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An Analysis of Solar Power Plants (PLTS) System as a Power Supply For Submersible Water Pumps

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Renewable Energy,
Voltage Stability.

ABSTRACT

Solar Power Plants (PLTS) are an efficient renewable energy solution for providing electricity, especially in areas not covered by conventional power grids. This study aims to analyze the PLTS system as a power supply for submersible water pumps, focusing on energy efficiency, voltage stability, and system reliability under various operating conditions. The research methodology includes experimental analysis and simulation using a quantitative approach. Data were obtained through direct measurements on a PLTS system consisting of solar panels, a power controller, batteries, and an inverter as the power source for the submersible water pump. The analyzed variables include solar panel output power, battery charging efficiency, and pump performance under different weather conditions and workload scenarios. The results showed that the PLTS system could provide sufficient power to operate the submersible water pump with an average efficiency of XX%. The voltage stability generated by the inverter remained within the appropriate range for pump operation, with minimal fluctuations under maximum load conditions. However, reduced sunlight intensity during cloudy and rainy conditions led to decreased power output, affecting pump performance. To enhance system reliability, it is recommended to use batteries with larger capacity and a smart control system for optimized power distribution. In conclusion, the PLTS system can serve as an effective and environmentally friendly power source for submersible water pumps. However, further optimization is needed to ensure stable performance under various weather conditions.

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INTRODUCTION

Solar Power Plants (PLTS) are one of the most widely used renewable energy solutions across various sectors, including electricity supply for water pumping systems. Using PLTS as a power source for submersible water pumps is an environmentally friendly and sustainable alternative, especially in areas that are not covered by conventional power grids or experience limited electricity supply. Submersible water pumps are commonly used in agricultural irrigation systems, clean water supply in rural areas, and various industrial applications. However, the main challenge in their operation is the availability of a stable and efficient power source. By utilizing PLTS, water pumping systems can operate

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independently without relying on the main power grid, reducing operational costs and dependency on fossil fuels. Although PLTS offers numerous advantages, several challenges must be addressed, such as power fluctuations due to varying sunlight intensity, system efficiency under different weather conditions, and voltage stability required to optimize pump performance. Therefore, an in-depth analysis of the PLTS system's performance in supplying power to submersible water pumps is necessary to ensure reliability and efficiency.

Based on the background above, this study aims to address the following key questions the efficient is the PLTS system in supplying power to submersible water pumps and stable is the voltage output from the PLTS system under different weather conditions also factors influence the performance of submersible water pumps powered by PLTS.

Literature Review

Energy from the Sun

The Sun is a vital source of energy that is essential for the Earth and all its inhabitants. Solar energy influences various natural phenomena on Earth, including seasonal changes, ocean currents, weather patterns, climate changes, solar radiation, and even the aurora phenomenon at the poles. Solar energy that reaches the Earth's surface is called solar irradiance or solar radiation, which is measured by the amount of solar energy per unit area. The characteristics of solar energy are crucial for assessing the performance of photovoltaic systems. Solar radiation on the Earth's surface can be categorized into three components: Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and Global Horizontal Irradiance (GHI).

1. Direct Normal Irradiance (DNI) – This refers to the amount of solar radiation received by a surface that is perpendicular (normal) to the incoming sunlight per unit area. DNI is significantly influenced by the zenith angle (θ), which is the angle between the sun's rays and the vertical axis.
2. Diffuse Horizontal Irradiance (DHI) – This is the portion of solar radiation that is scattered by particles and molecules in the atmosphere before reaching the Earth's surface. It is received indirectly rather than directly from the Sun.
3. Global Horizontal Irradiance (GHI) – This represents the total amount of solar radiation received on a horizontal surface. It is the sum of both direct and diffuse irradiance components.

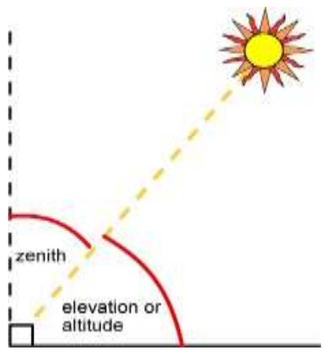

Figure 1. The Zenithi angle between the Earth's surface and the Sun

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Several types of optimization can be applied to maximize solar radiation absorption. These include adjusting the position of photovoltaic modules, tracking the Sun's movement, determining the optimal tilt angle, setting the declination angle, selecting the appropriate longitude and latitude, considering the zenith angle, the Sun's incident angle, the azimuth angle of the surface, and the angle of the Sun’s movement. The relative position of the Sun in the sky (sky dome) concerning the position of the photovoltaic module to achieve maximum energy absorption is referred to as solar orientation.

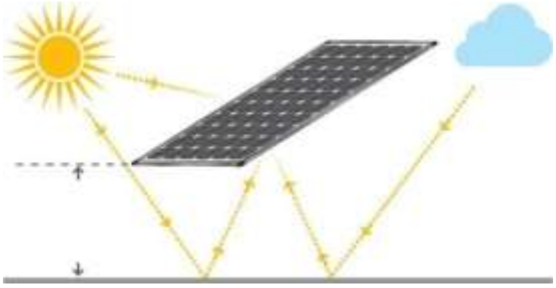

Figure 2. Orientation of the Angle between the Solar Panel and the Sun

The abundance of renewable energy sources presents an opportunity for Indonesia to achieve energy independence and resilience. The potential of renewable energy, particularly solar energy for electricity generation, is significant and evenly distributed across all regions of Indonesia. This is because, from an astronomical perspective, Indonesia is located around the equator, allowing sunlight to be available throughout the year. The advantages of utilizing solar energy include its easy availability, environmental friendliness, and adaptability for use in various geographical conditions.

Generator Electricity Power Sun (PLTS)

Solar energy is one of the most promising alternative energy sources due to its vast potential. Since sunlight is an inexhaustible resource, it can be effectively utilized for electricity generation, making its development highly prospective. In Samarinda, solar radiation fluctuates from 6:00 AM to 6:00 PM, providing sufficient intensity throughout the day.

To harness solar energy as an electricity source, specific devices are required to convert sunlight into electrical energy. This conversion is achieved using semiconductors in the form of solar cells. The photovoltaic generation process is highly efficient, as it does not require specialized skills for installation, operation, or maintenance. For relatively low-power applications, solar power plants can be used for small loads or as backup power. For instance, they can serve as an emergency power source during electricity blackouts, replacing traditional generators.

Solar power plants are simple and easily applicable solutions for meeting daily household electricity needs, making them an environmentally friendly method to support public electricity demand by utilizing sunlight. In general, solar power plants are also referred to as solar energy systems. One of the most important components of a solar power system responsible for converting solar energy into electricity is the photovoltaic module. The technological advancements in photovoltaic systems, from one generation to the next, have led to innovations aimed at improving efficiency and reliability. These

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developments include dielectric passivation, bifacial photovoltaic technology, and back-surface interdigitated contact designs.

Photovoltaic modules utilize solar radiation by converting sunlight into electrical energy through photovoltaic cells. A solar cell is a medium that transforms solar energy (light rays) into direct current (DC) electricity using semiconductor materials. The working principle of a photovoltaic cell is relatively simple—it involves utilizing the collision of photon particles from sunlight with electrons in a PN junction, a fundamental component of semiconductor materials. This interaction can be measured in volts (V).

When photons from sunlight strike valence electrons in semiconductor atoms with sufficient energy, the electrons are released from their atoms and move into the conduction band. These freed electrons generate an electric current when captured, producing electrical energy, as illustrated in the following diagram.

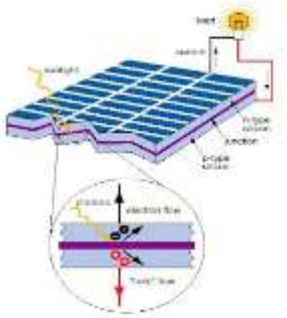

Figure 3. Principle Work Panel

Photovoltaic cells are grouped by connecting multiple solar cells in series, forming a photovoltaic module (solar module). These photovoltaic modules are then encased in transparent glass and aluminum (Al) to protect the solar cells from external environmental factors and ensure optimal performance.

Solar Charge Controller (SCC)

A Solar Charge Controller (SCC), also known as a battery charging controller, is an electronic device that regulates the current flowing from the photovoltaic module into the battery. Its main function is to optimize battery charging while preventing undercharging and overcharging.

To achieve the maximum power output from photovoltaic modules, an algorithmic system is required to maximize module performance and ensure optimal operation. When a photovoltaic module is directly integrated with a battery or a DC load, its operational efficiency depends entirely on the intensity of sunlight at any given moment.

Figure 4. *Solar Charge Controller* (SCC)

One of the key rapidly growing technologies in solar power plants is energy storage. Energy storage, also known as an accumulator, serves as a medium for storing different forms of energy for various applications, particularly in the field of electricity. The types of energy that can be stored include potential energy, chemical energy, and electrical energy.
A significant portion of the electricity generated by a solar power plant cannot always be used immediately and must be stored for later use. Stored energy is typically consumed during the evening, power failures, or specific operational conditions. Among various energy storage technologies, one of the most commonly used methods in solar energy systems is the battery energy storage system (BESS).

In simple terms, a battery consists of two electrochemical cells with a positive polarity (anode) and a negative polarity (cathode), along with an electrolyte that acts as a conductor. The output current generated is direct current (DC). Batteries generally operate at 6V DC, 12V DC, 24V DC, or 48V DC. A battery has the ability to store and discharge power, which allows it to be recharged multiple times. Due to this capability, batteries used in solar power plants are referred to as secondary batteries. Although batteries do not generate electricity themselves, their role in energy storage is crucial when designing a solar power system, whether for stand-alone configurations or grid-connected systems. Without a BESS, solar energy can only be utilized during daylight hours. However, with the addition of a battery storage system, electricity generated from sunlight can be stored during the day and used at night, improving the reliability and efficiency of the solar power system.

Figure 5. LifePo 12 Volt 100 Ah

METHOD STUDY

The use of a Solar Power System (PLTS) as a power source for a submersible water pump consists of several key components, including solar panels, a Solar Charge Controller (SCC), a battery, an inverter, and the submersible pump. The solar panels used in this system are monocrystalline, with each panel having a maximum power of 250 WP to serve as the energy source for the system. A Mini Circuit Breaker (MCB) is used to isolate the system's circuit from overcurrent and short circuits.

The Solar Charge Controller (SCC) functions to prevent overcharging of the batteries by limiting the charging current and voltage to a safe level. The battery stores the electrical energy produced by the solar panels. The battery used in this system is a LifePo4 12V, 200Ah type. The inverter is responsible for converting the Direct Current (DC) generated by the solar panels into Alternating Current (AC), which is used by the load. The inverter used is a pure sine wave inverter with a capacity of 2000 Watts.

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The load or submersible water pump has a power rating of 1500 Watts, as indicated on its nameplate.

Table 1. Specification Pump Water Submersible

No	Information	Specification
1	Model	SP-4010(M4)
2	Voltage (V)	220V
3	Frequency (f)	50Hz
4	Phase	1
5	Power (MOBILE PHONE)	2 MOBILE PHONE
6	Power (kW)	1.5 kW

The calculation of the energy burden is performed in a mathematical manner, which will be discussed through the power usage of the submersible water pump. The power used by the pump can be calculated using the following equation:

Energy Usage = Power × Time of Usage
= 1500 Watt × 4 hours
= 6000 Wh

In the Solar Power System, to determine the number of solar panels required, we need to consider the Peak Watt value, which represents the maximum amount of power produced by a solar panel under optimal sunlight conditions, typically occurring around 5:00 PM. The solar panels used in this system have a capacity of 500 Watt peak.

To understand the specifications of the solar panels used, it is essential to check the specifications written on the panels themselves. The panels are arranged in a parallel configuration to achieve the required system voltage of 12V, which is suitable for the Solar Charge Controller (SCC) that operates in the 12/24 VDC range.

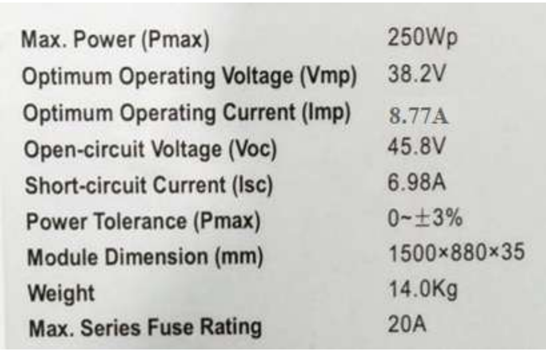

Figure 6. Nameplate Solar Cell

The SCC capacity used is based on the maximum power that can be produced by the solar panel array. The array is made up of two 250 Wp panels, which together provide a total of 500 Wp. Based on the calculation, the SCC capacity used is 1, with a minimum specification of 17 Ampere. However, in this Solar Power Plant system, a Maximum Power Point Tracking Solar Charge Controller is used, with a capacity as high as 25 Ampere.

In this system, the battery is used to store electricity from the solar panels to provide power efficiently to the burden (submersible water pump) as follows: The battery capacity is based on the energy needed to run the submersible water pump for 4 hours, which is 6000

W. The capacity produced by the battery is calculated by multiplying the voltage and current stated on the battery, which is 12 V and 200 Ah, respectively, resulting in 2400 Wh.

The inverter capacity used in this Solar Power Plant system is 2000 W, determined based on the maximum power used by the burden (submersible water pump) and safety factors. For installation, a safety factor ratio between 1.15 and 1.25is applied, in accordance with the PUIL 2011 guidelines. In this case, the safety factor used is 1.25.

The inverter capacity is then calculated as follows:

Inverter Capacity=Pmax×Safety FactorInverter Capacity=Pmax ×Safety Factor=1500 W×1.25=1500W×1.25=1875 W=1875W

Results and Analysis

Testing the Solar Power Plant System Without Burden In this test, measurements were taken without using the burden. The objective of this test was to measure the magnitude of the voltage and current produced by the solar panel at the moment of charging the battery. The results of the measurements for the Solar Power Plant system without the burden can be seen in the table below:

Table 2. Average Results Testing System Solar Power Plant Without Burden During 4 Day

Time (O'clock)	Output Panel Current (A)	Output Panel Voltage (V)	Filling Battery Current (A)	Filling Battery Voltage (V)	Irradiation Sun (W/m²)	Temperature Panel (°C)
9.30-10.00	10.9	21.80	8.8	12.80	476.7	28.4
10.00-10.30	12.2	20.77	9.9	12.81	812.6	30.1
10.30-11.00	13.2	22.96	12.7	12.82	974.7	29.8
11.00-11.30	12.9	22.29	11.8	12.95	1011.1	30.6
11.30-12.00	11.6	21.87	8.9	12.61	692.0	31.3
12.00-12.30	13.9	21.25	10.7	12.97	794.3	33.6
12.30-13.00	11.8	20.71	9.6	12.72	531.1	34.0
13.00-13.30	14.8	21.63	11.8	12.71	875.3	33.3
13.30-14.00	12.8	21.38	10.6	12.74	749.6	31.6
14.00-14.30	11.9	20.59	7.8	12.64	696.0	31.3

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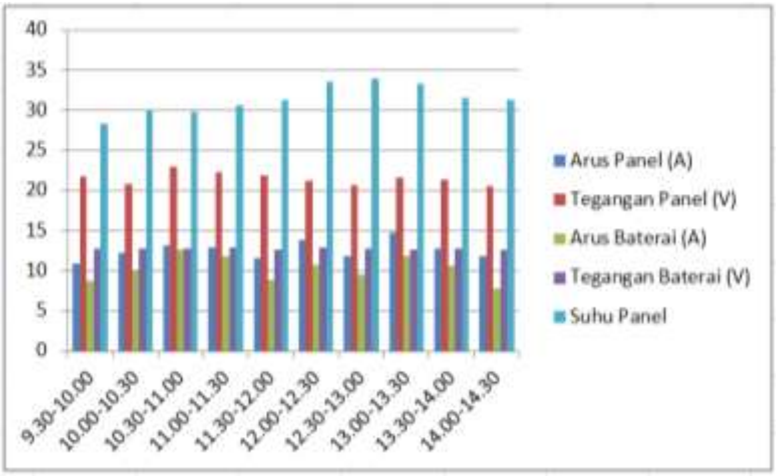

Figure 7. Chart Testing System Solar Power Plant Without Burden

Testing the Solar Power Plant System During the Day In this test, the measurements taken for the Solar Power Plant system showed variability based on the intensity of solar radiation on the panel surface. Solar radiation, influenced by factors such as shadows or clouds, will affect the voltage and current produced by the solar panel. The higher the solar radiation, the more voltage and current are produced by the solar panel. The size of the current produced by the solar panel depends on the magnitude of the solar radiation accepted by the panel's surface.

The voltage produced by the panel exceeds the current when charging the battery, typically reaching around ±12 volts. This is because the panel's maximum voltage is generated when the intensity of solar radiation is at its peak, and to adapt to the voltage required for battery charging (12 volts), the Solar Charge Controller (SCC) is used for automating the charging process. The current generated by the panel at this moment adjusts to match the power produced.

In general, the time required to fill the battery with power is influenced by weather conditions and the location of the solar panel. To estimate the time needed to charge the battery, the following formula was used: Based on the calculation, to fill the battery with a capacity of 200 Ah, the required time is about 9 hours and 11 minutes, considering the maximum current produced by the solar panel. The maximum current produced by the panel, as stated in the panel's nameplate, is 22.96 Amperes with two 500 Wp solar panels connected in parallel. Additionally, the time needed to fill the battery depends on whether the battery is in an empty condition or whether the system is already powering the burden, such as the submersible water pump. Testing System Solar Power Plant with Pump Water Submersible Use Input 12 Volt DC

Table 3. Testing System Solar Power PlantiWithiBurdeniPumpiWithiPoweriInputiInverteri12iVoltidci Battery 200 Ah

Minute To	Measurement Battery			Measurement Pump Water		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
10	12.98	42.8	555.54	221	6.41	1416
30	12.89	41.9	540.09	221	6.39	1412

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Minute To	Measurement Battery			Measurement Pump Water		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
60	12.87	40.8	525.09	221	6.40	1414
90	12.79	40.7	520.55	220	6.39	1405
120	12.71	40.5	514.75	220	6.39	1405
Average	12.84	41.34	531.20	220.6	6.39	1410

Results from Testing the Solar Power Plant System with Water Pump From the results of testing the Solar Power Plant system with the submersible water pump, I observed from the data measured on the battery that the voltage and current gradually decline between minute 10 and minute 120. This decline in voltage and current occurs because the energy in the battery is used to supply the burden. The longer the battery is used to supply the burden, the more the voltage will decrease.

For measurements taken from the inverter output, the voltage at minute 10 was 221V under normal conditions, while at minute 120, the voltage reached 220V under air conditioning conditions. The decrease in voltage produced by the inverter is due to the magnitude of the current drawn from the battery. The higher the current input into the inverter, the lower the output voltage.

From the measurements obtained during the testing of the Solar Power Plant system with the submersible water pump, the decline in voltage from the pump occurred at every interval where data was taken. This decrease in voltage is influenced by the amount of energy stored in the battery, which is used to run the water pump. The size of the current flowing into the inverter also influences the power produced by the system. In addition, the depth of discharge (DoD) of the battery also affects the duration of battery use in supplying the burden.

For the measurement of the amount of water pumped by the submersible water pump, a manual method was used with a 20-liter measuring receptacle. The time it took to fill the receptacle was 15.03 seconds. The amount of water produced by the pump is around 1,330 liters per second. Therefore, over the 120-minute operation time, a total of 9,576 liters of water was pumped.

CONCLUSION

Conclusion of this paper are: Voltage, current, and power produced by the solar panel depend on solar irradiation. Therefore, the highest voltage measurement will occur when the solar irradiation is brightest, and the temperature is under 310°C. For filling the battery with a capacity of 200Ah, it takes 9 hours and 11 minutes, using the maximum current produced by the solar panel. The maximum current specified on the solar panel nameplate is 22.96 Amperes, with two solar panels connected in parallel, each with a capacity of 500W. The longer the battery is used to supply the burden, the more the voltage will decline. On the other hand, for measurements taken from the burden parameter output from the inverter, the voltage at minute 10 is 221V under normal conditions, while at minute 120, the voltage reaches 220V under air conditioning. The amount of water produced by the submersible water pump is 1,330 liters per second.

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