Optimisation solar and wind hybrid energy for model catamaran ship

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Abstract. Based on WindSat data from 2004 to 2014, Indonesia has an average wind speed of above 8m/second at sea. In addition, the energy potential of the sun is around 4.8 kWh/m². A mechanical model ship with a catamaran type will be installed photovoltaic module and wind turbine generator which are equipped with microprocessor to control the angle of the wind turbine blades, the energy generated by the PV and wind turbine generator will be regulated by the dual input buck boost converter using the PID method to regulated voltage to 14 Volt used to charge the battery. The power stored in the battery will be used to drive the ship model propulsion system. The paper discusses about pv performance, generator performance, dual input buck boost calculation, and simulation. From testing the energy obtained is 774WH. From the simulation of the dual input buck boost converter circuit, the setling time is 11ms when using the PID control system and 35ms when using PI. Energy from the sun and wind can be combined into one with a dual input buck boost converter so that the energy can be absorbed is more optimal.

1. Introduction
Indonesia is the largest archipelago country in the world which consists of around 17,058 islands with a coastline length of 81,000 km. The sea area in Indonesia reaches 5.8 million km² or about 75% of the total area of Indonesia. Therefore, ship transportation is one of the most important components.

The wind speed map based on the WindSat data, in Indonesia has wind speeds from 5m/s to 10m/s or greater than the minimum wind speed to drive wind turbine generator which is 4m/s [1]. Apart from wind energy, Indonesia has solar energy potential. Based on solar radiation data collected from 18 locations in Indonesia, solar radiation in the Western Region of Indonesia is around 4.5kWh/m²/day with a monthly variation of around 10%, and in Eastern Indonesia around 5.1 kWh/m²/day with a monthly variation of around 9%. Thus, Indonesia's average solar radiation potential is around 4.8kWh/m²/day with a monthly variation of around 9% [2].

From the data on the potential for wind and sunlight in Indonesia. This study intends to determine the ability of the two energies to drive the catamaran ship propulsion system. This study makes an empirical model of catamaran ships by adding PV and wind turbine generators as energy.
2. Literature review

2.1. Catamaran ship
Catamaran ship is a twin hull ship, where the two hulls are connected with a strong deck construction and stretches on it to withstand large bending moments and shear forces and work towards the midline (Center line) ship. The shape of the catamaran hull on various ships is not the same. There are many models of catamaran body shapes, but in general there are three basic forms of catamarans [3,4].

- Symetric
- Asymmetric with a straight inside
- Asymmetric with a straight outside

2.2. Wind turbine generator
Wind turbines are alternative energy technologies that are able to convert wind energy into electrical energy [5]. There are 2 types of wind turbines, namely horizontal vertical axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). The working principle of the HAWT wind turbine is based on the lift force of the wind energy while the VAWT wind turbine is based on the drag force that occurs due to wind movement [6,7]. HAWT is widely used for higher production volumes that require a large investment and occupy more space for installation compared to VAWT. VAWT requires a low cost investment and less space for installation compared to HAWT [6,7].

2.3. Photovoltaic module
Photovoltaic Module is a semiconductor consisting of a diode p-n junction, which when exposed to sunlight will create electrical energy that can be utilized, this energy conversion is called the photoelectric effect [8].

2.4. Dual input buck boost converter
The dual-input DC-DC converter is a development of power electronics technology where two DC-DC converters are combined either in parallel or in series to supply the same load from several different sources interconnected. Before using a multi-input DC-DC converter, a separate converter for each source is usually used, the output of each converter is then managed by DC Bus so that the output voltage is the same and stable [9-11].

2.5. PID controller
PID is a controller system to determine the precision of a system with the feedback on the system [12]. Set point is a certain condition to be achieved. The sensor functions to detect the plan output and convert it into the same quantity as the set point unit. The sensor output is a feedback signal which will be subtracted from the set point resulting in an error signal. The goal of the control is to make the output of the plan equal to the set point, which means that the error signal is (or is close to) zero [13,14].

2.6. Ziegler Nichols method
Ziegler Nichols’ PID tuning method is experimental (assuming the model plan is not yet known). There are two ways of tuning the PID with this method, namely [12,14].

2.6.1. Ziegler Nichols 1 method. The tuning method using this method is by looking at the response plan first by giving input unit steps and then a curve will be obtained in which there are variables for further calculations.

2.6.2. Ziegler Nichols 2 method. This method is used for Plans which have an oscillatory response when given a certain Kp value. The method of tuning the PID with this method is to give a certain Kp value until the system oscillations per period are found
3. Methods
In this study utilizing renewable solar and wind energy as a driving force for catamarans as explained in Figure 1 below.

![Diagram block system.](image)

**Figure 1.** Diagram block system.

From the block diagram above, the mechanical design ship is mounted by PV and Wind Turbine as an energy source for motor. The voltage generated by the PV and the wind turbine generator goes to the dual input buck boost converter for the regulation process so that the voltage generated is stable at 14V and the energy absorbed is optimal.

Figure 2 is a ship's mechanical design with the specifications Length of Arc 170 cm, Beam 100 cm and Depth 32 cm Depth. At the top of the ship an array of PV will be installed along the deck of the ship and the Wind Turbine is placed at the middle of the ship described in the figure 3.

![Ship mechanical design](image)

**Figure 2.** Ship mechanical design

![Ship mechanical design with PV and wind turbine generator.](image)

**Figure 3.** Ship mechanical design with PV and wind turbine generator.

The dual input buck boost converter circuit is described in the figure 4 below.
Figure 4. Dual input buck boost converter circuit.

4. Results

4.1. Generator
Measurement of generator performance is done by directly coupling the generator using a drill and the generator is given a battery load. The RPM is obtained from the tachometer. The results of generator performance measurements are shown at the charts below.

Figure 5. Voltage chart of generator.

Figure 6. Current chart of generator.

From the measurement results of the minimum RPM generator performance that can be used for charging a battery of around 170 RPM which produces a voltage of about 10.2 Volts and a charging current of about 0.2 Ampere.
4.2. Photovoltaic module

The chart above shows the lux value in the time range 08.56 to 15.50 hours. The highest lux value was obtained at 11.15, which is around 110,000 lux and the average lux at the time of testing was around 66,365 lux. The highest power is obtained around 75 Watt. Meanwhile, the average power during the testing period is around 60.07 Watt.

4.3. Wind turbine generator

Wind turbine generator testing is carried out for 24 hours and the results are as shown in the chart below.

From chart above, the maximum power that can be released by the wind turbine is around 40 Watts. The total power that can be generated by the wind turbine is 354Wh.
4.4. Simulation dual input buck boost converter

After identifying the performance of PV and Wind Turbine, the PV and Wind Turbine parameter values are obtained which will be used for the calculation of buck boost. From the calculation results have obtained the inductor value of 656uH and capacitor 200uF. The PID calculation uses the Ziegler Nichols type 2 method and the results are as shown in Figures 10 and 11 below.

![Figure 10. Signal output using KP 0.495 KI 528 and KD 2112](image1)

From the signal output image above using the KP value 0.495, KI 528, and KD 2112, the result is a rise time of 8ms while the setting time is 11ms. For a maximum oscillation voltage of 16.8 Volts and a minimum of 10.5 Volts. The RMS value is in accordance with the 14 Volt set point, which is 14,119 Volts.

![Figure 11. Signal output using KP 0.495 and KI 237.6](image2)

From the signal output image above using the KP value 0.495, and KI 237.6, the result is a rise time of 20ms while the setting time is 35ms. For a maximum oscillation voltage of 16.8 Volts and a minimum of 10.5 Volts. The RMS value is in accordance with the 14 Volt setpoint, which is 14,119 Volts.

5. Conclusion

The conclusion from this research is that the energy produced by PV and wind turbine generators is 774Wh. To optimally absorb the two energies, can use a dual input buck boost converter circuit with a PID control system that can combine the two energies to produce a fixed voltage. From the simulation when using the PI control system, the setting time is 35ms, while when using the PID, the setting time is 11ms.

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