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Design and Manufacture of a Solar-Powered Electrical Energy System for Traditional Fishing Boat

Khakam Ma'ruf
Dept of Industrial Engineering, Faculty of Engineering
Gadjah Mada University
Yogyakarta, Republic of Indonesia
hakammaruf70@gmail.com

Rizal Justian Setiawan
Dept of Industrial Engineering and Management, College of Engineering
Yuan Ze University
Taoyuan, Taiwan
rizaljustiansetiawan99@gmail.com

Nur Azizah
Dept of International Public Health, School of Public Health
China Medical University
Taichung, Taiwan
nazizah169@gmail.com

Darmono
Dept of Civil Engineering Education, Faculty of Engineering
Yogyakarta State University
Yogyakarta, Republic of Indonesia
darmono@uny.ac.id

Nur Evirda Khosyiati
Dept of Culinary Technology Education, Faculty of Engineering,
Yogyakarta State University
Yogyakarta, Republic of Indonesia
nkhosyiati@gmail.com

***Abstract*—Indonesia, as the world's largest maritime nation, supports millions of traditional fishermen who rely heavily on diesel or gasoline engines, which contribute significantly to environmental emission and high operational costs. In response to these challenges, the adoption of renewable energy sources including solar power, presents a viable solution to reduce environmental impacts while optimizing the operational costs of fishing boats. This study adopts a Research and Development (R&D) approach to develop an energy system that minimizes dependence on fossil fuels and improves operational efficiency. Utilizing a 200 WP solar panel and a 200 Ah battery, the system can generate up to 864 Wh of electricity per day, supporting a DC motor with a 3 HP capacity for approximately 1.46 hours of continuous operation. The system achieved an overall efficiency of 58.1%, calculated based on the combined efficiency of the solar panel, solar charge controller, and battery. Testing and simulations conducted on a traditional fishing boat demonstrated optimal performance in meeting the electrical demands of the boat, showcasing the potential for solar energy to transform energy management in the fisheries sector. By employing this system, traditional fishermen are expected to enhance the sustainability of their operations and reduce carbon emissions.**

***Keywords*— Boat, DC Motor, Emission, Fishermen, Renewable Energy, Solar Energy.**

I. INTRODUCTION

Indonesia, as the world's largest maritime nation, holds vast fishery resources [1-2]. With a coastline stretching 95,181 kilometers, millions of traditional fishermen rely on the sea to sustain their livelihoods [3]. However, many of the fishing boats they use are still equipped with limited and inefficient technology [4-5]. Small fishing boats, typically carrying 2-5 people, lack onboard electricity generation systems and depend on batteries that must be recharged on land [6]. This dependence hampers fishermen's ability to operate efficiently and significantly increases operational costs.

The propulsion system of these fishing boats generally relies on fuel-based engines (diesel or gasoline), which serve as the primary energy source for their operation [7-8]. Fuel is essential to generate sufficient power for the boats to sail efficiently. However, this reliance not only drives up operational expenses but also has adverse environmental consequences [9-10]. As energy demands increase for electronics and other onboard systems, the long-term use of fuel poses risks to the marine ecosystem and jeopardizes the livelihoods of fishermen [11-12]. To mitigate these challenges, solar power as an renewable energy, present viable alternatives that can reduce environmental impacts and optimize the operational costs of fishing boats [13].

Given Indonesia's potential for renewable energy, solar power emerges as a promising solution to meet the electrical needs of fishing boats. Situated in the equatorial region, Indonesia enjoys consistent sunlight, providing an excellent opportunity for harnessing solar energy through photovoltaic panels [14-15]. By reducing dependence on fossil fuels, solar energy not only holds the potential to significantly benefit fishermen but also entire coastal communities. Positive outcomes from the use of renewable energy include lower operational costs, enhanced efficiency, and improved environmental sustainability [16].

The innovation proposed in this research involves the development of an electrical energy system specifically designed for traditional fishing boats, utilizing solar panels. This system not only addresses the aforementioned challenges but also enhances the competitiveness of fishermen in the fisheries market. By adopting renewable energy solutions, fishermen can operate more independently and efficiently while contributing to environmental sustainability.

II. LITERATURE REVIEW

Several previous studies have explored the application of solar energy in fishing boats. The first study investigated the use of solar cells on fishing boats in Rokan Hilir Regency, Riau, to enhance energy efficiency. Quantitative data indicated that the total energy load required during fishing activities was approximately 4,686 Watt-hours, necessitating a panel capacity of 686 Watt Peak. The integration of solar cells not only reduced dependence on fossil fuels but also showed potential for significant operational cost savings. The study recommended further development to support the sustainability of the fisheries sector through renewable energy [17].

The second study focused on the implementation of solar panels on fishing boats, with the goal of reducing fossil fuel consumption and operational costs. It found that to meet the total energy needs during fishing activities, which amounted to 4,686 Watt-hours, a solar panel with a capacity of 686 Watt Peak was required. Additionally, the study highlighted that the use of solar technology could contribute to greater sustainability and energy efficiency in the fishing industry, with an average of 6.84 peak sunlight hours per day [18].

Another study examined the implementation of solar panels on fishing boats in Tablolong, East Nusa Tenggara, aimed at replacing fossil fuel use. Quantitative data revealed that solar photovoltaic (PV) systems could generate 593.83 Watt-hours of electricity per day, with peak output reaching 656.69 Watt-hours on certain days. The solar panels, with a capacity of 100 WP, fulfilled 50.52% of the total energy needs for lighting and communication. The findings underscored the potential of renewable energy to improve efficiency and sustainability in the fishing sector [19].

From these three previous studies, it can be concluded that while significant progress has been made in utilizing solar energy in the fisheries sector, there is still a need for more specific research on the design and development of electrical energy systems for traditional fishing boats. This research aims to address that gap by developing and producing accessible energy systems for fishermen in Indonesia.

III. Research Method

The research method employed in this study is Research and Development (R&D), designed to create and test a new product [20]. This approach aims to design and develop an electrical energy system for traditional fishing boats, utilizing solar energy. The R&D methodology was chosen for its suitability in developing innovative and efficient solutions, allowing for product advancements that more effectively meet specific needs [21-22]. The stages of the R&D process are illustrated in Fig. 1.

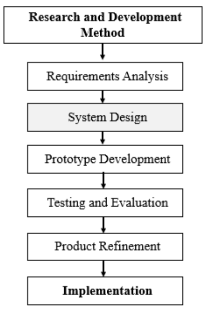

Fig 1. R&D Research Stages

The R&D method in this study involves a series of structured steps designed to develop an efficient electrical energy system for fishermen. The process begins with the following stages:

A. *Requirement Analysis*

The initial stage is a requirement analysis, during which the research team conducts surveys with fishermen and traditional boat owners. This step aims to identify specific needs and challenges in procuring an efficient and eco-friendly energy source. Data collected includes user preferences, technical limitations, and local environmental conditions, such as the types of equipment in use and the duration of fishing trips.

B. *System Design*

Based on the needs analysis results, the design of the electrical energy system is developed. In this stage, key components such as solar panels, inverters, and batteries are selected. The design also considers the energy capacity required for various onboard equipment, including lighting and propulsion motors, to ensure the system meets the fishermen's daily operational needs.

C. *Prototype Development*

After finalizing the system design, the next step is prototype development. This prototype is built according to the established design, with attention to both functionality and aesthetics. During this development phase, preliminary testing is conducted to ensure that all components operate effectively as an integrated system.

D. *Testing and Evaluation*

Testing is conducted to evaluate the performance of the assembled electrical energy system. Parameters tested include solar panel efficiency, energy storage capacity of the battery, and power output for onboard equipment. This testing occurs under real operational conditions, involving fishermen who use the boat, to confirm that the system performs effectively in its intended environment.

E. *Product Refinement*

Based on the testing results, data analysis is performed to identify the strengths and weaknesses of the designed system. Adjustments are made to improve any design or component elements that do not meet the expected standards. These refinements are necessary to enhance the system's efficiency and alignment with user needs.

F. *Implementation*

After all refinements are complete, the system will be implemented on several traditional fishing boats. The research team will collaborate with fishermen to ensure proper installation and provide training on system usage and maintenance. This implementation is crucial to confirm that the system not only functions effectively but is also sustainable over the long term.

IV. Results and Discussion

A. *Solar Cell System on Fishing Boats*

In efforts to enhance energy efficiency on a traditional fishing boat, the integration of solar panels has become an increasingly relevant solution. The system designed for this purpose includes key components, such as a solar panel with a capacity of 200 WP (Watt Peak) and a battery with a capacity of 200 Ah. Figure 2 provides a detailed schematic of this solar energy system, illustrating how energy generated by the solar panels is transmitted, stored, and managed onboard. This setup optimizes energy distribution for various operational needs on the boat, ensuring reliable power for essential functions like lighting and motor propulsion while minimizing reliance on conventional fuel sources.

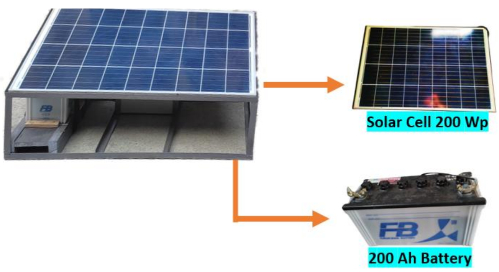

Fig 2. Fishing Boat Solar Cell System

The primary specifications of this solar panel include an open-circuit voltage (Voc) of approximately 42-44 V and a short-circuit current (Isc) of around 6-6.5 A. The solar panel's efficiency, a critical parameter for assessing energy output relative to sunlight input, can be calculated using the formula presented in Equation 1. This efficiency measurement is important for determining the panel's performance under typical operational conditions, allowing for accurate projections of energy yield and system reliability on the fishing boat.

$$\eta = (Pmax / (E \times A)) \times 100\% \quad (1)$$
$$\eta = (200\ W / (1000\ W/m^2 \times 0.2666\ m^2)) \times 100\%$$
$$\eta = (200 / 266.6) \times 100\%$$
$$\eta = 0.72 \times 100\%$$
$$\eta = 72\%$$

Where:

η = solar panel efficiency (72%)
Pmax = maximum panel power (200 W)
E = standard solar irradiation (1000 W/m²)
A = solar panel surface area (0.2666 m²)

Based on the calculation of the efficiency of a 200 Wp solar panel, it is 72%, then the optimal electrical power of the solar panel can be seen in Equation 2.

$$E = Pmax \times t \times \eta \quad (2)$$
$$E = 200\ W \times 6\ h \times 72\%$$
$$E = 200 \times 6 \times 0.72$$
$$E = 864\ Wh\ per\ day$$

Where:

E = electrical energy produced (Wh)
Pmax = maximum panel power(100 W)
t = sun exposure time (6 hours)
η = solar panel efficiency (72%)

The energy storage system utilizes a battery with a capacity of 200 Ah (Ampere-hour) and a voltage of 12 V. The total energy storage capacity, representing the maximum amount of energy available for operational use, can be calculated using the formula provided in Equation 3. This calculation is essential for accurately determining the system's ability to supply consistent power to the boat's equipment over time, thereby ensuring sustained functionality during fishing operations.

$$E = V \times Q \quad (3)$$
$$E = 12\ V \times 200\ Ah$$
$$E = 2400\ Wh$$

Where:

E = stored energy(Wh)
V = battery voltage (12 V)
Q = battery capacity (100 Ah)

B. *Technology Specifications*

Fig. 3 illustrates a comprehensive solar energy system designed for electric fishing boats, aimed at enhancing energy efficiency and reducing reliance on fossil fuels. The system consists of several interconnected components, each playing a crucial role in energy generation, conversion, storage, and utilization.

According to the flowchart in Fig. 3, the system begins with solar panels, which convert sunlight into electrical energy. These panels are rated to produce direct current (DC) electricity, which is then processed by the subsequent components to ensure efficient energy management on the fishing boat. Then, electrical output from the solar panel is monitored by a watt meter. This device measures the real-time power output in watts, providing essential data on the system's performance and ensuring that energy generation is optimized based on solar conditions. After that, the solar energy generated is regulated by a solar charge controller (SCC). The SCC ensures that the energy flow to the battery is controlled to prevent overcharging or excessive discharge, maintaining the longevity and efficiency of the battery system. This component is crucial in managing the fluctuating energy input from the solar panels based on sunlight availability.

Furthermore, the electrical circuit and PCB act as the core distribution and management center of the system. They control the flow of electricity from the solar charge controller to the battery and other components, ensuring proper functioning and preventing electrical faults. To save energy, this system uses a 100 Ah battery for energy storage, allowing the fishing boat to store electricity generated during the day for later use, such as nighttime fishing or during periods of low sunlight. The battery stores direct current (DC) energy and provides a stable power supply to the boat's equipment. Moreover, step-up converter is employed to increase the voltage to 24V DC. This conversion is necessary to match the power requirements of the DC motor drive and other electrical components onboard the boat.

To use the energy obtained, rhe converted 24V DC power is supplied to the DC motor drive, which powers the boat's propeller. The motor provides thrust for the electric fishing boat, allowing for smooth and efficient operation without the need for conventional fuel-based engines. The system powers the electric fishing boat, demonstrating a sustainable and eco-friendly alternative to traditional fishing boats that rely on fossil fuels.

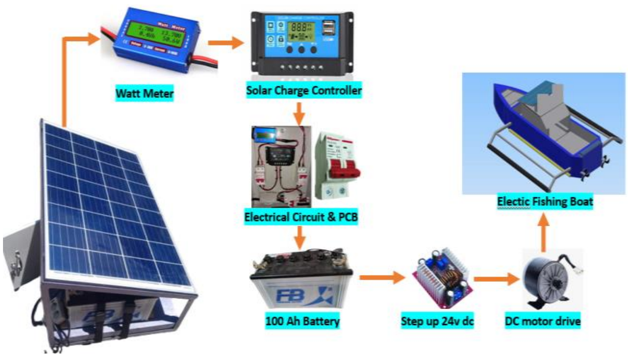

Fig 3. Fishing Boat Solar Cell System

Regarding the solar cell system, fishing boats have several components with detailed specifications in Table I.

TABLE I. COMPONENT SPECIFICATIONS

No	Components	Types	Specifications
1	Solar Panel	Photovoltaic Panel	Capacity 200 WP
2	Watt Meter	Measuring Instrument	Calculating the power generated
3	Solar Charge Controller	Charging Controller	Setting the battery charge
4	Battery	Lead Acid Battery	Capacity 100 Ah
5	Panel Box	Electrical Circuit and PCB	Setting the electric flow
6	Step up 24v Dc	Step Up Kit	To increase the voltage from a direct current (DC) source
7	DC Motor	Boat Propeller Drive	Driven by DC electricity
8	Fishing Boat	Boat Structure	Small boat for fishing

The electrical system workflow of the boat harnesses solar energy by utilizing a 200 WP solar panel to capture sunlight. The energy generated is measured using a wattmeter, while a solar charge controller regulates the charging of a 100 Ah lead-acid battery, storing the energy for future use. The electrical circuit and PCB incorporate a 24V DC step-up converter to boost the voltage for distribution to the DC motor. The motor serves as the final component in the system, driving the ship's propeller. This efficient workflow not only maximizes the use of renewable energy but also ensures that the electrical system on the fishing boat provides the necessary power for sustainable and continuous operation.

C. Implementation Results

The results of the system implementation demonstrate a high level of efficiency, as evidenced by simulations and testing conducted on a traditional fishing boat. The system operates optimally, meeting the electrical demands of the boat effectively. Figure 4 illustrates the successful application of the solar panel system on the fishing boat, showcasing its integration and functionality in providing a reliable source of renewable energy for maritime operations.

Fig 4. Fishing Boat Solar Cell System

The implementation phase involves a detailed analysis of the electrical power calculations for batteries used to drive the DC motor, which powers the ship's propeller dynamo. Accurately determining the power requirements for the DC motor in fishing boats necessitates the use of current (I) values, derived from the specifications provided for the boat's propulsion system. These values are essential for calculating the required electrical power to ensure optimal motor performance and efficient energy usage. Equation 4 serves as a fundamental tool in performing these calculations, enabling precise assessment of the motor's power consumption and its implications for the overall energy management of the fishing boat.

$$P = V \times I \quad (4)$$
$$2237W = 24\ V \times I$$
$$I = 2237\ W \div 24\ V$$
$$I = 93.21\ A$$

The next step involves calculating the electrical energy based on the assumption of a one-hour operational period. The results of this power calculation will be used to determine the duration for which the fishing boat's system or engine can operate, utilizing the energy supplied by the solar panel. This assessment is conducted using the calculation method outlined in Equation 5, which provides a framework for estimating the boat's operational time powered by renewable energy sources.

$$P = V \times I \times t \quad (5)$$
$$P = 24\ V \times 93.21\ A \times 1\ h$$
$$P = 2237\ Wh$$

Where:

P = Power/Energy (Watt hour/Wh)
V = Voltage (24 Volts)
I = Current (93.21 Ampere)
t = Time (1 hour)

Based on power calculations, the energy requirement for the DC motor is 3 horsepower (HP), equivalent to 2237 watt-hours (Wh) for one hour of operation. In these calculations, it is also essential to consider the electrical power generated by the solar panel, the storage capacity of the battery, and the overall energy demands of the system, as outlined in Equation 6. These factors play a crucial role in assessing the system's ability to meet the operational needs of the fishing boat while optimizing energy utilization.

$$t = (E_{panel}+E_{battery})/P_{motor} \quad (6)$$
$$t = (864 + 2400) / 2237$$
$$t = 3264 / 2237$$
$$t = 1.46\ hours$$

Where:

t = Operating hours (hours)
E_{panel} = Energy generated by solar panels (864 Wh)
P_{motor} = Power required by DC motor (350 W)
$E_{battery}$ = Battery stored energy (2400 Wh)

The system is estimated to sustain operation for approximately 1.46 hours, or around 1 hour and 30 minutes. This indicates that the combination of a solar panel and battery can effectively provide sustainable energy for powering the fishing boat's propulsion system. This operational time estimate is crucial for planning and optimizing the system's performance, enabling fishermen to reduce their dependence on fossil fuels for boat operation. By transforming the propulsion system into a hybrid energy solution, the system can integrate renewable energy with fossil fuel sources, offering a versatile approach to energy management. Since fishermen often spend more than 1 hour and 30 minutes at sea, fossil fuels serve as a necessary backup to ensure extended operational capacity.

The system's operational framework begins with the solar panel, which converts sunlight into electricity. This electrical current is then regulated by the solar charge controller (SCC), which manages the charging process of the battery. The energy stored in the battery can be utilized directly to power DC loads or routed through an inverter to support alternating current (AC) loads. The overall system efficiency (ηsystem) can be calculated using Equation 7, considering the efficiency of each component, thereby providing a comprehensive measure of the system's performance.

$$\eta_{system} = \eta_{panel} \times \eta SCC \times \eta_{battery} \quad (7)$$
$$\eta_{system} = 72\% \times 95\% \times 85\%$$
$$\eta_{system} = 0.72 \times 0.95 \times 0.85$$
$$\eta_{system} = 0.581$$
$$= 58.1\%$$

Based on these calculations, each efficiency value (η) represents the performance of its respective component. Assuming a solar panel efficiency of 72%, a Solar Charge Controller (SCC) efficiency of 95%, and a battery efficiency of 85%, the system achieves a total efficiency of 58.1%. This efficiency rating reflects the system's capacity to convert and store energy effectively, ensuring reliable support for the DC motor operations on the fishing boat. With a battery storage capacity of 200 Ah, equivalent to 2400 Wh, the system is well-suited to meet the energy demands of traditional fishing activities while optimizing energy utilization onboard.

The innovation in the solar energy system for a fishing boat involves the use of a 200 Wp solar panel, an integrated energy management system for a 3 HP DC motor, and comprehensive mathematical calculations enabling system operation for 1.46 hours. This analysis provides a more detailed assessment compared to previous studies.

D. Installation and Maintenance

The installation of a solar panel on a fishing boat requires special attention to stability and efficiency. A specialized mounting design is essential to dampen vibrations caused by the boat's motion, employing either a gimbal system or flexible mounting. Efficiency correction calculations indicate a potential reduction of 5-10% under moderate wave conditions, necessitating the selection of solar cells with a wider angle tolerance. The maintenance of the solar system is crucial for ensuring long-term success. The use of corrosion-resistant materials and special coatings on panels and electronic components can protect against damage from seawater. With regular maintenance, the estimated lifespan of the system ranges from 3 to 5 years. Additionally, passive cooling designs are vital to prevent solar panel overheating, ensuring optimal performance under extreme maritime conditions.

V. Conclusion

This study successfully demonstrated the feasibility and benefits of implementing a solar-based electrical energy system on traditional fishing boats. The system, consisting of a 200 WP solar panel and a 200 Ah lead-acid battery, generated an average of 864 Wh of energy daily and achieved a total system efficiency of 58.1%. The setup allowed for up to 1.46 hours of 3HP DC motor operation, providing sufficient power for propulsion. This hybrid energy approach, combining renewable energy with fossil fuel as a backup, significantly reduces the reliance on conventional fuels and mitigates the environmental impact. The findings support the integration of renewable energy technologies in maritime operations, paving the way for sustainable fishing practices while addressing economic and ecological challenges. Future enhancements could focus on increasing battery capacity and optimizing solar panel placement to extend operational hours.

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