Design of Hybrid Solar and Wind Energy Harvester for Fishing Boat

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Abstract. In southern beach of West Java, Indonesia, there are many villagers live as fishermen. They use small boats for fishing, in one to three days. Therefore, they need a fish preservation system. Fortunately, the area has high potential of solar and wind energy. This paper presents the design of a hybrid solar and wind energy harvester to power a refrigerator in the fishing boat. The refrigerator should keep the fish in 2 – 4 °C. The energy needed is 720 Wh daily. In the area, the daily average wind velocity is 4.27 m/s and the sun irradiation is 672 W/m². The design combined two 100W solar panels and a 300W wind turbine. The testing showed that the solar panels can harvest 815 – 817 Wh of energy, while the wind turbine can harvest 43 – 62 Wh of energy daily. Therefore, the system can fulfil the energy requirement in fishing boat, although the solar panels were more dominant. To install the wind turbine on the fishing-boat, a computational design had been conducted. The boat hydrostatic dimension was measured to determine its stability condition. To reach a stable equilibrium condition, the wind turbine should be installed no more than 1.7 m of height.

1. Introduction
Rancabuaya is a small coastal village located in southern Garut, West Java. Based on the survey that had been conducted by us, the majority of people there live as fishermen. When fishing, they need electricity to light the boat and especially to store the fishes in refrigerator. To this day, fishermen there use fossil fuel, which contributes to air pollution, to fulfil the electricity needed. Meanwhile, Rancabuaya has a high potential of solar and wind energy. The daily average wind velocity is 4.27 m/s and the sun irradiation is 672 W/m². To meet the daily energy needed in a fishing boat and to utilize these renewable energy resources, a hybrid energy harvester is designed. This hybrid energy harvester will be installed on the fishing boat; thus, the fishermen can harvest and consume the energy while fishing. The system includes the energy storage system, energy monitoring system, and maximum power point tracking to enhance the efficiency of energy harnessed. The choosing of solar panel, battery, and charge controller depend on the energy produced by wind turbines used. Based on experiment that had been conducted [1], the amount of this energy is about 24 Wh on average.

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2. Experimental

2.1. Battery selection
The load, which is a cooling machine, needs an input voltage of 12 V and 180 W power. It will be turned on for four hours (4 h) a day, whenever fishes need to be cooled. If this cooling machine is needed at night, the energy would be supplied by battery only, since there is no solar irradiation, and the wind energy will only contribute a little. Considering this worst scenario, the battery capacity needed would be: (180 W)(4 h)/12 V = 60 Ah (Ampere hour). To keep the battery long-lasting, it should not be used too much. The ideal percentage of usage of a battery is 60%. Therefore, the battery capacity should be: 60 Ah/60% = 100 Ah. The 100 Ah capacity can be obtained by stringing three batteries parallel with capacity of 35 Ah each. This configuration is chosen because it will keep the voltage at 12 V, the same value as the cooling machine input voltage, and it minimizes the current losses.

2.2. Solar panel selection
The daily energy needed is 180 W x 4h = 720 Wh, where a power of 2 W is provided by the wind turbine [1]. The wind blows for 24 hours a day in Rancabuaya, so the wind turbine can operate 24 hours a day. That means, the energy from wind turbine equals to 2 W x 24 h = 48 Wh. Therefore, the energy needed from solar panel is 720 Wh – 48 Wh = 672 Wh. To fulfil that energy, the amount of power that solar panel should provide is 672 Wh/5 h = 134.4 W. Considering simplicity in installation, and also the losses (temperature, battery charging and discharging process, and losses in charge controller and wiring [2]), a 200 W output solar panel is chosen.

For this, four solar panels, 50 W each, can be installed. The second alternative is installing two solar panels, 100 W each. The third is choosing one solar panel with 200 W output. The second alternative is chosen because of the simplicity in installation and because of its lighter mass, regarding the boat stability. Besides, a four solar panel modules configuration will inflict more losses compared to two modules only. While a 200 W single module solar panel is the easiest to install, it is rarely sold in the market.

With only two modules, the solar panel can be stringed series or parallel. The parallel configuration gives a much safer system because one module is not affected by another, not like series configuration. For these reasons, a parallel configuration is chosen. The solar panel chosen is a monocrystalline solar cell type due to its high efficiency and its high number of availability in the market.

2.3. Charge controller
Charge controller chosen is hybrid charge controller for solar panel and wind turbine, Mars Rock type 750W50. Its function is to adjust current and voltage from both solar panel and wind turbine to battery specification, DC current with 12 V input. Charge controller also control the charging and discharging process to avoid overcharging and overdischarging.

From the charge controller specification, it is known that if the battery voltage reaches 16 V, the current from power supply will be disconnected so that the charging process stopped. While if battery reaches 10.8 V, the current flowing to the load will be disconnected so that the discharging process stopped.

This charge controller uses Pulse Width Modulation (PWM) type. It works whenever battery reaches overcharged point. In this condition, charge controller will turn the current connection on and off. The higher the battery voltage, the smaller the duty cycle is. When battery voltage reaches 16 V, the current flowing into the battery will be disconnected (duty cycle value = 0).
2.4. Design of data logger
Data logger is the instrument used to record, save, and display power and energy harvested from solar panel and wind turbine. It uses current sensor ACS712 and voltage sensor 25 V as inputs. Since there are two points of measurement, the data logger will need two current sensors and two voltage sensors. The measurement data is processed with Arduino Uno to later be saved in SD Card and displayed using LCD 16x2. RTC DS1307 is used as time indicator in Arduino. Energy for this processing is provided by the battery, using a voltage regulator 12 V – 5 V. Figure 1 below is schematic of the data logger designed.

![Data Logger Design Schematic](image)

Figure 1. Data Logger Design Schematic.

2.5. Boat stability design
Figure 2 is boat design on Solidworks, of which the dimension and shape are based on real boats usually used in Rancabuaya beach.

![Boat Design on Solidworks Without Loads](image)

Figure 2. Boat Design on Solidworks Without Loads.

Boat stability condition is determined by position of mass centre (G), point of buoyancy (B), and point of metacentre (M) [3]. If M is above G, the boat will have enough force moment to restore the boat to stable equilibrium condition. If M is precisely coinciding with G, the boat will have zero force moment so that when given a disruption, the boat tilted and stay in that condition. This is known as neutral equilibrium condition. While if M is below G, the boat will have a negative force moment so that when given a disruption, the boat tilted and keep being tilted until it sinks. This is known as unstable equilibrium condition. This means that the condition we are trying to achieve is the stable equilibrium. In this case, the disruption given is adding loads to the boat.

After given the load consisting of two modules of solar panel, wind turbine, cooling machine, battery, and charge controller, the position of mass centre on boat changes. Using "mass properties"
feature on Solidworks, the position of mass centre before and after the loading is obtained. To know whether the boat is sinking or not after loading, mass properties from each condition is observed. Mass property shows the mass and volume of boat and salt water. The mass, volume, and area surface is obtained from material type of boat’s component and the dimension of the boat given. The material given is based on material used on real boat.

One parameter that has the biggest effect on stability is the height of wind turbine installation on boat. The higher the installation, the lower the stability is, and vice versa. Thus, the design sets the upper limit at 2 m and the lower limit at 1.7 m. The height above 2 m will give an unsteady equilibrium as will be shown in the simulation, while the height below 1.7 m will collide with middle pole, as shown in Figure 2.

3. Results and Discussion

3.1. Solar panel testing result
Solar panel testing in ITB area aims to obtain the relationship between output power and irradiance per time unit. The following is the data recorded using data logger, shown in Figure 3.

![Solar Panel Power Measurement on August 18 2016](image)

Figure 3 shows measurement data on August 18 2016 from 10 a.m to 5 p.m. Since the relationship between power and irradiance shown is linear, the equation of solar panel power can be obtained, using first order regression, as shown below.

\[
\text{Solar panel power} = 0.15 \times \text{Irradiance} + 9.03
\]  

3.2. Integrated system testing result
System testing using Wind Turbine 2 (System 2) was done on August 27 2016, at ITB Research and Development rooftop, from 11.30 a.m to 2.50 p.m. While system testing using Turbine 1 (System 1) was conducted on August 30 2016. During testing, the sky condition varied a lot, from cloudy, overcast, to bright sky. From power measurement using data logger, the graph in Figure 4 is obtained.
In System 1, the average power produced using solar panel is 60.17 W, while average power getting into the battery is 61.75 W. While in System 2, the average power produced by solar panel is 77.47 W and the power getting into the battery is 79.94 W. From the above experiments, and by using output power equation, the power output of the whole system in a day can be determined, as shown in Figure 5 below.

### Figure 5. Rancabuaya Output Power Expected from The Integrated System.

Using Turbine 1, the total energy harvested is 858 Wh, with 95% harnessed by solar panel and 5% from wind turbine. While using Turbine 2, the total energy harvested is 877.92 Wh, with 93% comes from solar panel and 7% from wind turbine.

3.3. **Boat stability simulation result**

The followings are G, B, and M position before and after the loading.

#### 3.3.1. 2 Meter height of wind turbine installation

Table 1 shows mass properties of **Boat** and **Salt Water** after the loading, with the height of wind turbine installation: 2 m.

**Table 1. Boat Floatation Position Toward Salt Water.**

| Boat Mass Properties          | Salt Water Mass Properties       |
|-------------------------------|----------------------------------|
| Mass = 1498.94 kilograms      | Mass = 1995.52 kilograms         |
| Volume = 1.95 cubic meters    | Volume = 1.95 cubic meters       |
| Surface area = 68.54 square meters | Surface area = 68.54 square meters |
For a same volume, salt water has a higher mass than the boat. This means that the boat has a lower density so that it can stay floating. The mass difference between them is 496.58 kg, which means, the boat can carry up to eight passengers with total mass 496.58 kg.

Next, the boat stability condition is determined by examining the position of G, B, and M before and after the loading. Figure 6 and Figure 7 are the illustrations. By looking at Figure 7, G coincides with M, meaning that the boat has a neutral equilibrium condition. Thus, a 2 m height of wind turbine installation would disrupt the boat stability.

![Figure 6](image)

**Figure 6.** Boat Stability Condition Before The Loading.

![Figure 7](image)

**Figure 7.** Boat Stability Condition After The Loading.

### 3.3.2 1.7 Meter height of wind turbine installation

**Table 2.** Boat Floatation Position Toward Salt Water.

| Boat Mass Properties                      | Salt Water Mass Properties                  |
|-------------------------------------------|---------------------------------------------|
| Mass = 1491.40 kilograms                  | Mass = 1994.53 kilograms                    |
| Volume = 1.95 cubic meters                | Volume = 1.95 cubic meters                  |
| Surface area = 68.44 square meters        | Surface area = 68.44 square meters          |
The M position that is above the G in Figure 8 shows that the boat has enough amount of force moment to keep it stable when given a disruption. Thus, the boat has a stable equilibrium condition.

4. Conclusion
An energy harvester system has been designed to be installed on Rancabuaya fishing boat. It is expected that the total energy harnessed in a day is 858 Wh using Turbine 1, and 877.92 Wh using Turbine 2. The energy needed in Rancabuaya fishing boat itself is 720 Wh per day. Thus, the energy harvester system designed has been able to provide the energy needed. To store this energy, three batteries of which each capacity is 35 Ah are chosen. These three batteries are stringed parallel. The boat will have a stable equilibrium condition after the loading if the wind turbine is installed on a 1.7 m height.

References
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