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Implementation of Portable Off-Grid Solar Water Pump for Irrigation Systems

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ABSTRACT

The need for irrigation is absolute for the agricultural system. Water pump is a highly needed tool by society in providing clean water and irrigation. If we only rely on rainwater, the land becomes unproductive in the dry season. The unavailability of electricity in many locations in Indonesia is an obstacle for farmers to install drilled wells or draw water from rivers. In this research, a solar water pump system is designed that allows it to be moved easily. The solar pump uses a 100 Ah battery, a 120 WP solar panel and a 1000 watt inverter. The model has been tested to irrigate strawberry gardens in Pintubosi Village, Toba Regency. The pump has been running for 4 hours (12.00 – 16.00 AM) while irrigating and charging the battery are running simultaneously.

1. Introduction

As the world's population continues to grow, more effort and innovation will be urgently needed to increase agricultural production in a sustainable manner, improve global supply chains, reduce food loss and waste, and ensure that all those suffering from hunger and malnutrition have access to nutritious food [1] .

The need for energy sources to support the agricultural sector is very much needed in areas where the majority of the population works as farmers. There are many obstacles faced by farmers, especially during the dry season, namely the unavailability of sufficient water to irrigate the land. This has an impact on drought, and often results in unproductive land [2],[3],[4],[5].

And the solution of installing boreholes at several points of land has the potential to be one of the solutions that can be offered, but the cost of diesel fuel to operate the pump economically is too expensive because of its routine use [6],[7].

Also, it was found that in many rural areas in Indonesia there are still many problems with electricity. Electricity has indeed entered almost all villages in the country, but this is not the case for fields, gardens or rice fields managed by the community. They were forced to run the water pump with a diesel engine. The use of diesel fuel requires an expensive cost, especially if it is used regularly, for example 4-6 hours in one day to do watering on agricultural land. Also, the use of diesel power will increase pollution in rural areas. The use of renewable energy sources such as solar power plants is one solution that can be offered to the community.

Solar water pumping system is considered as a promising solution to overcome these problems. It provides a source of clean water supply for irrigation with low maintenance required and with a reliable system that adapts the energy generated to the water requirements for irrigation. This is also in sync with the irrigation needs of agricultural crops where the increase in water demand in summer corresponds to the increase in energy produced by the solar system in summer. Pumping solar water in remote areas is an environmentally friendly method, low operating costs, long service life when compared to diesel generators [7]. The application of solar panels to pump water may seem expensive at the outset,

In this study, a study was conducted on several components needed to install solar power for low-cost pumping. Utilization of this technology will also be compared with the use of pumps with diesel fuel. Another thing to do is design a portable solar power system, making it easier to move from one location to

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another. This is necessary, if in the future there will be socialization of the use of solar power from village to village in the surrounding Toba Regency. And according to BPS Toba data, there are still many people's fields or rice fields that do not have an irrigation system [8]

The design of solar power systems to turn on irrigation pumps has been carried out by many researchers. In [6] it is discussed about the design of a direct solar water pumping system without using a battery. Technical, economic and environmental parameters are considered in the design procedure. While in paper [9], presented the stages of developing a solar water pumping system (SWPS) as a renewable energy application to overcome water supply problems in Purwodadi Village, Tepus District, which is located in the Gunungkidul karst area. This SWPS can lift water horizontally as far as 1,400 meters with a total head of 218.34 meters. This system uses 32 solar panels to generate 3,200 Wp of maximum power which is then used to operate 2 submersible pumps with a total head of 250 meters. The resulting water flow rate is about 0.4 – 0, 9 liters/second. To analyze the selection of the type of pump used for irrigation, in paper [10] a comparative analysis of the use of DC or AC motors has been carried out to drive the pump with energy supply from solar power. Meanwhile, to monitor irrigation systems in agriculture, several studies such as [11],[12],[13],[14,[15] have implemented a monitoring system with IoT technology. In paper [11], the monitoring and controlling system uses PLC and WSN. [15] has implemented a monitoring system with IoT technology. In paper [11], the monitoring and controlling system uses PLC and WSN. [15] has implemented a monitoring system with IoT technology. In paper [11], the monitoring and controlling system uses PLC and WSN.

Furthermore, the systematics of writing in this paper are as follows: Chapter 2 is the system model designed and implemented, Chapter 3 is the methodology of the research carried out. Furthermore, in Chapter 4, the results and limitations are described. Conclusions are written in Chapter 5.

2. Method

An overview of the solar pump system is shown in Figure 1. In the first section (1) is a set of solar cells with sufficient number to run a pump. This section will consist of several main components such as: batteries, inverter, SCC (Solar Charge Controller), equipped with several types of sensors such as current and voltage sensors to monitor the condition of batteries and solar panels. While the storage tank is equipped with a set of ultrasonic sensors that will detect the water level in the storage tank. The water level will trigger the pump (3) which is connected via a relay (4). Loads in the form of AC or DC pumps can be connected to the relay. In section (5) is a microcontroller board, an intelligent system developed to store all data from solar cells. In section (6) the LoRa gateway configuration is carried out which will accommodate all data sent by the board to the plant. Furthermore, it can be seen in section (7) is a web monitoring application that will be developed.

In this paper, points (1), (2), (3) and (4) are reported. While section (5) and section (6) do not include the section to be reported, this section is so large that it will be reported in another article. System (1)-(4) is a solar power generation system which has the ability to run a pump.

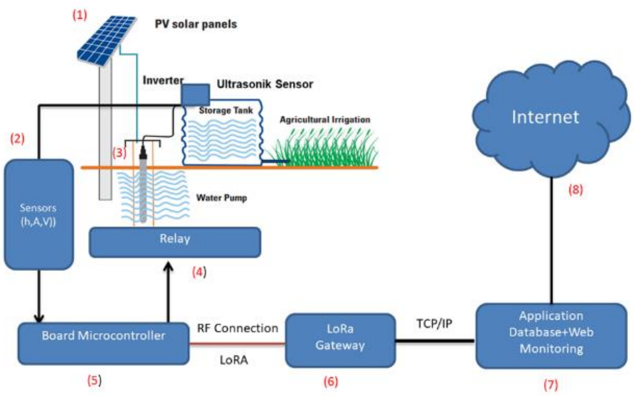

Image 1 General Solar Water Pump Model

3. Results and Discussion

3.1 Research Location and Time

The research location is in Pintubosi District, Toba Regency, North Sumatra. The research was carried out in several stages as shown in the following table.

TABLE 1
RESEARCH SCHEDULE

No	Activity	Execution time
1	Formulation of the problem	April
2	Determination of the specifications solar water pump	May – June
3	Solar Water Pump Installation	July
4	Field trials	July-August

The technique used to produce a prototype solar water pump goes through several stages as follows:

1. Determine the characteristics of the load used. In this section, it is necessary to carry out an inventory of the load to be served by the generating system. In this study, a generator system is needed that is able to run the AC pump during the day and provide lighting at night.
2. After knowing the amount of load required, then the selection of several components that support the installation of solar power plants is carried out.

3.2 Calculation of Total Energy Load

Every electrical equipment (AC/DC) used is an electrical load that requires a supply of electrical energy. Through the specifications of electrical equipment, it can be seen the amount of electrical energy consumed per day. The greater the electrical energy used, the more expensive electricity costs must be paid by consumers. The high cost of electricity encourages some people to generate electricity independently by using solar cells. Solar cells (photovoltaic) are a set of tools that function to convert directly exposed sunlight into electrical energy. Installation of solar cells as a power plant requires information on the amount of electrical energy consumed per day, then determines the capacity of the battery used, then calculates how many solar panels are needed to supply the electrical load.

$$W = Daya\ x\ Waktu$$
$$W = V\ x\ i\ x\ t$$

With description:
W: Electrical Energy (Joule)
V: Mains Voltage (Volt)
i: Electric Current (Amperes)
t: time in hours (hours).
So that electrical energy can be written in units of Watt-hour.
In the designed solar pump, the electrical energy requirements are as follows:

a. Pump (inductive) with an average power of 125 Watt works for 4 hours per day
b. Lights can be provided at night: 8 lamps with a power of 5 watts each. The light will be on for 12 hours

So the total load per day is as follows (See Table 2):
Total load per day = 125 Watt x 4 Hour + 8 x 5 Watt x 12 Hour
= 500 Watt-hour + 480 Watt hour
= 980 Watt-hour

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TABLE 2
ELECTRIC LOAD USAGE DATA

Electrical Load Type	Amount	Time (hours)	Power (Watts)	Total (Wh)
1 . lighting lamp	4	12	5	240
2 lighting lamp	4	12	5	240
Pump	1	4	125	500
Total				980

3.3 Battery Capacity Calculation

Battery capacity is expressed in units of Ah (Ampere-hour), can be calculated using the following equation:

$$\boldsymbol{Kapasitas\ Baterai} = \frac{\boldsymbol{Kebutuhan\ Energi\ Listrik\ per\ Hari\ (Wh)}}{\boldsymbol{Beda\ Potensial\ Baterai}}$$

For the proposed solar water pump, using a 12 V battery potential difference, the required battery capacity is:

$$\boldsymbol{Kapasitas\ Baterai} = \frac{\boldsymbol{980\ Wh}}{\boldsymbol{12\ V}} = \boldsymbol{81.66\ Ah}$$

From the calculations above, there are several alternative batteries that can be used. However, for battery storage efficiency, one battery unit with a capacity of 100 Ah is then used.

3.4 Calculation of Solar Cell Capacity

To generate electricity off the grid using solar cells, it is necessary to know the capacity of the solar cells to be used. Determination of solar cell capacity is very dependent on the amount of electrical energy (Wh) consumed and the duration of solar cells getting exposure to sunlight per day so that it can be seen the amount of electrical energy that can be generated by one solar panel. The amount of electrical energy that can be generated by one solar panel can be calculated by the following equation:

$$\boldsymbol{Kapasitas\ Panel\ (Wh) = Daya\ Luaran\ Panel\ x\ Lama\ Pencahayaan}$$

The energy capacity that can be generated by solar cells can determine the number of panels to be used with the following equation:

$$\boldsymbol{Jumlah\ Panel} = \frac{\boldsymbol{Jumlah\ Energi\ Listrik\ yang\ dikonsumsi\ (Wh)}}{\boldsymbol{Kapasitas\ Panel\ (Wh)}}$$

If it is assumed that the average total panel time has a high intensity for 3 hours, then the number of panels required is as follows:

$$Jumlah\ Panel = \frac{980\ Wh}{120x3\ Wh} = 2.72\ \sim 3\ panel$$

From the calculation above, it takes 3 panels with the capacity of each panel is 120 Wp, and it is estimated that each panel can get maximum intensity of sunlight for 3 - 4 hours. If so, then a pump with a specification of 1.25 Ampere 220V can operate for about 3-4 hours during the day, simultaneously the battery charging process controlled by the solar charge controller can also run.

3.5 Solar Inverter Selection

Because the normal load to be run is a pump with a specification of 1.25 Ampere 220 V, so that the supply at a normal running load is used, an inverter capacity of 1000 W is used. This is also in accordance with the estimated battery capacity calculation with specifications of 100 Ah, 12 Volt (100 Ah x 12). Volts = 1200 VAh). In order to keep the battery having a long life, the normal usage of the VRLA battery that is used is a maximum of 50% DoD (Depth of discharge). And this can be obtained by using the pump for only 3-4 hours assuming the charging process runs simultaneously.

3.6 Realization of Portable Solar Water Pump

After obtaining the specifications for the solar pump to be built, the interconnection between the components used in the implementation of the solar water pump is shown in Figure 2. The DC output from the solar panel is connected to the SCC via the DC MCB, as well as the 100 Ah battery used to connect to the SCC. via a DC MCB. DC MCB is needed so that during operation, the operator can easily turn on/off the battery charging from the SCC. The output from the DC battery is then converted to AC via a 1000W AC inverter. Furthermore, the AC power load can be directly connected to the inverter.

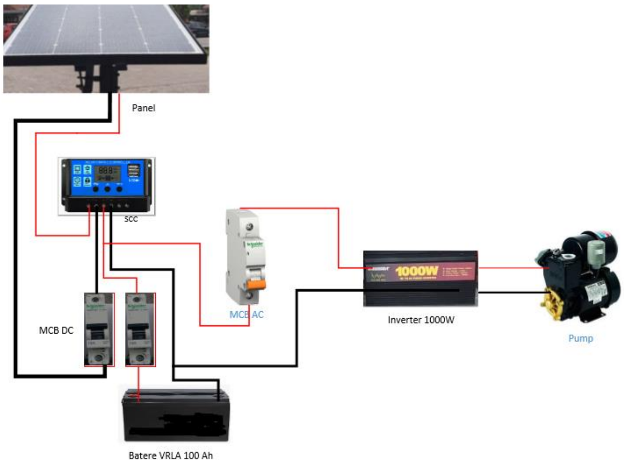

Figure 2. Wiring Diagram of Solar Water Pump Panel

The final implementation shown in Figure 3, a portable solar water pump, allows the system to be moved easily from one location to another. The solar panel installation frame uses an unused parabolic frame, with a height of +/- 2 meters and a width of +/- 80 centimeters. And the base is equipped with two pairs of wheels that make it easy for the panel system to move. The position of the battery and box panel is placed right under the panel. In this model, while only a 120 Wp panel is used, this is done to make the process of moving panels easier.

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Picture1Portable Solar Water Pump

Picture2Testing the solar water pump in the field-filling the water tank

Picture3Solar Water Pump Trial in the Field

3.7 Test

The test was carried out in July 2021 in the Pintubosi Village area, Kab. Toba. Conditions when tested, the intensity of the sun is very high (100,000 lux), using only one panel (120 WP) and a 100 Ah battery. The average current from the Panel to the Battery is close to the maximum (6.6 A), the pump is able to run for ~ 4.5 to fill a water tank (2000 Liter) and a Water Tank (250L), see Figure 4 and Figure 5. After all the tub and tank fully charged, watering the strawberry garden until the battery gives an alarm Low (below 10.6 Volts). It should be noted that it takes 15 minutes to fill a 250 liter water tank. So that the water discharge that comes out is about 17 liters/minute

4. Conclusion

In this research, a portable solar-powered pump system was produced, making it easier for the system to be carried everywhere. The resulting system can run well, with only 1 panel of 120 WP, one unit of 100 Ah VRLA battery can run a pump with a load of 1.25 A 220 V for +/- 4 hours with bright sunlight conditions. For weather that is not so bright, in the next implementation, solar panels can be arranged in parallel.

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