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Prototype Hybrid Power Plant of Solar Panel and Vertical Wind Turbine as a Provider of Alternative Electrical Energy at Kenjeran Beach Surabaya

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Abstract

Indonesia, which is a tropical country, has a very large potential for solar energy because of its area that stretches across the equator, with a radiation magnitude of 4.80 kWh / m2 / day or equivalent to 112,000 GWp. On the other hand, the earth receives solar power of 1.74 x 1017 W / hour and about 1-2% of it is converted into wind energy. However, from the total energy potential, Indonesia has only utilized around 10 MWp for solar energy and not much different, wind energy, whose utilization is planned to reach 250 MW in 2025, has only been utilized around 1 MW of the total existing potential. With this potential, to be able to supply additional power and help save energy for existing facilities in the building, a Prototype of Solar Panel Hybrid and Vertical Axis Wind Turbine was created. The design of this prototype is a combination of savonious type turbines and solar panels, where the use of this type of turbine is because it can rotate at low wind speeds (low wind velocity) and its construction is very simple.

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I. INTRODUCTION

With the addition of power generation capacity, in 2025 coal-fired power plants are estimated to still dominate with a share of up to 58% or around 50 GW [1] - [2]. However, the existence of coal as a fuel for electricity generation is decreasing over time and of course, it cannot be renewed. According to BPPT in 2018 coal reserves will be exhausted within 68 years [3] - [4]. Therefore, innovations are needed in terms of meeting the needs of electrical energy in Indonesia continuously [5]. One way that can be done is by utilizing renewable energy that is so abundant in nature. Renewable energy that can be used as electrical energy with great potential is wind and solar energy [6]. Indonesia has great wind energy potential, this is due to the monsoon wind phenomenon which is supported by Indonesia's territory, 70% of which is water. The potential for wind energy in Indonesia according to BPPT 2018 is 9.29 GW and its utilization is around 0.0005 GW [7].

A skyscraper is a place that has great wind energy potential. Because the benchmark of a building can be called a skyscraper if the height is above 150 m, which makes the wind speed at the top of the building very high. This phenomenon is caused by the influence of the frictional force that inhibits the speed of air, so the higher a place, the greater the wind speed [8]. With this potential, to be able to supply additional power and help save energy for existing facilities in the building, a Prototype of Solar Panel Hybrid and Vertical Axis Wind Turbine was created. The design of this prototype is a combination of turbines and solar panels, where the use of this type of turbine is because it can rotate at low wind velocity (low wind velocity) and its construction is very simple [9]. Besides, because it uses a vertical axis, the generator and gearbox can be placed near the ground, making it easier for maintenance purposes. The working principle of this prototype design is to use a turbine to convert wind energy on the roof of the building into electrical energy which will then be hybridized with the electrical energy

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generated from the conversion of solar energy by solar panels so that the power produced will be more optimal [10].

II. Materials and Methods

A. Materials and Equipment

The tools and materials needed in the manufacture and testing of this hybrid power plant include:

1. Meter
2. Battery
3. Charge controller
4. 10 WP solar panels
5. Anemometer
6. Wrench 10
7. 10 watt DC lamp
8. Multimeter
9. DC Motor dynamo TG-25B-AG-36 No.40705
10. Vertical wind turbine
11. Stopwatch

B. DC generator

The DC generator only has one ring that is split in the middle so it is called a commutator. The DC generator consists of two parts, namely the stator, which is the stationary part of the DC engine, and the rotor, which is the rotating part of the DC engine. The stator consists of a motor frame, stator winding, charcoal brush, bearing, and terminal box. While the rotor consists of a commutator, rotor winding, rotor fan, and rotor shaft. (**Fig. 1.**)

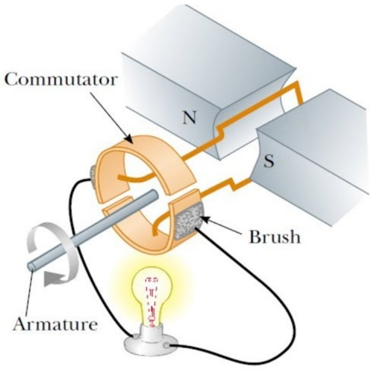

Fig. 1. DC generator

C. Solar Panel

Solar cells are an active element that converts sunlight into electrical energy. Solar cells generally have a minimum thickness of 0.3 mm and are made of slices of semiconductor material with positive and negative caps. The basic principle of making solar cells is to take advantage of the photovoltaic effect, which is an effect that can directly convert sunlight into electrical energy. This principle was first discovered by Bacquere, a French physicist in 1839. (**Fig. 2.**)

Fig. 2. Solar Panels

D. Solar Charge Control (SCC)

The technology applied in SCC is Pulse Width Modulation (PWM) technology. In addition to the SCC, it can also be used to regulate the supply from the battery to load in order to prevent the battery from overloading and not experiencing a full discharge. SCC can be used to protect solar panels from reverse current from batteries at night. (**Fig. 3.**)

Fig. 3. Solar Charge Control (SCC)

E. Mechanical Design

The design here has a function as a model and a reference in the form of installation and performance design. (**Fig. 4.**)

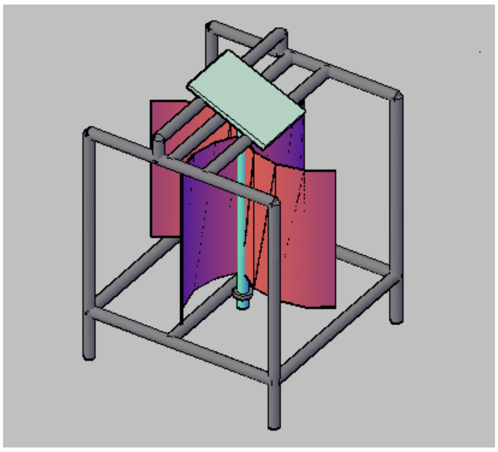

Fig. 4. Hybrid Powerplant Design

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This power plant design was created using the Autocad 2007 application. The design of this design is intended to facilitate the realization of this hybrid power plant. (**Fig. 5.**)

Fig. 5. Mechanical Design

In this prototype design, there are solar panels that are useful as a hybrid of a vertical windmill to increase the output power of this hybrid power plant. Also, placing solar panels on top of the turbines can reduce the temperature of the solar panels, thereby increasing the efficiency of this power plant.

F. Electrical Design

The working scheme of the Prototype Hybrid Solar Panel and Vertical Axis Wind Turbine is divided into three parts, namely, the input includes solar and wind radiation. Then the process is vertical wind turbines, solar panels, charge, and batteries. And the last part is the output in the form of DC electricity which can be used for DC loads as well as for AC loads that must go through an inverter first. (**Fig. 6.**)

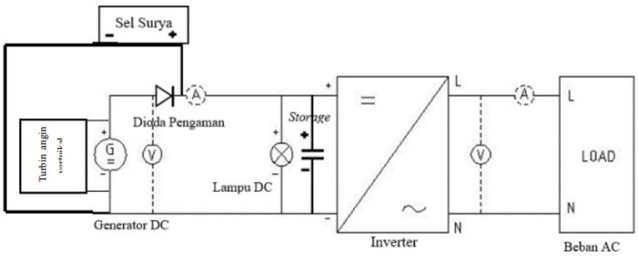

Fig. 6. Wiring Diagram

G. Block Diagram Tool

Below is a block diagram of how a hybrid power plant works or the system works. (**Fig. 7.**)

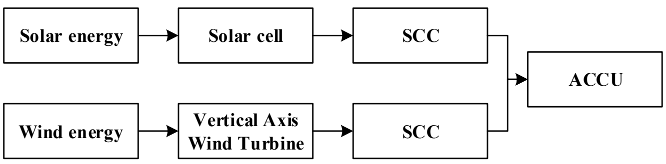

Fig. 7. Block Diagram Tool

The working system of this tool is divided into 2, namely the first is the Vertical Axis Wind Turbine system plus Solar Cells. The wind input rotates the Vertical Axis Wind Turbine and generator, generates an electric voltage to the SCC, and fills the Accu. The input of sunlight is captured by solar panels, producing an electric voltage. Then go to SCC and fill Accu. Second, the air filtration system, enter the CO gas captured by the MQ-7 sensor. Then the logic is processed by Arduino and the output is a PPM display on the LCD and the fan motor rotates.

III. RESULTS

A. Wind Speed Testing.

Testing is done using an anemometer, this is done so that the test gets the right data. Based on test data, the average wind speed on the rooftop is 6,025 m /s.

TABLE I. ROOFTOP WIND SPEED TEST DATA

NO	Hour	Wind speed (m/s)
1	12.00	6,2
2	03.00	5,2
3	06.00	7
4	09.00	5,7
Average		6,025

From the test data that has been done, a graph can be made that contains the relationship between wind speed, voltage, current, and power generated by the wind turbine. (**Fig. 8.**)

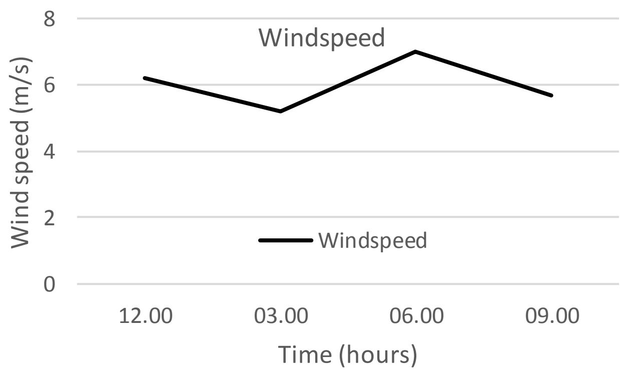

Fig. 8. Wind Speed Graph

In testing the power of this wind turbine, it is concluded that the largest output power is obtained at 12.00 and the smallest power is at 03.00.

B. Wind Turbine Testing.

TABLE II. VERTICAL WIND TURBINE TESTING.

Wind speed variation	Voltage (v)	Current (mA)
4.5	7,5	390
6	7,8	417

Wind speed variation	Voltage (v)	Current (mA)
5.4	7,1	402
Average	7,4	405
Power	3.006	

From the tests carried out, it can be seen that the greater the wind speed that hits the turbine, the greater the voltage generated by the vertical wind turbine, and vice versa that the smaller the wind speed, the smaller the resulting voltage. (**Fig. 9.** & **Fig. 10.**)

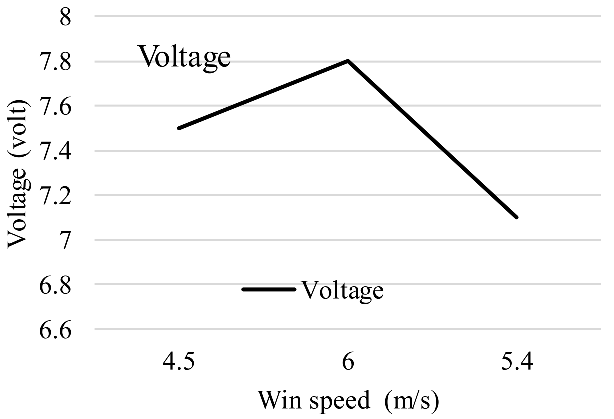

Fig. 9. Vertical Wind Turbine Output Voltage Graph

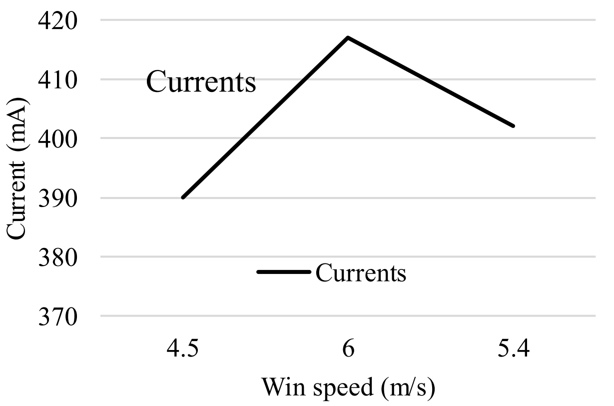

Fig. 10. Vertical Wind Turbine Output flow chart

Based on the test data obtained, the average electric power is 3.006 Watts. In this test, a good wind speed was taken for this wind turbine, this is because previously the wind turbine was designed for wind with a speed of 6 m / s. The faster the wind speed, the greater the power produced.

C. Solar Panel Testing.

The test was carried out to know the maximum electrical power that can be generated by a 10 Wp solar panel by calculating the tilt angle and obtained 24.21. Strength measurement is carried out using weights. The load used is a DC lamp with a power of 5 Watts. The test data can be seen as follows. It was found that the higher the intensity of sunlight hitting the panel, the higher the voltage and current generated and vice versa. In this test, the resulting average power is 10.28 Watt. (**Fig. 11.**)

TABLE III. TABLE 3 SOLAR PANEL TESTING DATA

Time	Voltage	Current	Power	Intensity (Cd)
03.00	15,72	0.64	10.13	89
06.00	15,24	0.68	10.456	93
09.00	15,54	0.63	10.231	96
Average	15.45	0.65	10.28	93

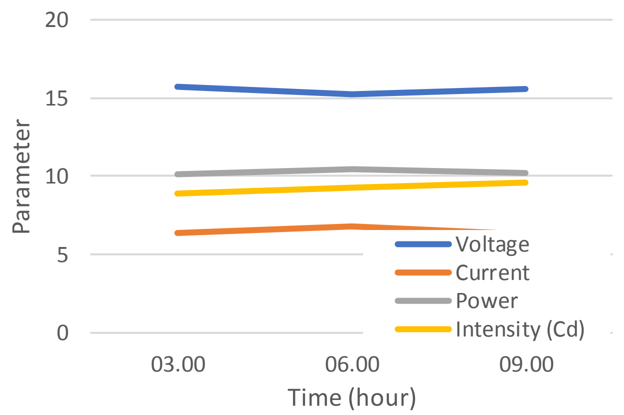

Fig. 11. Solar Panel Testing Charts

In solar panel testing, data is obtained where the greater the intensity of sunlight received by the solar panels, the greater the power produced, and vice versa. The solar panels generate the most power at 9 am.

IV. DISCUSSION

In the initial stage of power energy system development, the electricity is supplied to the users in a type of bulk electric transmission system. Due to the technology of the power system is improved, the traditional type of power system operating pattern seems to occur some weak points in the field of flexibleness and securities. Besides that, fossil fuel price is fluctuating due to the global economic and limited resources, it found that producing electricity with conventional fossil fuel will lead to environmental pollution. In order to overcome all these issues, the hybrid solar wind turbine system based on renewable energy such as solar and wind is taken into account as the alternative method to produce and supply electricity power energy to the users.

Solar and wind can be categorized as an intermittent source of energy since it is not a continuous supply and does not meet electricity load demand in some time. For these two types of renewable energy, wind energy is the more affected source if compared to solar energy due to its inconstancy. Similarly, these two unpredictable energy sources standalone systems will produce fluctuated output energy and thus cannot ensure the minimum level of power continuity required by the load.

The solar energy system, Photovoltaic (PV) cells are electronic devices that are based on semiconductor technology and can produce an electric current directly from sunlight. The best silicon PV modules currently commercially available have an efficiency of over 18%, and it is expected that in about 10 years' time module efficiencies may raise to 25%. The photovoltaic system also depends on the weather conditions and only can operate during the day-time. Wind power is basically electricity produced by a generator, which is driven by a turbine according to flowing air's aerodynamics and is one of the fastest-growing renewable energy technologies around the world.

A hybrid energy system is defined as the component combination of two or more types of the power generation system. For this research, the solar energy system is integrated with a wind turbine system to form a hybrid renewable energy system. Since the power output of these renewable energies is ultimately depends on climatic conditions such as temperature, solar irradiance, wind speed, etc., the instability of the system output is compensated by adding a suitable energy storage system to the hybrid energy system. The power autonomy greatly relies on the perfect balance exist between power demand and generated power.

The benefits of utilizing renewable energy sources such as hybrid solar wind turbine systems are increased the reliability of the hybrid energy system because it is based on more than one electricity generation source. Besides that, it is free from pollution and environmentally friendly system, since it does not use any fossil fuel to drive a gas turbine for a generator. Solar energy also becomes one of the most promising alternatives for conventional energy sources and has been increasingly used to generate electric power from sunshine (Popni, 2010). Moreover, the hybrid solar wind energy system is suitable to use in remote areas with inaccessible to the utility grid. However, there is also a disadvantage of using hybrid systems such as in most cases the system is oversized because it contains different types of the power generation system.

From the research that has been done, it is known that the hybrid power generated by the turbine and solar panel is 11,5146 watts. In addition, from the test carried out, the turbine can work well and can be applied in everyday life. However, this study also has a deficiency, the load used in this time of research is the direction of electric DC.

In this study, the turbine used was the savonius tubin with 3 blades. The selection of the number of blades as many as 3 pieces is due to the increasing number of blades, the smaller the rotational speed of the turbine which in turn will result in the resulting power being smaller too. however, in this case, 2 blades were not selected. this is because 2 blades will increase the power loss from the turbine itself. After all, the blade forms a 180-degree angle so that it will mutually eliminate each other's torque. Besides that, by placing solar panels on top of the wind turbines, the wind from the wind turbines will be channeled to the solar panels and the temperature on the solar panels will be smaller which affects the electrical power generated by the solar panels themselves.

In the power test carried out, it can be seen that the greater the wind speed, the greater the electric power generated from the vertical wind turbine rotation. In addition, through the use of vertical wind turbines, the conversion of electric power is more efficient. This is because the vertical wind turbine is very suitable for low wind speeds, which is in accordance with the low wind characteristics in Indonesia and is not suitable for the use of horizontal type wind turbines.

From the research that has been done, it can be seen that the use of vertical wind turbines provides greater energy efficiency than the use of horizontal type wind turbines. This can be seen from the research conducted where the efficiency resulting from the use of vertical wind turbines is greater than the horizontal type of wind turbines.

V. Conclusion

The use of a vertical axis on the turbine makes this design easier to apply anywhere because this turbine does not have to be directed towards the wind, so this turbine can be placed in a place that has varying wind directions. This is known as a portable and flexible device. The rotation of the generator increases with the difference in gear ratios. With the higher the intensity of sunlight, the higher the voltage and current generated and vice versa. The power generated from the design of this prototype is 11.5146 Watts.

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