Analysis of The Effect of Speed on The Use of Electric Power on Solar Boat Re 15

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ABSTRACT
This study aims to analyze the effect of speed on the use of electrical power on the solar-powered ship Solar Boat RE 15. This ship uses solar panels as the main energy source to drive the electric motor, which is controlled by a battery system and solar controller. In this study, measurements were taken at several speed points to study the impact of changes in speed on power consumption. The results showed that the higher the speed of the ship, the greater the electrical power required. This is due to the increased friction and water resistance that must be overcome at high speeds. The solar panels used have a capacity of 20 Wp, which is capable of producing 120 Wh of power per day under optimal weather conditions. However, at high speeds, higher power consumption causes the battery to drain quickly, thus affecting the operational duration of the ship. Based on the results of the analysis, it is recommended that the ship be operated at a speed of around 10 km/h to achieve a balance between power efficiency and operational duration. This study provides insight into optimizing the performance of solar-powered ships and their contribution to supporting sustainable maritime transportation.

Keywords: Solar Boat RE 15, Speed, Electric Power, Solar Panel, Battery, Energy Efficiency.

Introduction

Climate change is a global challenge that requires innovative and sustainable solutions, especially in the transportation sector, which contributes a significant portion of global carbon emissions. Maritime transportation, which is the backbone of international trade, is under pressure to adapt to environmentally friendly technologies to reduce dependence on fossil fuels and their negative impact on the environment. The development of solar-powered ships is one concrete step in responding to this challenge, combining renewable energy technology with the need for efficiency in maritime transportation.

Solar-powered ships rely on solar panels to capture solar energy, which is then converted into electrical energy to drive the ship's motor. This technology provides a number of benefits, such as reducing dependence on fossil fuels, namely reducing the consumption of conventional fuels whose prices fluctuate and are limited in availability. Reducing Greenhouse Gas Emissions which contribute to global targets to reduce carbon emissions. Reducing marine pollution which reduces oil spills and other pollutants from the use of fossil fuels in the maritime sector. As technology advances, solar panel efficiency and battery capacity continue to increase, allowing solar-powered ships to become a more competitive and viable alternative to conventional ships. However, the implementation of this technology still faces several technical challenges, especially in terms of optimizing energy efficiency.

Solar Boat RE 15 is one of the prototype solar-powered boats designed to optimally utilize solar energy. This prototype is not only designed to produce enough power to support ship operations, but also to ensure energy efficiency under various operational conditions. One of the main challenges is understanding how variations in ship speed affect electrical power consumption. High speeds require more power, which directly affects the duration of ship operations and the distance that can be achieved. Therefore, research on the relationship between speed and power consumption is crucial to identify the optimal speed that can maximize energy efficiency.

This analysis has broad implications. Not only does it help improve the technical performance of the Solar Boat RE 15, but it also provides valuable input for the maritime industry in the transition to environmentally friendly technologies. Furthermore, the data generated from this study can be the basis for policy makers to design regulations that encourage the adoption of solar-powered vessels in the maritime transportation sector. This analysis is important in supporting the development of sustainable maritime transportation technology. In addition to providing insights into the design and operation of solar-powered vessels, this study can also be a reference in the development of energy policies and technological innovations in the maritime transportation sector.

Formulation of the problem:

1) How does speed affect the power consumption of the Solar Boat RE 15?
2) Is there an optimal speed that can produce the highest energy efficiency on this ship?
3) What is the relationship between ship speed and electrical energy consumption based on data obtained from the experiment?

Literature Review

1. **Solar Powered Ship Technology**

Solar-powered ships harness solar energy through solar panels, which convert solar radiation into electrical energy using the principle of the photovoltaic effect. This energy is stored in batteries and used to drive electric motors. Previous studies have shown that the efficiency of solar panels is highly dependent on the type of panel material, installation position, and sunlight intensity (Fraunhofer Institute for Solar Energy Systems, 2021; Chen & Zhang, 2019).

Energy storage technology also plays an important role. Lithium-ion batteries are the primary choice due to their high storage capacity, durability, and fast recharge rates compared to conventional batteries (Smith et al., 2020). In the context of solar-powered ships, the optimization between energy storage capacity and power requirements during operation is a major challenge.

2. **Relationship Between Speed and Power Consumption**

Ship speed is one of the main factors affecting electrical power consumption. Research shows that higher speeds require more power due to increased hydrodynamic resistance. *Froude number* and water resistance are important indicators in analyzing this relationship (Kim, Lee, & Park, 2020; Froude, 1872).

A study by Kim et al. (2020) showed that in electric powered ships, power consumption increases exponentially at high speeds. This is due to the increase in drag force that must be overcome by the ship's electric motor. Therefore, the analysis of the relationship between speed, power consumption, and energy efficiency becomes relevant to determine the optimal operating speed.

3. **Energy Efficiency in Solar Powered Ships**

Energy efficiency on solar-powered ships is not only influenced by speed, but also by ship design, electric motor efficiency, and energy management strategies. A study by the Solar Energy Institute (2021) emphasized the importance of aerodynamic and hydrodynamic ship design to reduce drag and increase energy efficiency. Energy management technology is also a concern, such as the use of power demand prediction software based on operating patterns and solar intensity. This allows for optimization of power usage during the voyage, especially in changing weather conditions (European Commission, 2021).

4. **Solar Powered Ship Applications**

The use of solar-powered ships has grown rapidly in recent decades. Projects such as *PlanetSolar* and *Solar Voyager* demonstrate the great potential of this technology for both long-distance and short-distance maritime transportation applications (PlanetSolar Project, 2013; Solar Voyager Team, 2017). In addition, the use of solar-powered ships has also begun to be applied for passenger and logistics transportation in coastal areas, especially in areas with high exposure to sunlight throughout the year.

Research Method

System workflow planning on Solar Boats that use *solar*:

1) Sunlight
    a) The system utilizes energy from sunlight as the main power source.
    b) When sunlight is available, the system will begin the process of searching for and capturing energy.
2) Solar Tracker OFF
    a) If *the solar tracker* is not activated, the solar panel remains stationary in a fixed position.
    b) Energy is only generated according to the position of the panel in relation to sunlight without automatic adjustment.
3) Solar Tracker ON
    a) When *the solar tracker* is activated, from 07.00 to 17.00, the solar panels automatically move following the direction of the sunlight.
    b) This system increases energy capture efficiency because the panels remain aligned with the sun throughout the day.
4) The Process of Searching for Light
    a) In *solar tracker mode* , the solar panel actively searches for the best light.
    b) The light sensor detects the highest intensity and directs the panel to the optimal position.
5) Battery Charging and Usage
    a) The energy generated by the solar panels is used to automatically charge the battery.
    b) When the battery reaches full capacity, the system automatically regulates the power flow to prevent overcharging.
6) Finished
    a) After sunset (outside 5:00 PM), *the solar tracker* stops moving and returns to its starting position to start the next day's cycle.

b) A fully charged battery can be used to operate the boat's electric motor or other systems on the Solar Boat.

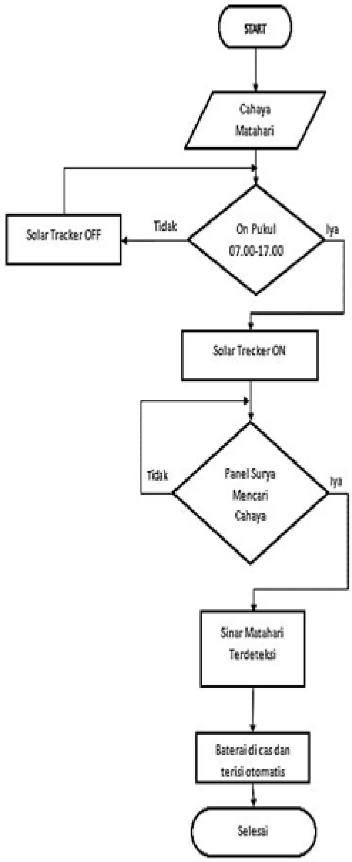

Figure 1. Flowchart Diagram

The working system of the solar panel generator with the single axis *solar tracker method* utilizes various main components that are integrated with each other to optimize the capture of solar energy. The 20 WP (Polycrystalline) solar panel functions to convert sunlight into electrical energy which is then stored in a 12V battery. This energy is regulated by a 12V/24V 20A PWM solar controller charger, which ensures efficient battery charging while protecting it from *overcharging* or *deep discharge* . A 12V digital timer switch is used to set the system's operating time as needed, while a 12V relay acts as an electronic switch that controls the flow of power to devices such as a 12V linear actuator motor. This motor moves the solar panel following the movement of the sun based on signals sent by the 12V LDR switch relay (XH-M131 module), which detects the highest light intensity. The 12V battery indicator allows monitoring of battery capacity to ensure the system is working optimally. With this combination of devices, the solar panel can maximize energy capture throughout the day, increasing system efficiency and reliability.

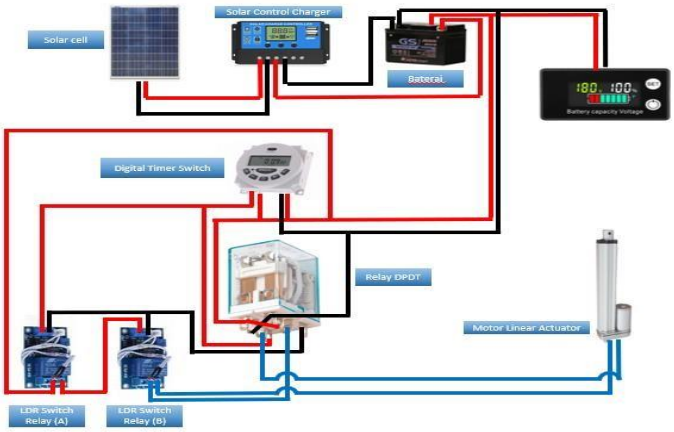

Figure 2. Solar Circuit Schematic

In this system, the battery acts as the main energy source that supports the entire circuit. The voltage from the battery is lowered by a step-down module to provide the appropriate power for the Arduino Uno as the main microcontroller. The Arduino Uno is responsible for processing data and sending signals to various components. This signal used to display the motor speed and current values on the LCD screen, which are obtained from infrared sensor readings for speed and the ACS712 current sensor module for electric current. In addition, a potentiometer is used to regulate the motor speed by sending an input signal to the Arduino Uno, which is then forwarded to the motor driver. The motor driver processes the signal to regulate power to the motor, so that the motor rotates at the desired speed. This combination of components allows the system to work in an integrated manner with precise control.

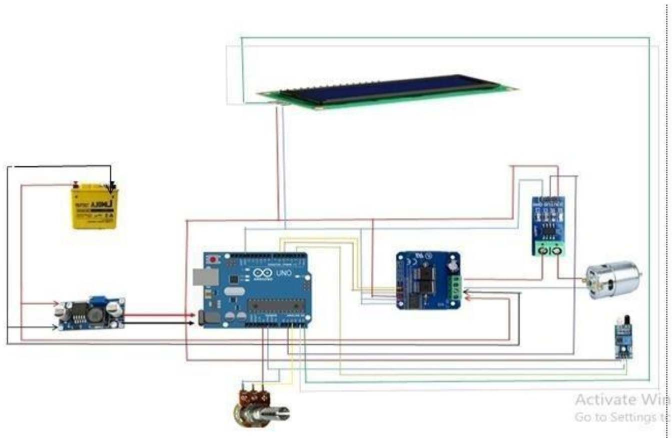

Figure 3. Control Tool Design

Results and Discussion

Measurements were taken at the beginning of battery usage with 5 measurements at each point. The following are the measurement data obtained:

Table 1. Table showing the results of battery measurements, 5 times.

No	Measurement Position	Measurement Point	Unit	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5	Average X

1	Battery	TP 1 (Battery Output)	VDC	12.3	12.2	12.3	12.2	12.3	12.26
			IDC (mA)	10.2	10.1	10.2	10.2	10.2	10.24
2	DC Motor	TP 10 (DC Motor Input)	VDC	12.3	12.3	12.3	12.3	12.3	12.3
			IDC (mA)	10.0	10.1	10.1	10.2	10.1	10.16

Information:

a. VDC (Volt DC): DC voltage measured at the measuring point.
b. IDC (mA): DC current measured at the measuring point in milliamperes (mA).
c. Mean X: The average value of measurements taken at five points.

From the above measurements, it can be concluded that the average battery output voltage is around 12.26 V, and the average current output by the battery is 10.24 mA. On the DC motor, the voltage remains stable at 12.3 V, with an average current of 10.16 mA.

In this study, measurements were made of the electrical power used by the Solar Boat RE 15 at various operating speeds to analyze how speed affects electrical power consumption. The measurement results show a significant relationship between ship speed and electrical power usage. Below is an analysis of the discussion of the results found in the test.

1. Relationship between Speed and Electric Power Consumption on Solar Boat RE 15
   The results of the measurements carried out show that there is a direct relationship between the operational speed of the Solar Boat RE 15 and the required electrical power consumption. The higher the speed of the ship, the greater the electrical power consumption required. This is influenced by the increase in friction and water resistance that the ship must overcome at high speeds. At low speeds, the water resistance faced is relatively small, so power consumption remains low. Conversely, at high speeds, water resistance increases significantly, requiring the motor to work harder. Measurements at various speeds provide a clear picture of power consumption, namely:
   a. Low speed (5 km/h) results in power consumption of around 20W.
   b. Medium speed (10 km/h) produces power consumption of around 40W.
   c. High speed (15 km/h) produces a power consumption of about 60W. This increase in power consumption shows that speed is directly proportional to the power consumption used. Each increase in speed affects the power required by the motor proportionally, with the greatest effect occurring at high speeds.
2. Optimal Speed That Can Produce the Highest Energy Efficiency on This Ship
   The optimum speed for the Solar Boat RE 15 that yields the highest energy efficiency is found to be around 10 km/h. At this speed, the boat can travel a considerable distance with relatively low power consumption. On the other hand, high speed (15 km/h) although it speeds up the journey, leads to a significant increase in power consumption, which will reduce the battery life in the long term.
   In addition, at a speed of 10 km/h, the power consumption and energy output of the solar panel are more balanced. A solar panel with a capacity of 20 Wp can produce sufficient power to charge the battery in sunny weather conditions, so the boat can operate for a

longer duration without the need for frequent battery charging. This shows that a speed of 10 km/h is the optimum point where the highest energy efficiency can be achieved considering the power consumption and charging capability of the solar panel.

3. Relationship between Ship Speed and Electrical Energy Consumption Based on Data Obtained from Experiments
   Based on the experimental data, the relationship between ship speed and electrical energy consumption is clearly visible. At low speeds, electrical power consumption is less due to lower friction and water resistance. However, as the speed increases, friction and water resistance increase, resulting in a significant increase in power consumption. Experimental data show that power consumption increases with increasing ship speed:
   a. At low speed (5 km/h), power consumption reaches 20W, which shows efficient energy use.
   b. At moderate speed (10 km/h), power consumption reaches 40W, which is still within the power limit that can be generated by solar panels in sunny conditions.
   c. At high speeds (15 km/h), power consumption increases to 60W, which makes energy use less efficient, considering that the power required is greater than the solar panels can supply in a short time.

Thus, this experiment proves that the higher the speed, the greater the energy consumption required to maintain that speed. Therefore, choosing the right speed is very important to maintain a balance between power consumption and operational efficiency. From the discussion above, it can be concluded that speed has a significant effect on the electric power consumption of the Solar Boat RE 15. Higher speeds increase power consumption proportionally, while an optimal speed of around 10 km/h can produce the highest energy efficiency with lower power consumption. Therefore, to achieve optimal energy efficiency, it is important for ship operators to maintain speeds in this range, as well as paying attention to other factors such as weather conditions and water resistance that can affect the overall performance of the ship.

Conclusion

Based on the results of measurements and analysis carried out on the Solar Boat RE 15, it can be concluded that there is a clear relationship between ship speed and electrical power consumption. The higher the speed applied, the greater the electrical power required to drive the ship's motor. This is due to the increased friction and water resistance that must be overcome at high speeds. The solar panel with a capacity of 20 Wp used in the Solar Boat RE 15 is capable of producing around 120 Wh of power per day under optimal weather conditions. However, at high speeds, higher power consumption causes the battery to drain quickly, thus limiting the duration of the ship's operation. With a battery capacity of 240 Wh, the ship's operational duration can be maintained at low to medium speeds. However, at high speeds, greater power consumption accelerates battery discharge, which affects the ship's operational duration. Therefore, to achieve a balance between performance and energy efficiency, it is recommended to operate the Solar Boat RE 15 at a speed of around 10 km/h. This speed allows the ship to remain efficient in power usage without significantly shortening the operational duration. Proper speed control, combined with monitoring weather conditions and sunlight intensity, is essential to ensure optimal battery charging and control of power consumption. This research provides valuable insights for the development of more efficient and sustainable solar-powered vessels.

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