sources that can be developed, one of which is PLTS [3]. Indonesia's geographical position around the equator provides the most exposure to sunlight throughout the year [4]. To meet the country's electricity needs, Indonesia's solar energy potential must be utilized [5]. According to data from the Indonesia Energy Outlook [6], power plants currently have a total capacity of 64.5 GW to meet national energy needs. Of this capacity, coal contributes 50%, natural gas 29%, and fuel oil 7%, and renewable energy sources only 14%. This percentage is far below the target of the Indonesian General Energy Plan [7]. Solar energy is one type of renewable energy (EBT) that has great potential in Indonesia [8][9].

Because Indonesia is on the equator, sunlight will continue to shine throughout the year. This is a potential that must be utilized to generate electricity. Indonesia can take advantage of this advantage by building a Solar Power Plant (PLTS) to support renewable energy sources. However, the PLTS system faces problems due to its repetitive nature, which causes an imbalance between the amount of energy produced by PLTS and consumer energy demand [10].

Electricity demand is expected to increase up to 9 times by 2050, increasing from 254.6 TWh in 2018 to 1,918 TWh in 2050. During the 2018–2050 period, electricity demand is expected to increase by 6.5% per year with a relatively similar pattern. The household sector requires the largest amount of electricity, followed by industry, business, transportation, and other fields. The main energy mix plan is expected to be met by the large amount of new renewable energy in Indonesia [11]. Solar energy is the best option for use on a small household scale. This is because the average daily radiation level in Indonesia is 4.80 KWp/m2, which is a relatively high level [12]. PLTS, a flexible and efficient power plant, can be easily applied to the roof of a house, caravan, bus, or even a car without disrupting production activities and the surrounding environment.

Therefore, PLTS solar panels are a strategic choice for alternative electricity use for small-scale businesses (MSMEs) located in remote places without electricity [13][14]. By utilizing the available space, PLTS solar panels are one of the options for utilizing environmentally friendly renewable energy. Although its contribution is not yet significant, the use of this renewable energy will help reduce the impact of global warming.

The need for solar energy to meet human needs is increasing. In addition, solar power generation technology has been widely used in society [15]. In this community service, solar PV technology is used to operate juice blenders, cup seals, and energy-efficient lighting. Solar PV is the main part of the solar power plant and functions as an energy source for juice traders. Using a trading place that has dimensions of 100 cm long, 75 cm wide, and 150 cm high. This monocrystalline solar panel has a power capacity of 3 x 200 WP. Other components include a 300 Ah VRLA battery, a 2000 W inverter, and a 50 A battery Solar Charger Controller (SCC). This juice trader has a blender, cup sealer and lighting equipment with an average power rating of 600 Watts. The purpose of this study is to utilize the energy they have and to introduce it to the surrounding community. The designer of a solar-powered power plant with an off-grid system that can be used for juice trader applications in operating a blender, closing cups using a cup sealer, and an energy-efficient lighting process.

LITERATURE REVIEW

Developing a 600 WP off-grid solar power plant requires many important considerations, such as selecting the right components, setting up the system, and creating an energy management strategy. Well-documented literature on methods for designing this type of system emphasizes the importance of accurately determining system dimensions based on operational patterns and load requirements [26]. This method reduces dependence on conventional power sources by providing a reliable electricity supply in remote areas. Calculating and selecting photovoltaic modules, which serve as the center of system capacity, is usually the first step in the design process. A 600-kW distributed photovoltaic system study showed that selecting the right number and type of modules, junction boxes, and inverters fulfills energy requirements [27]. The principles of component selection and system balancing also apply to off-grid design, although this study focuses on grid-connected systems. Demand side management (DSM) is an important approach to optimize energy distribution among various loads in off-grid systems. DSM involves prioritizing loads to ensure that critical loads receive power during shortages [28]. This strategy improves the reliability and efficiency of the off-grid system while making it easier to adjust to varying solar insolation conditions. Using simulation tools such as PVsyst can also aid in designing and analyzing off-grid solar power systems, enabling the assessment of economics and electrical performance [29]. This method helps determine the best configuration for solar modules, batteries, and inverters. This ensures that the system meets the specific energy needs of the location. Overall, the design of a 600 WP off-grid solar power plant requires a thorough understanding of component selection, energy management, and system optimization. Combining these components allows designers to create efficient and sustainable solar power solutions for remote and isolated regions [26][28][29].

METHODOLOGY

Off-Grid PLTS Working Principle

The off-grid PLTS system is not connected to the PLN network [15]. This is called a Stand Alone System because it only relies on solar energy as its main source [16][17]. A series of solar modules are used to generate energy as needed. Figure 1 shows a schematic of the working principle of PLTS.

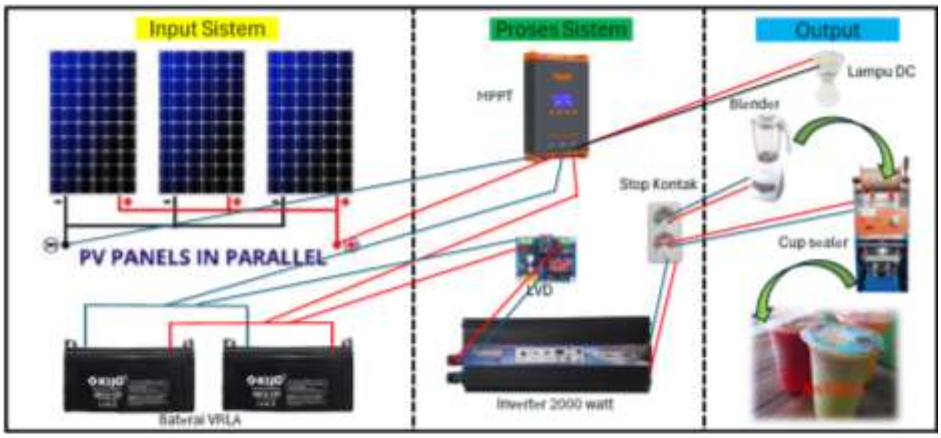

Figure 1. Solar Power Generation System for Juice Vendors

This system uses several stages to optimize the use of solar energy. In the first stage, the input system consists of three photovoltaic (PV) panels arranged in parallel to collect solar energy and convert it into DC electrical energy. These three photovoltaic panels are then connected to a VRLA (Valve-Regulated Lead-Acid) battery, which functions to store the energy produced.

The process system involves several important components to manage and optimize the energy stored in the second stage. First, the energy from the photovoltaic panels is directed to the MPPT (Maximum Power Point Tracking). The MPPT ensures that the photovoltaic panels operate at maximum efficiency by adjusting the maximum power point. In addition, the energy goes through the LVD (Low Voltage Disconnect) unit, which protects the battery from excessive discharge, which can damage and reduce the battery's lifespan.

In the third stage, a 2000-watt inverter is used to convert the direct current (DC) stored in the battery into alternating current (AC) that can be used by various electrical devices. The AC power is then distributed to various output devices through electrical outlets, also known as power outlets. These output devices include DC lamps for lighting, blenders for making drinks, and cups.

Solar energy can be utilized well to support small-scale beverage production businesses with this system. This method not only produces a sustainable energy source, but also ensures that energy is managed properly to maximize the efficiency and life of system components.

Components of Solar Power Plants

1. Solar Energy Modules

Solar modules, also known as solar cells, use the photoelectric effect to convert light energy into electrical energy.

2. Solar Charge Controller

A solar charge controller is an electronic device that regulates the direct current that is charged to the battery and taken from the battery to the load. This equipment also controls overcharging, which is excessive charging due to a full battery, and excess voltage from the solar panel or solar cell.

3. Battery Power

During the day, the battery stores the solar energy generated.

4. Inverter

An electrical device known as an inverter functions to convert direct current (DC) into alternating current (AC).

5. Cables (Conductors)

Because they deliver current to the attached load, cables are one of the most common electrical installation methods.

PLTS Calculations

Calculations to determine the size of an off-grid solar power system, including load analysis, solar panel size, battery bank, inverter, and solar charge controller.

1. Overview of off-grid solar power system design and calculations and load analysis for off-grid settings

$$\text{Total Power (W)} = \sum Power\ of\ Load\ (W)\ x\ No\ of\ Load$$

$$\text{Total Energy (wh)} = \sum Total\ Power\ (W)\ x\ operating\ hours\ (H)$$

2. Calculating the required solar panel capacity based on daily consumption and peak sun hours

$$\text{Power required from solar panel PV (W)} = \frac{\text{Total energy required from solar PV (wh)}}{\text{Effective sunshine hours x system efficiency } \eta_s}$$

$$\text{System efficiency } (\eta_s) = \eta_B\ x\ \eta_i\ x\ \eta_{Oth}$$

$$\eta_B = Battery\ efficiency\ (assume\ 90\%)$$

$$\eta_i = Inventer\ efficiency\ (assume\ 95\%)$$

$$\eta_{Oth} = Other\ compon\ (Charcontroller, cable)\ efficiency\ (Assume\ 85\%)$$

$$\text{Number of solar panel required} = \frac{\text{Power required from solar PV (wh)}}{\text{Output power of solar panel (wh)}} \quad (A)$$

3. Determining Battery Bank Size

$$\text{Total required battery capacity (AH)} = \frac{\text{Total backup energy required per day}}{\text{Battery voltage x depth of discharge x battery efficiency}}$$

$$\text{Number of battery} = \frac{\text{Required battery capacity (AH) } x\ Backup\ day}{\text{Required AH of the battery}}$$

4. Determine the inverter size for off-grid systems. Consider surge power for load analysis.

$$\text{Required inverter power} = \frac{\text{Total power required per day x safety of factor}}{\text{Inverter Efficiency (96\%)}} \quad (watt)$$

Safty of factor = 1.25 (According to NEC inverter should be 25% to 30% high)

5. Determining the size of the solar charge controller based on the panel specifications

Charger controller is normally calculatted by

Battery bank voltage (v)

Total solar panel power (w)

$$\text{Charger controller current} = \frac{\text{Total solar panel power (w)}}{\text{Battery bank voltage (v)}} \quad (A)$$

RESULT AND DISCUSSION

Juice Merchant Electrical Load Calculation

Tabel 1. Electrical Load

Load Name	Power of Load (W)	No of Load	Total Power (W)	Operating Hours (H)	Total Energy (Wh)
LED lamp	5	2	10	12	120
Cealer Cup	300	1	300	5	1500
Blender	120	1	120	5	600
		Total Power	430	Total Energy	2220

Table 1 above shows some important steps needed to calculate the electricity load required for a juice business. The table shows some of the main equipment used, including LED lights, cup sealers, and blenders, as well as the power of each equipment in watts (W), the number of equipment used, the total power of the equipment, the daily usage time in hours (H), and the total energy consumed in watt-hours (Wh). Two units of 5W LED lights are used, producing a total of 10W, and using them for 12 hours every day. To ensure that the juice business gets sufficient electricity supply and optimizes daily operational efficiency, this information is important to plan properly.

Solar Panel Selection

To ensure a profitable and productive investment, it is important to choose the right solar panel by considering various important aspects [18]. Thin-film, polycrystalline, and monocrystalline solar panels have their respective advantages in terms of efficiency, price, and flexibility. To measure energy productivity in a limited space, panel efficiency, which measures how much sunlight can be converted into electricity, is very important. In addition, the power output of the panel, measured in watts, indicates its electricity production capacity. To ensure long-term reliability, it is important to consider the duration and warranty, usually 25 years [19]. A low temperature coefficient is better for hot climates, while well-known brands offer quality assurance and after-sales service. If making a profitable initial investment, the investment cost must be balanced with the potential future savings. If on a rooftop, aesthetics should also be an important consideration [20]. In addition, an evaluation of local regulations and local climate conditions is necessary to ensure compliance and maximize available incentives. Selecting the right solar panel can provide efficient and sustainable energy benefits by conducting thorough research and considering long-term benefits. Solar panel selection calculations

Total Power required per day = 430 w

Total Energy required per day = 2220 wh

$$\text{Power required from solar panel PV (W)} = \frac{\text{Total energy required from solar PV (wh)}}{\text{Effective sunshine hours x system efficiency } \eta_s}$$

Total Energy required from solar PV = 2220 wh
Effective sunshine hours in indonesia = 5.0

$$\text{System efficiency } (\eta_s) = \eta_B \; x \; \eta_i \; x \; \eta_{Oth}$$

System efficiency = 0.90 x 0.95 x 0.85 = 0.73

$$\text{Power required from solar panel PV (W)} = \frac{2220}{5.0 \text{ x } 0.73} = 608 \; watt$$

Power required from solar panel = 600 watt (Appoxmate)

$$\text{Number of solar panel required} = \frac{600}{200} = 3 \; Panel$$

Solar Panel Selection = 3 Panel

Battery Selection

For a particular application, selecting the right battery requires many considerations to ensure the best performance and long life. First, figure out what the application requires. This should include voltage, current, capacity, size, weight, operating environment, and expected cycle life. Then select the appropriate battery chemistry. This can include Li-ion batteries, which have high energy density and long cycle life, or Nickel-Metal Hydride, which are more environmentally friendly. To ensure compatibility and performance, refer to the manufacturer's datasheet and user reviews [21]. Also, make sure the battery has the proper safety certifications and sufficient protection circuitry. Consider the initial cost and total cost of ownership, including replacement and maintenance. By considering all these aspects, you can choose the battery that best suits your application needs, ensuring safety, performance, and sustainability. Battery selection calculations

Total Power required per day = 430 w
Total Energy required per day = 2220 wh

$$\text{Total required battery capacity (AH)} = \frac{2220}{12 \text{ x } 0.85 \text{ x } 0.85} = 256$$

Battery Selection = 300 AH
Number of Battery required
We are take 12 v 150 AH battery

$$\text{Number of battery} = \frac{300 \text{ AH } x \; 1}{150 \; AH} = 2 \; Battery$$

Inverter Selection

Selecting the right inverter is a crucial step in ensuring your energy system operates efficiently and reliably. The first step is to determine the total power requirements of the appliances and devices you will be using, ensuring that the inverter’s continuous power capacity exceeds that total. It’s also important to consider surge capacity, as some devices require a higher starting power than their operating power. You’ll also need to match the inverter’s input voltage to your power source, such as 12V, 24V, or 48V for battery-based systems [22].

Selecting an inverter with the appropriate waveform is also crucial; a pure sine wave is better suited for sensitive electronics as it provides clean, consistent power like that from the mains. Meanwhile, a modified sine wave is more affordable but may not be suitable for all devices. Inverter efficiency is another factor to consider, as high-efficiency inverters convert more DC power to AC power, reducing energy loss and extending battery life.

Physical factors such as size, weight, and cooling and ventilation systems also influence your choice, especially if space is limited or portability is required. Safety features such as over-voltage, under-voltage, overload, short circuit, and overheating protection ensure the inverter operates safely and reliably. Also make sure the inverter meets relevant safety and performance standards such as UL, CE, and FCC [23].

Price and warranty considerations are also important to ensure you get the best value and reliable support. Researching brands and reading customer reviews can give you an idea of the inverter's reliability and performance in everyday use. By considering all of these factors, you can choose the inverter that best suits your needs, ensuring reliable and efficient performance from your energy system. Calculations for Inverter selection

Total Power required per day = 430 w

$$\text{Required inverter power} = \frac{430 \text{ x } 1.25}{0.96} = 560\ watt$$

Required inventer power = 600 watt (Approximate)

Charger Controller Selection

Selecting the right charge controller is essential to ensure the charging system works safely and efficiently. First, make sure the system used is a battery charging system or a photovoltaic (PV) system. Then, make sure the controller is compatible with the battery used. Next, pay attention to the system voltage and current. The controller must be compatible with the system voltage, such as 12V, 24V, or 48V, and must be able to handle the maximum system current [24].

The selection of the controller depends on the type of battery. The charging profiles of lithium-ion, nickel-cadmium, lead-acid, and other batteries are different. To optimize battery charging, the ampere-hour (Ah) capacity must be considered. The system needs must also influence the type of controller chosen: the more cost-effective Pulse Width Modulation (PWM) or the more efficient Maximum Power Point Tracking (MPPT) [25].

It is important to consider additional system features, such as load control, data logging, temperature compensation, and displays and indicators that visually show the system status and performance. Finally, to ensure its quality and reliability, choose a controller from a trusted and certified brand. Although MPPT controllers cost more, the expense may be worth the increased efficiency, especially for larger systems. An MPPT controller with a current rating of slightly above 16.67A would be a good choice for a photovoltaic system with 200W solar panels and 12V lead-acid batteries. Charger controller selection calculation

$$\text{Charger controller current} = \frac{600}{12} = 50\ A$$

Charger controller current = 50 A

Cost Requirements Needed for PLTS for Juice Traders

Table 2. Cost Requirements for PLTS

No	Component	Unit Volume Price Quantity	Unit Volume Price Quantity	Unit Volume Price Quantity	Unit Volume Price Quantity
1	200 Wp solar panel	unit	3	Rp 2.000.000	Rp 6.000.000
2	150AH Battery	Pcs	2	Rp 3.500.000	Rp 7.000.000
3	50A Charger Controller	Pcs	1	Rp 3.750.000	Rp 3.750.000
4	2000 Watt Inverter	Pcs	1	Rp 1.250.000	Rp 1.250.000
5	2.5mm Cable	Roll	2	Rp 750.000	Rp 1.500.000
6	Installation	service	1	Rp 2.500.000	Rp 2.500.000
			Total cost		Rp 22.000.000

Table 2 details the six main components and costs required to build a solar power generation system (PLTS). The table includes the units, volume, price per unit, and total cost required for each component.

Three 200 Wp solar panels are required, priced at 2,000,000 per unit, for a total of Rp 6,000,000. The main component of this solar panel converts sunlight into electrical energy. 150 AH Battery: This battery is used to store the electrical energy generated by the solar panels, so that it can be used when there is no sunlight. These batteries cost Rp 3,500,000 each, for a total of Rp 7,000,000. 50 A Charger Controller: One 50 A charger controller is required, priced at Rp 3,750,000. This tool controls the battery charging so that it does not become too full, which can damage the battery. The 2000-watt inverter costs Rp1,250,000 and functions to convert direct current (DC) generated by the solar panels and stored in the battery into alternating current (AC) that can be used for household electrical appliances. 2.5 mm cable: This cable is used to connect the components in the PLTS system. The cost for two rolls of 2.5 mm cable is Rp750,000, for a total of Rp1,500,000. Installation services include the installation and setup of all system components so that they can operate properly.

Building a solar power generation system (PLTS) costs Rp22,000,000, which includes all the essential components and services needed to ensure that the system can operate properly

CONCLUSION AND RECOMMENDATION

This study developed a 600-watt peak solar power plant (PLTS) with an off-grid system intended for use by juice vendors. Monocrystalline solar panels, VRLA batteries, inverters, and solar charge controllers are the main components of this PLTS. This study achieved several important results: Solar Energy Potential in Indonesia: Indonesia's location close to the equator provides great potential to harness solar energy due to its year-round exposure to sunlight. Components of Solar Power Plants: The system consists of monocrystalline solar panels with a total power capacity of 600 WP, a 300 AH VRLA battery, a 2000 W inverter, and a 50 A solar charge controller (SCC). System Design and Calculation: To operate LED lights, blenders, and cup sealers every day. System Efficiency: With an efficiency calculation of 80%, this system can be fully utilized to support business operations. Social and Environmental Benefits: Solar power plant technology reduces energy consumption, supports the use of environmentally friendly renewable energy, and reduces dependence on fossil fuels. providing small and micro businesses with a cost-effective and sustainable energy solution available in remote areas that do not have electricity supply. Overall, this study shows that Solar Power Plants are a good alternative to meet the energy needs of small businesses in Indonesia and help global efforts to reduce fossil fuel use and the impact of global warming.

FURTHER STUDY

This research still has limitations, so further research is needed related to the topic of Design of 600 WP Solar Power Plant for Juice Vendors Through Off-Grid System in order to perfect this research and increase insight for readers.

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