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Eco-Friendly Mini Hybrid Wind Solar Power Plant at Jetty PLTU Rembang

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Abstract— The geographical position of the Steam Coal Power Plant Rembang 2 X 315 MW (PT PJB UBJ O&M PLTU Rembang) which is located on the northern coast of Java, makes the area get a very large supply of sea breezes. The sun's heat in the beach area is also very optimal. According to Indonesia's regulation (Peraturan Presiden No. 22 Tahun 2017), the potential for wind energy that can be utilized by Indonesia reaches 60,65 GW. However, until 2021 the utilization of wind energy that can be utilized by Indonesia has only reached 131 MW. Meanwhile, Indonesia's solar energy potential is very large, around 4,8 KWh/m^2 or the equivalent of 112.000 GW. Thus, the development of wind and solar energy in Indonesia is still a national challenge. To maximize the potential of these two energies, a hybrid power plant can be made. A hybrid power plant is a power plant consisting of a minimum of two or more types of renewable energy-based power plants. This power plant does not use fuel so that it can save fuel use by 10,546,210.83 kg/year, reduce self-consumtion electricity by 0.58 GJ/year and reduce pollutan emissions by 0.052 TonCO_2eq and save the budget of Rp. 7,500,642,125.00 in 2021.

Index Terms— Wind Turbine, Photovoltaic, Solard, Hybrid, Renewable Energy, Emission, Green Power Plant

1 Introduction

A Hybrid power plant is a power plant consisting of a minimum of two or more types of renewable energy-based power plants. Where, several power plants are operated simultaneously on one bus to carry the load. The main objective of this hybrid system is to combine renewable energy generation systems, each of which has its own drawbacks. Solar Power Plants have the disadvantage of not being able to extract power from solar panels optimally when it is dark, while Wind Power Plants can work during the day and night. However, the Wind Power Plant has a drawback that is very dependent on the level of wind speed to extract power from the wind turbine generator. The advantages of this hybrid system during the day can make maximum use of solar power plants and wind power plants when the wind speed is sufficient to rotate the wind turbine generator. Meanwhile, at night, the Wind Power Generation system will be more dominant than the Solar Power Plant in extracting energy.

The most widely used renewable energy in Indonesia and the world is solar energy and wind energy. Solar energy is energy in the form of heat and sunlight. Wind energy is one type of renewable energy source that has the potential to produce electrical energy from mechanical energy conversion. The kinetic energy contained in the wind can be converted into mechanical energy through a wind turbine, then converted back into electrical energy using a generator. Photovoltaic is a device that can convert sunlight energy into electrical energy using the photoelectric effect.

Carbon dioxide emissions caused by the use of energy as fuel oil and coal are one of the causes of global warming. Emissions of carbon dioxide (CO_2) and other impurities (pollutants) collect in the atmosphere and absorb sunlight and solar radiation that has bounced off the earth's surface. Under normal circumstances, the radiation will be released into space. However, due to the presence of impurities that can survive in the atmosphere for years and even centuries, solar radiation is trapped in the atmosphere and makes the earth's temperature hot.[1]

2 Procedure for Built Hybryd System

Figure 1 is a schematic that can describe how the process of designing a hybrid power plant system is made. Starting with a literature study, then analyzing the wind and heat potential in the jetty area of the PLTU Rembang. From the wind and heat potential, the design of the wind turbine and the selection of solar panels are carried out. From the design, product is analyzed and the design is carried out, then testing is carried out on the products that have been made and the electricity yield and cost savings are calculated. The hybrid generator will be used for lighting the Jetty PLTU Rembang area.

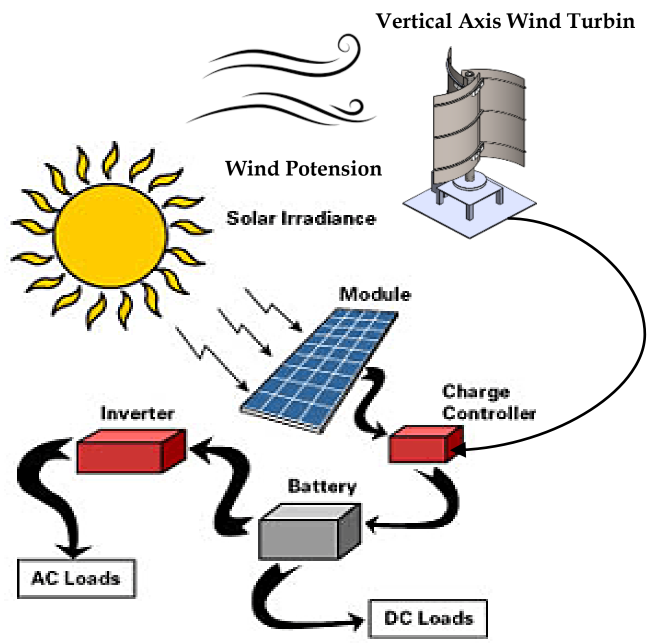

Figure 1. Schematic of hybrid wind solar energy design

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2.1 Review of Wind Potential and Heat Potential

Measurement of wind speed and direction can be done by manual observation using a measuring instrument in the form of an anemometer, but the level of accuracy is still minimal [2]. To determine the value of wind speed, a wind speed detector design is made where the wind speed sensor will be used as a wind speed detector. The design of this wind detector speed utilized technology in the form of a NodeMCU microcontroller. This tool detects wind speed which makes it easy to find out the magnitude or value of the wind speed that will be generated. Wireless artificial wind sensor systems have great potential in environmental monitoring applications [3].
The wind depends on the sun and the season. Often wind properties are expressed by averaging monthly data throughout the year to get an idea of wind strength at a location. In this study, the available wind data for 3 months (September – November 2020) average value was 5.23 m/s.

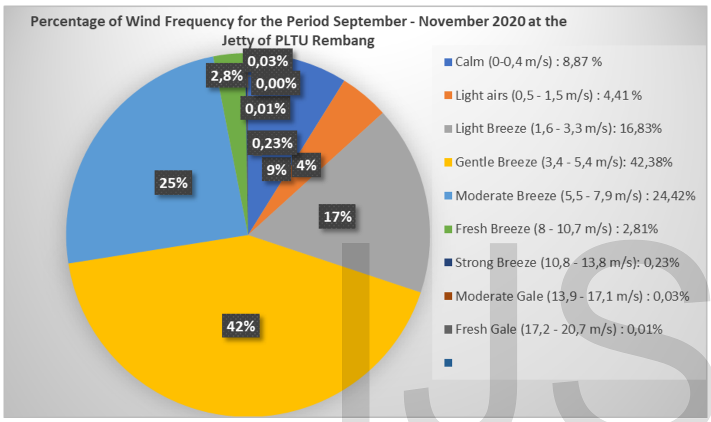

Figure 2. Percentage of Wind Frequency for the Period September – November 2020 at the Jetty of PLTU Rembang

The highest percentage indicates the most frequent wind speed but not the average wind speed. For areas where the wind speed does not vary too much, it could be that the average wind speed is the wind speed that often occurs. However, in areas with highly fluctuating wind speeds, the average wind speed is generally different from the wind speed that occurs most frequently. In the monitoring period from September to November 2021, the highest percentage of 42% is Gentle Breeze type winds with speed between 3.4 – 5.4 m/s as shown in Figure 2.

2.2 Wind Turbine Design and Photovoltaic Selection

Although the Savonius type has lower efficiency than other types of wind turbines due to the high negative torque generated by the return blades. However, the Savonius is a drag-based vertical axis turbine and is used as an alternative source in small-scale generators. Simplicity of construction, low cost, good starting capability, relatively low operating speed and independent of wind direction [4]. With consideration of simplicity of construction and low cost, the Savonius type Vertical Axis Wind Turbine was chosen and the manufacture of this wind turbine used waste from the PLTU Rembang, so that the design of the blades and frames chosen was simple and easy in the manufacturing process.
In this design study, a Savonius type vertical axis turbine with three blades was selected. Three blades are selected the power coefficient will drop drastically when the blade is reduced from three to two [5]. The number of blades is not selected more than three so that the blade structure is not too heavy and increases production costs [6]. Based on the simulation results at a speed of 5 m/s, a rotor with three blades provides a higher speed distribution than a rotor with four blades and two blades [7]. In addition, the number of blades of three has a tip speed ratio value that is greater than the number of blades of four at a speed of 1-10 m/s [6]. The greater the tip-speed ratio, the wind turbine rotational speed will be the same as the wind speed. The curve type was chosen because of its simple design and wind speed of 3.8 m/s resulting in the same optimal rpm as the twisted type compared to the straight and aerofoil types [8]

The selection of the type of photovoltaic or solar panels in the design of a hybrid power generation system is something important, because by choosing the right type of solar panel and knowing the environmental conditions well, the efficiency of the power issued by the solar panels will be maximized. In power plants that are designed to use monocrystalline solar panels, the advantage offered by this type of solar panel is that it has the highest efficiency among other types of solar panels.

2.3 Wind Turbine Analysis

Computational Fluid Dinamics analysis was carried out at a speed variation of 5.5 m/s which is the average wind speed in the 3 month data collection period.

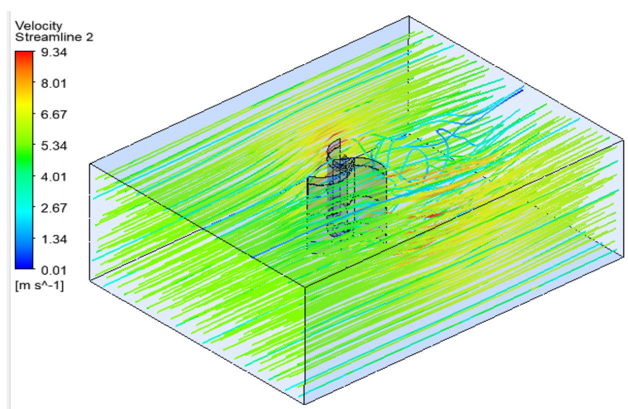

Figure 3. Isometric View–CFD Simulation at Wind Speed 5.5 m/s

Figure 3 shows an isometric view while Figure 4 shows a side view and Figure 5 shows a top view of the overall distribution of air velocity at a wind speed of 5.5 m/s

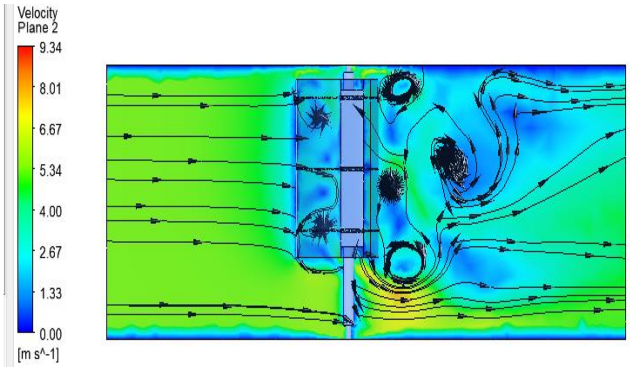

Figure 4. Side View – CFD Simulation at Wind Speed 5.5 m/s

Seen the maximum velocity of 9,34 m/s in the red area. The speed distribution looks more evenly distributed on each blade and there is a constant high speed above 5,5 m/s on each blade so that this has the potential to provide a higher rotational speed on the turbine rotor.

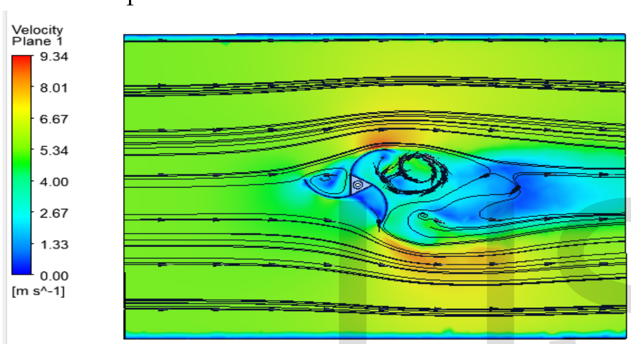

Figure 5. Top View – CFD Simulation at Wind Speed 5.5 m/s

The speed of the rotor is directly proportional to the conversion of the rotational (mechanical) energy of the rotor into electrical energy, as the conversion of the rotation of the rotor ehen connected to an electrical generator.

2.4 Component, Assembling, Manufacturing and Finishing

The main system in this hybrid design is a vertical wind turbine of the savonius type with a maximum capacity of 100 Watt and a solar panel of 100 Wp as shown in Figure 6.

Figure 6. Wind turbine components and solar panels

Solar panels will be optimum for 4 hours in one day so that it reaches 400 Wh/day.

3 PRODUK TEST

The test was carried out in stage starting with testing on a Savonius type vertical wind turbine to determine the effect of wind speed on the generator used. Wind speed measurement uses a wind speed detector whose data is taken simultaneously. Table 1 shown the vertical axis wind test data on February 5, 2020

TABLE 1
TEST DATA HYBRID SYSTEM WIND SOLAR

Wind speed (m/s)	Voltage (V)	Current (A)	Power (Watt)	Irradiance (W/m²)
5.25	2.72	0.981	7.14	503.43
5.20	7.30	0.999	7.30	529.65
5.20	7.27	0.992	7.22	498.19
5.18	7.30	0.981	7.16	436.76
5.20	7.30	0.977	7.11	400.80

After testing the wind-solar system, the hybrid wind and solar systems were installed in the jetty of PLTU Rembang for lighting as shown in Figure 7

Figure 7. Installation of a hybrid wind solar system at the jetty of PLTU Rembang

The results of the solar and wind installation will be monitored using a mini PC and the data is stored in a data storage system as shown in Figure 8

Figure 8. Monitoring and data storage system for the Rembang PLTU hybrid system

From the power monitoring system, data can be taken that this hybrid system is able to produce power of about 450 Wh/day so that in 1 year it can be calculated that the energy and costs that can be saved are shown in the table 2.

TABLE 2
ENERGY AND COST SAVINGS DATA

Produk Daya/hari	Saving Energy	Ton CO2eq	Biaya listrik	Biaya karbon
a	b*	c*	d*	e*
450 Watt	0.58 GJ	0.052	Rp.178,581	Rp. 4,806

b = ((a*356 day)/1000)*0.0036
c = b*0.09
d = (a*356 day*Rp.1,114.7)
e = (a*356 day*Rp. 30,000)

With coal calories of 4,371 Kcal/Kg, coal consumption at PLTU Rembang is 18,286,520 kg to produce 1 GJ of electricity. With a coal price of Rp. 711.2/kg, with the hybrid system, this system is able to save coal consumption of 10,546,201.83 kg/year or equivalent to saving of Rp. 7,500,458,738.48/year

4 CONCLUSION

The research article describes the steps for designing a hybrid system at the PLTU Rembang. Besides that, it is also to find out the benefits of this hybrid system both from the energy produced, fuel savings, electricity cost savings and carbon costs as well as fuel savings.

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