Supporting Secluded Farm Electricity Using Solar-Powered Hut: Electrifying Agriculture Preparation in Gunungkidul

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Abstract. Nowadays, the transition from conventional agriculture to modernization requires a touch of technology, one of which is the Electrifying Agriculture program. Farmers are switching to electricity-based agricultural tools and machinery from previously using fossil fuel machines, which are expensive and damaging to the environment. However, the vast agricultural area will generally experience electricity network constraints due to the distance between the location and settlements. Making an independent power network will incur very large costs, especially the purchase of very long cables. In addition, if each land makes an electricity network, it will pose its own danger from a non-standard and bad installation. Focused on Gunungkidul, located in West Nitikan, and Pragak village, Semanu, the solution to the problems is how to use solar power to provide power sources in secluded farming areas. The result was that in each hut was installed a solar-powered electrical installation with a power of 350 Wh in the form of a DC power source. For nighttime electrical energy reserves, it is backed up with a battery equivalent to 240 Wh. The installation is equipped with a 300-watt inverter to convert the DC power source to AC so that it can be used for appropriate equipment.

1 Introduction

This project is carried out in West Nitikan and Pragak villages, both in the Semanu government area of Gunungkidul regency. According to analytics, the typology area showed that most of the location is farming fields, and most of the occupation is farming, up to 3320 people. Due to the above conditions, challenges and demands arise for the farmers to transition from conventional ways into modern ones, starting to adopt supporting technology. Some farming tools can now be seen in many varieties, mostly with power sources from electricity and fossil fuels. Nowadays, the applications have begun to be favored because of their eco-friendly reasons, and also because the farming tools can be made in more efficient dimensions. Nevertheless, they commonly face electric installation problems due to the massive farming area. This is due to the distance of the location from the settlement. Making an independent power network will have very large costs, especially the purchase of very long cables The distance between one of the fields and the farthest power source point can

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reach 500 meters. In addition, if each land has an electricity network, it will pose danger from non-standard installations and network clutter.

In the current era, the transition from conventional agriculture to modernization requires a touch of technology, one of which is the *Electrifying Agriculture* program. This program is a big leap for the Indonesian Agriculture sector. The program initiated by PT PLN (Indonesian State Electricity Company) has proven to have made the agricultural sector more advanced and modern, with an increase in productivity reaching three times and an operational cost efficiency of 60 percent. Farmers are switching to electricity-based agricultural tools and machinery from previously using fossil fuel, which is expensive and damaging to the environment.

Current technological developments in renewable energy have offered many solutions for society to replace fossil fuel consumption. This is because fossil fuels, which are non-renewable energy, are used by conventional power plants for a long time and drain non-renewable energy sources, so the reserves are getting smaller. For example, solar energy through solar cells, which are abundantly available in the universe, has the potential to be a solution to the problem of electricity availability in the community.

Solar cells, or Solar panels, are tools to convert solar energy into electrical energy [1]. *Photovoltaic,* or PV, is a technology that serves to convert solar radiation directly into electrical energy (Figure 1). A solar/PV cell is formed by fabricating a p-n junction in a thin wafer of semiconductor [2]. Research advances in materials science are gradually increasing the efficiency of photovoltaic systems [3]. PV is usually packaged in a unit called a module. A solar module consists of many solar cells that can be arranged in series or parallel. Solar cells have an output power constraint that is not large enough, and one method of optimizing solar cells is to use sunlight-reflecting mirrors. The reflectivity of the mirror can provide more energy than traditional panels [4]. In its application, light intensity is one factor affecting the efficiency of monocrystalline silicon solar cells. Light intensity and temperature dependence of output performance parameters of mono-crystalline silicon and polycrystalline silicon solar modules [5]

Fig. 1. Photovoltaic or Solar Panel

The government has officially passed regulations related to the provision of electricity to people in border areas, disadvantaged areas, isolated areas, and outer islands. This regulation was issued in the form of a Presidential Regulation on the Provision of Energy-Saving Solar Lights for people who have not yet had access to electricity. The idea's basic tenet is that solar panels use energy from the sun to capture it, transform it into electrical energy, and then store it in batteries. The electrical energy inside this battery is then used to power the lights. The advantages of solar energy when compared to fossil energy are that solar energy is easy to obtain because it comes from the sun itself; it is environmentally friendly; it is compatible with various geographical conditions; installation, operation, and maintenance are not difficult; and Electrical energy obtained from solar energy can be stored in batteries. To overcome the limitations of solar energy when it begins to fall after noon, it is recommended to use batteries as a backup energy source [6]. The activity focused on applying solar energy to provide solutions to electricity needs in land areas far from settlements. Farmers cannot use electric power because electricity sources are unavailable on agricultural land. There is a threat of electric shock on some land provided by independent installations where the installation does not meet standards, and there is a lack of understanding among farmers regarding SOPs for PLN electricity utilization. In remote lands, it is difficult to provide a source of electricity unless electricity generation from renewable sources such as solar energy is applied. The solar energy that can be used for all of Indonesia's land with an area of 2 million km^2 is 4.8 kWh per m^2 daily, equivalent to 112,000 GWp distributed [7]. Based on the analysis of partner situations and problems, strategies are obtained as a form of solution to partner problems. In general, the solution to the problem at hand lies in the transformation of solar energy applications.

Fig. 2. Agricultural Huts (*Gubuk* : Javanese)

2 Methodology

The limitation of the problem is focused on two activities: 1) Education to find out the comparison of electricity consumption calculations between PLN and solar energy, including SOP and Safety rules; and 2) Installation of the solar power plant in a hut (Figure 2) in the agricultural land area of West Nitikan and Pragak.

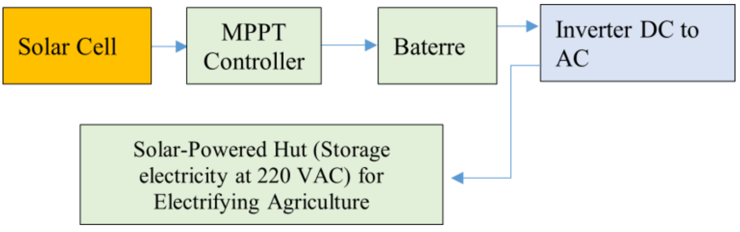

Fig. 3. Engineering of solar power plants on agricultural sites

This service activity will be carried out in stages of socialization, education, and application of solar power systems in an agricultural hut, followed by monitoring and evaluation of activities. Figure 3 is an engineering scheme for using solar energy to provide a 220 V Ac power source at the target location. Applying renewable energy as well as solar power systems requires several calculations to adjust the electrical load and the selection of solar panel capacity to obtain optimal system performance. The efficiency and power output of a PV module decrease at the peak of sunlight due to energy loss as heat energy, which reduces the module's power output [8]. One of the big problems with renewable energy in community-scale applications is the sustainability of the system [9]. Solar power plant design is carried out to determine the size of photovoltaic cells, batteries, and the solar charge controller (SCC) for the solar power system. The design steps are as follows:

2.1 Determine the need for electrical power.

The result of this calculation produces power in units of watt-hours per day by calculating how many watts of power each piece of equipment requires from the PV system and how many hours per day of use. However, the electrical energy produced by PLTS is not 100% usable because, during the transmission period from solar panels to the end of the load (electronic devices), up to 40% of the electrical energy is lost. Therefore, adding 40% of the total power is necessary (Equation 1).

$$\textit{Total power} = (\textit{number of loads x load power})\ \textit{x load usage time (time)}: (100\%–40\%) \quad (1)$$

2.2 Number of Solar panels (PV)

To determine the number of solar panels needed, it is important to know what the peak wattage (WP) is. So, Watt Peak is the magnitude, or optimal nominal highest power, that can be generated from a solar panel. For most homes in Indonesia, that solar panel requires about 4 hours of sunlight a day. The voltage value that the solar panel will generate will remain the same as the working voltage value in the layout of solar panels using a parallel connection, but the current value will keep rising [10]. Calculating the necessary number of solar panels is done using the following equation:

$$\textit{Solar panels} = \textit{total power: optimal time} \quad (2)$$

Connecting cells in parallel will yield a higher current; however, very significant problems exist with parallel connections. For example, shadow effects can shut down the weaker (less illuminated) parallel string (a number of series connected cells), causing substantial power loss and even damaging excessive reverse bias applied to the shadowed cells by their illuminated partners [11].

2.3 Calculating the Amount of Battery

The battery in the PLTS system is used as a component to store electrical energy generated by solar panels during the day, then drain the electricity load without PLN's electricity network at night or in cloudy weather. Battery chemistry with an energy storage efficiency as high as possible should be employed to achieve high overall efficiency. Storage efficiency depends on battery chemistry and is related to the types of battery electrodes and electrolytes. Storage efficiency is proportional to the change taken in the reaction path by the battery between charge and discharge processes [12]. The electrical energy in the battery is not 100%

usable. Because in the inverter, the potential energy loss can be as much as 5%, it is necessary to have a reserve of 5% that must be added. So, the formula used is Equation 3.

$$\text{Power reserve} = \text{total power}: (100\%-5\%) \quad (3)$$

Next, choose the right battery specifications as needed. And calculate the number of batteries used by Equation 4.

$$\text{Number of batteries} = \text{electric power}: \text{battery capacity} \quad (4)$$

2.4 Determining the Inverter

An inverter is a useful tool that converts DC current (direct current) into AC current (alternating current). It can be assumed that all the tools are powered on simultaneously to determine the inverter. Thus, choosing an inverter with an output greater than the required power is important.

2.5 Determining the capacity of the Solar Charge Controller (SCC)

Before determining the SCC (solar Charge controller), first look at the solar panel. Usually, on solar panels is written, for example, the following code: Pm = 100 WP, Vm = 18 VDC, Imp = 5.8 A, and Isc = 6 A. Then, multiply the Isc (short circuit current) by the quantity of solar panels. The formula is Equation 5 to determine the capacity of the SCC.

$$\text{Power SCC} = \text{Isc x Number of Solar Panels} \quad (5)$$

3 Results and Discussion

The following is an example of educational materials to compare the cost of solar power and PLN electricity. The calculation is carried out assuming a load power parameter (e.g., lamp) of 200 Watts and an assumption without component replacement. This calculation provides an overview of solar energy savings compared to PLN's electricity application (the price per kWh is IDR 1,350). Note that this does not compare to the available electrical power. Total operational costs for 6 months are 432 kWh x IDR 1,350/kWh, or IDR 583,200 or IDR 1,166,400/year. Based on these calculations, it can be predicted that the value of PLN's electricity consumption during the first year is procurement costs + operational costs, which is IDR 1,876,400. Compared to solar power with the same price of lighting equipment, it only costs IDR 1,300,000. The system is without operating costs (free energy source from the universe, hence no calculation of electricity payments).

3.1 First- and second-year cost savings (with solar power application)

For the first year, the calculation is obtained by calculating the difference between PLN's electrical energy costs and Solar Energy costs, namely IDR 1,876,400 minus IDR 1,300,000 = IDR 567,400. For the second year, it is necessary to calculate the maintenance and repair costs. For the PLN electricity usage scenario, the cost of replacing lamps plus annual operational costs are required for the IDR 1,376,400. Unlike the solar-powered light scenario, which only needs battery replacement and lamp repair at IDR 500,000 per year, Thus, the cost savings from the second year on can be assumed with the calculation of IDR 1,376,400 minus IDR 500,000 = IDR 876,400.

Fig. 4. Installation of the solar-powered hut (Pragak village).

3.2 Calculation of solar powerplant load and power

The main load on the hut is for charging three pest medicine sprayers of 24 watts each and one piece of 15-20 Watt lighting. Then the total load that will utilize solar power is 140 Watts. In this case, the charger load requires a mains voltage of 220 VAC, amounting to 120 watts, while the DC lamp is 20 watts. Available electrical power is reviewed based on battery capacity (Ah). Then the power is calculated based on the following equation:

$$P = V.\ I \qquad (6)$$

P = Power in 1 hour (*watt hour*), Wh, or VAh..
V = Battery voltage (V)
I = Battery current (Ah)

Thus, it is known that the available power is

P = 12 V x 20 Ah = 240 Wh (this power is in the form of a DC voltage of 12 V). In its application, the battery capacity can only be taken in the range of 80%, so that the estimated actual power is 192 Wh (meaning that if a load is used, for example, a 12 V DC lamp of 20 Watts, the battery will be empty in 9.6 hours). Figure 4 shows the installation of solar electricity in a farm hut in the Pragak farm area, while Figure 5 shows an installation in the West Nitikan farm area. If a solar battery is used at night on a 12 V to 220 V DC inverter, then there is a calculation that needs to be made to ensure that the inverter only works at a minimum DC input voltage in the range of 10 Volts (if the voltage is below 10 volts, then the inverter will protect). So if the starting voltage of the lithium battery is 13.6 V, then the voltage that the inverter can convert is 13.6 – 10 = 3.6 V. If using Equation 1, the output of the inverter in the form of a voltage of 220 V AC is as follows: P = 3.6 V x 20 Ah = 72 Wh (this power is in the form of 220 V AC mA). The conclusion is that inverter electricity is still able to supply the charging process of a maximum of three sprayer units. Thus, the total sprayer load of 72 watts will be able to be charged for 1 hour before the battery is empty.

Fig. 5. Installation of the solar-powered hut (West Nitikan village)

Performance during the day of a 50 WP panel through a fixed SCC controller provides a power source range of 350 Wh (DC electric form range 12–14 Volts). This condition can be used for the use of DC-current electric agricultural equipment such as automatic water sprinklers, humidity regulators, and several farming tools supported by microcontrollers with low electric current requirements.

PLTS is installed in this activity using an MPPT-type controller to achieve maximum current from solar panels. As per the specifications on the panel, it is known that
Current magnitude (Imp) = 2.78 A.
Max voltage (Vmp) = 18 Vdc.
Panel power = 50.04 WP.
For battery charging, the MPPT controller lowers the voltage (Vmp) to a range of 13.8 Vdc. This actually increases the charging current by:
50.04 W/13.8 Vdc = 3.6 A.
Thus, charging the battery to be full can be calculated by Equation 7.

$$Charging\ time\ = \left(\frac{Battere\ capacity}{Charging\ current}\right) + \left(\frac{20\%\ Capacity}{Charging\ current}\right) \quad (7)$$

The result is Charging time = (20/3.6) + (1.1) = 1.6 Hours.

Table 1. Average charging power of the battery (sunny day)

Measurement						
Time (GMT+7)	Voc (Volt)	Vsc1 (Volt)	Isc1 (Ampere)	Vsc2 (Volt)	Isc2 (Ampere)	Vsc2xIsc2 (Watt)
07:00	18.86	12.36	1.63	11.85	0.25	2.96
08:00	19.20	12.93	1.70	12.24	1.00	12.24
09:00	19.38	13.08	1.72	12.62	1.50	18.93
10:00	19.41	13.24	1.74	12.97	1.55	20.10
11:00	19.99	13.45	1.77	13.24	1.6	21.18
12:00	20.27	13.47	1.77	13.23	1.6	21.17
13:00	20.23	13.44	1.77	13.27	1.6	21.23
14:00	20.26	13.45	1.77	13.29	1.7	22.59
15:00	19.25	13.28	1.71	13.19	1.55	20.44
Total power charging						160.86
Average power per hour						17.87

In each hut, a solar-powered electrical installation with a power of 350 Wh is installed in the form of a DC power source. For nighttime electrical energy reserves, it is backed up with a battery equivalent to 240 Wh. The installation is equipped with a 300-watt inverter to convert the DC power source to AC so that it can be used for appropriate equipment.

Table 2. Measurement of load current

Time (minute)	Battery voltage (Volt)	Battery current to inverter (Ampere)
0	12.11	17
5	11.71	17
10	11.61	17
15	11.52	17
20	11.43	17
25	11.34	17
30	11.25	17
35	11.15	17
42	10.91	17

Based on Table 1, where *Voc* is PV open circuit voltage, *Vsc1 and Isc1* are SCC parameters, and *Vsc2* and *Isc2* are voltage and battery current, we can find out that the average charging power of the battery is 17.87 Amperes. Using the data in Table 2, we can know that with a water pump load of 125 watts, the system will last for 42 minutes. This is because the working voltage of the inverter is at least 10 volts, and below it, the inverter will protect. Two important aspects of designing a solar water pumping system are analyzing the piping system to determine the type of pump used and planning the power system to ensure the system operates properly [13]. But this simplicity is enough to help irrigate farmers, or at least the load of low-power agricultural equipment.

4 Conclusions

In the government's electrifying agricultural program, this solar-powered electric hut has the potential to succeed. So many benefits will be obtained, in addition to the availability of electricity sources on secluded land. A safe electricity network for farmers is very valuable. Gunungkidul, as one of the areas that were once notoriously poor, precisely with the potential for large agricultural land, will become a national food granary. West Nitikan and Pragak, as an area of Semanu village, are a sample of activities where there is great potential to advance conventional to modern agriculture. This is expected to be a replica model for other regions.

Solar power generation systems do require a high initial investment proportional to the power to be achieved. Nevertheless, it will have tremendous savings in the years after. Therefore, understanding and education are needed for the community, especially farmers.

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