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Wind Ventilator Utilization for Electrical Mini Power Plant: Residential Lighting

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Abstract: The development of renewable energy potential in Indonesia is actively carried out to obtain alternative energy sources along with the depletion of available fossil energy reserves. One of the green energy without polluting the environment is wind energy. Indonesia is an archipelago located in the tropics with a large potential source of wind energy, but until now it has not been optimal enough to be used for electricity generation. The utilization of energy produced by the wind is by changing it into mechanical energy by using wind turbines. Furthermore, mechanical energy from the turbine will be used to drive a dc generator to produce electrical energy. As a simple application in this study, the wind ventilator in the form of a turbine that is mounted on the top of the house roof is applied to be a wind turbine. Ventilators will move if there is wind touches its blades and it will suck out the air in the house. The axis of the ventilator will be coupled to the dc generator using pulley and v-belt. So, when the ventilator rotates, the generator will also rotate and will produce electrical energy. The objective of this study is to meet the energy needs for lighting requirement of a house. The experimental test results show that the use of ventilators as an alternative way for the wind energy utilization is worked well.

Keywords: Wind energy, ventilator, dc generator, electrical energy

1. Introduction

The need for energy in the world in general and Indonesia in particular, continuously increase time by time due to population growth and economic growth. This causes an energy deficit, due to not proportional between the growths in energy needs with energy generation. For this reason, it is necessary to empower other available energy sources, one of the energy sources that are still not optimally used is wind energy. The wind is one of the potential natural resources as an alternative and environmentally friendly and renewable energy, so there is a big opportunity for development [1].

Wind energy can be used as a driving turbine for electricity generation. At this time, electrical energy is a very important need and its use is very broad, but the majority of electricity used today still comes from power plants that use fossil fuels as an energy source. The use of fossil fuels has negative impacts such as environmental pollution and currently, fossil fuel reserves are also decreasing, so it cannot be relied upon as a sustainable energy source. To overcome this, there needs to be a serious effort to use alternative, which are environmentally friendly energy sources, including wind energy and solar energy [2].

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The average wind speed in Indonesia is classified as low speed, only certain areas have moderate to high wind speeds, such as in coastal areas or on hills. Low wind speed does not mean that the potential energy contained in it cannot be utilized or converted into electrical energy, it can still be utilized, but a generator that is by the characteristics of the wind speed is needed. Purwakarta regencies is one of the regency in the Province of West Java, Indonesia which has the potential of sufficient wind resources to be used as an alternative energy source. Based on The Central Statistics Agency of Purwakarta Regency (BPSKP) in 2019 recorded the largest average wind speed in the Purwakarta area of 5.14 m/s and an average temperature of 25 °C [3]. The available wind potential is enough to be used as an energy source.

2. Methodology

The research method used is by conducting literature studies, making prototypes, measuring electric current, voltage, and generator rotation connected to the roof ventilator from wind gusts during loading, for more details are described as follows.

The first stage in this research method, begins with researchers interested in conducting literature studies of several references regarding ventilator turbines at low wind speeds, which can be used as alternative power plants. Then the research method was continued by conducting a survey for the specified location, namely the location in the residential area of the lecturer, Indorama Polytechnic Engineering. Furthermore, the next stage is to measure the wind speed around the lecturer's residence.

The second step is to select the type of ventilator turbine and design a prototype, determine the need for the controller circuit, select the inverter and accumulator. Then proceed to the third stage, namely evaluating the system design.

Furthermore, the fourth stage is measuring and testing the feasibility of the device that will be installed on the roof of the residential later, if it has followed the design and produces the minimum power generated as an alternative power plant as residential lighting. The realized tool assembly is then tested and tested, if the device experiences problems, then repairs are made to the point where the problem is by repeating the repair process.

Meanwhile, if the tool is in accordance with the plan and there are no obstacles, then the process of taking data is carried out to measure the wind speed of the rotor rotation, current, voltage and the function of the tool performance. After that, the implementation of these stages is carried out by installing the prototype on the roof of the lecturer's residence.

2.1. Wind Ventilator

To convert kinetic energy from the wind into electrical energy, it can be done with the use of wind turbines. Then in the presence of a wind ventilator that has a structure like a turbine, it is usually used at home or industry to suck air from inside the house or industry. This ventilator will move if there is a wind blowing on the blades and at the same time will suck air in the building outside [2-4].

With the similarity in the structure of the wind ventilator to the turbine, it can be engineered so that it can function as a wind turbine. Like a turbine, the amount of energy that can be changed to the rotor depends on the wind speed, cross-section area, and air density [3] and given by the following formula [5].

$$P_w = 0.5\, \rho\, A\, v^3 \tag{1}$$

where:

- P_w : wind power (W)
- v : wind speed (m / s)
- A : cross-sectional area (m ^{2})
- ρ : air density (1.1726 kg / m^3)

Wind energy is an alternative energy that has good prospects because it is always available in nature, and is a clean and renewable energy source. The process of utilizing wind energy through the wind flow which will move the fins on the roof of the ventilator which will cause the generator rotor to rotate following the wind blowing. The rotor rotation is connected to the V-belt on the generator so that electricity can be generated.

2.2. Installation Rooftop

Wind ventilators that function to suck air from the room are mounted on top of the roof of the house as shown in Fig. 1. Unlike the normal fan that is driven by using electric power, but this wind ventilation works by utilizing the wind that blows outdoors [6]. Thus wind energy is kinetic energy derived from wind blowing to be used to rotate the fins.

Fig. 1 - Roof ventilator mounted on the residential [8]

This turbine is generally located at the top of the roof as an exhaust vent, to get the desired wind speed. Turbine ventilators come in many sizes, materials, and styles. Generally, the rotary mechanism design on its vertical axis helps generate airflow to the turbine to promote air extraction. The system, even if there is no wind, can still support the ventilator depending on the stack effect.

The advantage of this wind ventilator, it can be driven either by weak speed winds or high-speed winds that can rotate its blades and suck the indoor air out to room [8]. Fig. 2 shows the wind ventilator working principles [9].

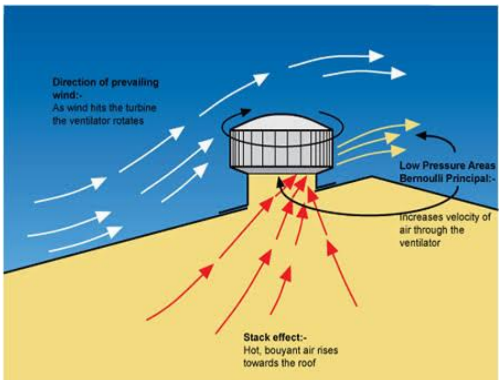

Fig. 2 - Wind ventilator working principles [9]

3. Prototype Design

The area where the design is tested is as shown by the Google map in Fig. 3. The area consists of a campus building and a lecturer's residence where the roof of the ventilator will be installed, which is indicated by a red dot (location).

Fig. 3 - The Indorama Engineering Polytechnic location [10]
(107.4^{O}16’87.51” East Longitude and 6.55^{O} 48’00.16” South Latitude)

After the location has been determined, the next step is to design the ventilator and other components, including: the control circuit, selecting the components, designing the inverter circuit and selecting its components, and finally choosing an accumulator with the appropriate capacity. The third stage is evaluating the system design and manufacturing. If at this stage no problems are found, then proceed with the fourth stage which is to test the system performance to see whether it meets the objectives and design requirements. The wind ventilator components and how its workflow as an electrical power plant is shown by the following figure.

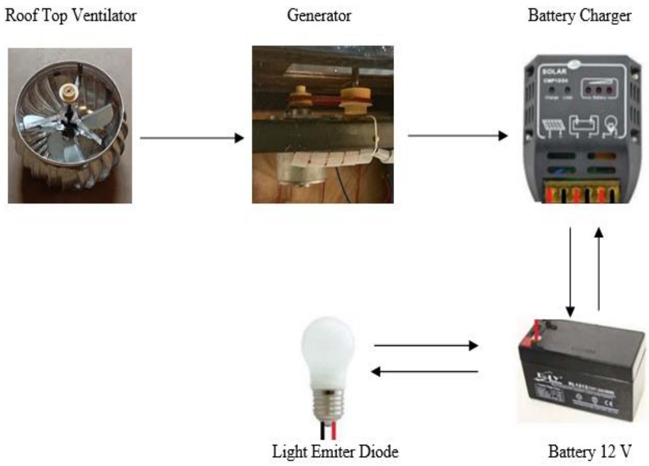

Fig. 4 - Workflow of wind ventilator as an electrical power generation system

Schematically the circuit for connecting each component of the power generation system by utilizing a wind ventilator as a prime mover of a dc generator is shown in Fig. 5 below.

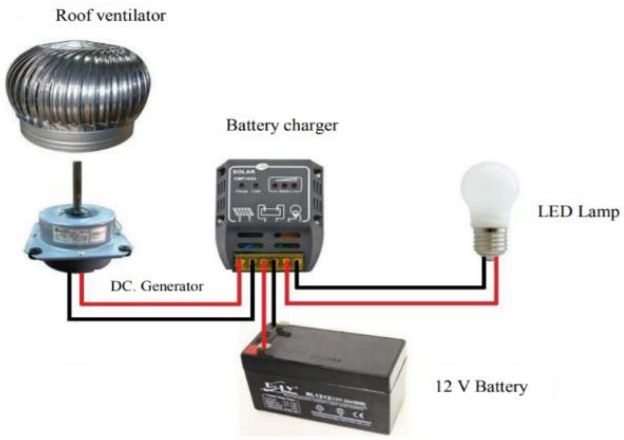

Fig. 5 - Schematically the circuit for connecting each component [8]

Roof top ventilators (RTV) or wind ventilators that function as turbines have been designed to work up to wind speeds of 100 km/h [7]. The materials used to fabricate the RTV are stainless steel or aluminum. Lightweight curved construction can help rotate at low wind speeds in all directions. The specifications of the RTV are elaborated in Table 1.

Table 1 - Technical specification of roof top ventilator

Technical specifications	Considered
Outer diameter	440 mm
Neck diameter	340 mm
Blade thickness	0.5 mm
Number of blades	24
Type of blades	Aluminum
Approximate weight	1.5 kg
Center assembly	MS galvanized

A dc generator is an electric machine that converts mechanical energy into direct current electrical energy. The principle of energy conversion is based on dynamically induced emf. Faraday's Law states that electromagnetic induction will occur every time a conductor cuts a variable magnetic field. If the conductor is a closed-loop, the induced current will circulate in the conductor. In a dc generator, the field coil will produce an electromagnetic field and the winding turn to rotate to cut the magnetic field [10-11]. Fig. 6 below shows the visual of the dc generator used in this research.

Fig. 6 - DC Generator

The specifications of this dc generator as elaborating in Table 2.

Table 2 – Specifications DC generator

Power	Voltage	Rpm
10 W	12 Vdc	480

Table 2 shows the generator used, where the 12Vdc output voltage will be generated if the maximum rotation of 480 rpm from the generator can be achieved. The output voltage of the generator depends on the wind speed at that location. If the wind speed increases, the generator speed also increases and vice versa.

As a connection between the turbine shaft and the dc generator, the V-belt is used, because it is easy to install and economical in price, V-belt transmission systems can transmit large power even at low speeds. The V-belt is a connecting transmission system made of rubber and has a cross-section of a truss wrapped around a shaped pulley groove [12-13].

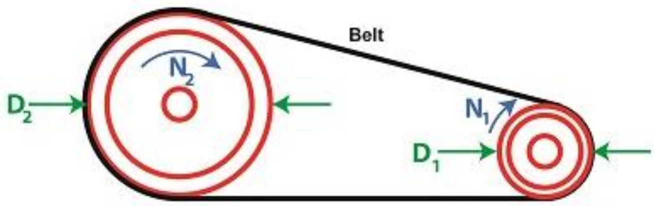

Fig. 7 - DC Generator rotation transmission [12].

Fig. 7 shows the comparison between the resulting speed at the generator, with the ratio of the pulley ventilator diameter to the pulley generator diameter mathematically as follows [12].

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \tag{2}$$

where:

N_1 = speed generator pulley (rpm)
N_2 = speed ventilator pulley (rpm)
D_1 = diameter generator pulley (m)
D_2 = diameter ventilator pulley (m)

In this case, the traveling speed can also be calculated using the diameter and radius around the belt, with belt rotation (rpm), mathematically as follows [12].

$$n = \frac{v\,60}{2\pi r} \tag{3}$$

where:

n : turbine ventilator speed (rpm)
v : wind speed (m/s)
r : ventilator spin radius (m)

Figure 8 shows the installation of the V-belt. The ratio of the turbine shaft pulley to the generator pulley is 2:1. Based on formula (2), the turbine shaft rotation will be twice the speed of the wind that drives the turbine.

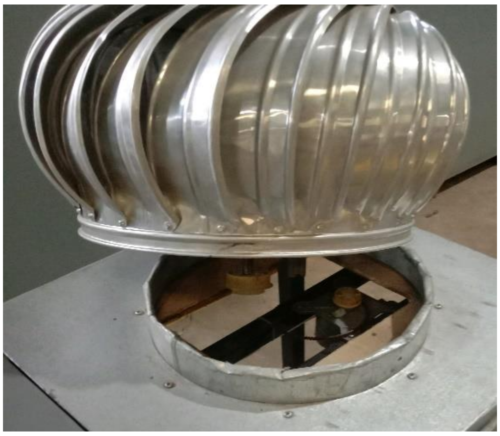

Fig. 8 - Installation of the V-belt

After assembling one part of the device can be realized, then testing will be done, if a problem is found, then repairs are made to the part that is experiencing the problem. Then the test will be done again if all the parts have met the requirements and passed the test, then all the parts will be combined into a complete tool. If no more problems are encountered, then the next step is the process of data collecting which includes of the generator speed, current, and voltage based on the wind speed [14-19].

The RTV is fabricated by using high-quality stainless steel material which is strong and durable. This wind ventilator mimics the concept of a vertical axis wind turbine that is used to drive a generator to produce electricity, but the process to turn a wind ventilator into a prime mover is not straight forward, there needs to be a slight modification [20]. This wind energy prototype is planned to be installed on the Rooftop of the lecturer's house as previously described and in Fig. 9 is a prototype that has been designed for experimentation and measurement purposes. Fig. 9 shows the prototype of a mini wind electrical power plant.

Fig. 9 - Prototype of a mini electrical power plant with a win ventilator as a turbine

4. Result and Discussion

After the prototype is fabricated, the test is carried out for the ventilator on no-load test, while the measurement data is shown in the Table 3. The lowest wind speed data is 2.14 m/s which results in the generator speed is 188 rpm and output voltage is 4.70 V. While the maximum wind speed achieved at this location is 5.31 m/s and can generate a generator speed of 463 rpm and an output voltage of 11.58 V.

Table 3 - Measurement no-load on location

No-loading test				
Measure to	Speed. wind (m/s)	Voltage (V)	Current (A)	Rotation. gen. (rpm)
1	2.14	4.70	0	188
2	2.27	4.98	0	199
3	2.56	5.60	0	224
4	3.67	8.03	0	321
5	3.81	8.30	0	332
6	4.32	9.43	0	377
7	4.72	10.30	0	412
8	4.92	10.70	0	428
9	5.18	11.30	0	452
10	5.31	11.58	0	463

For more details Figure 10 on the characteristics of the generator generation of the wind speed that drives the ventilator turbine. It can be seen in the graph which shows that the lower the wind speed, the smaller the resulting generation capability in a no-load condition.

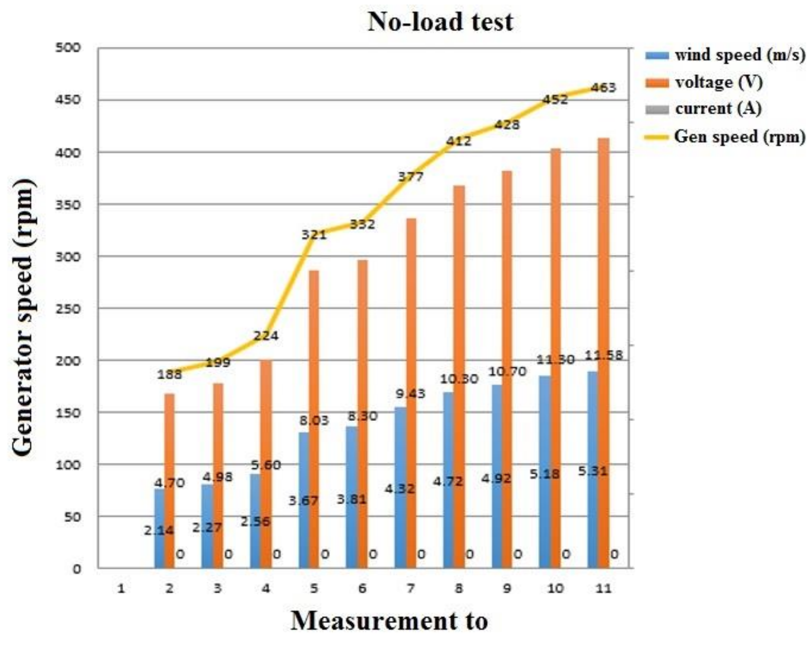

Fig. 10 - No-loading test result

The location that has been determined is a potential wind condition for the power plant. The specified location is chosen based on the location which has the potential wind speed for the power plant. The roof ventilator rotates when there is a wind blowing on the fins. The rotation of the ventilator will be proportional to the wind speed, therefore by integrating wind energy techniques into the roof ventilator, it will be able to ensure ventilation as the turbine produces energy [21-23]. Tests on the mini wind electric power plant developed in this study at the previously chosen location gave results as shown in following the table.

Table 4 - Measurement loading on location

Loading test				
Measure to	Speed. wind (m/s)	Voltage (V)	Current (A)	Rotation. gen. (rpm)
1	2.12	4.60	0.32	184
2	2.25	4.89	0.34	195
3	2.48	5.39	0.37	215
4	3.56	7.73	0.53	309
5	3.78	8.21	0.57	328
6	4.26	9.25	0.64	370
7	4.67	10.14	0.70	406
8	4.88	10.60	0.73	424
9	5.16	11.20	0.77	448
10	5.28	11.46	0.79	459

Furthermore, Figure 11 shows the speed of the generator produced under load conditions indicated by blue while the electric current generated is shown by light green [24-25]. The maximum output power generated is 9.05 W at wind speed is 5.28 m/s. The voltage and current generated are used for charging the battery and supplied the load. The loads used is this test are 3 watts LED lights. The graph shows that the lower the wind speed, the less the ability to supply the load.

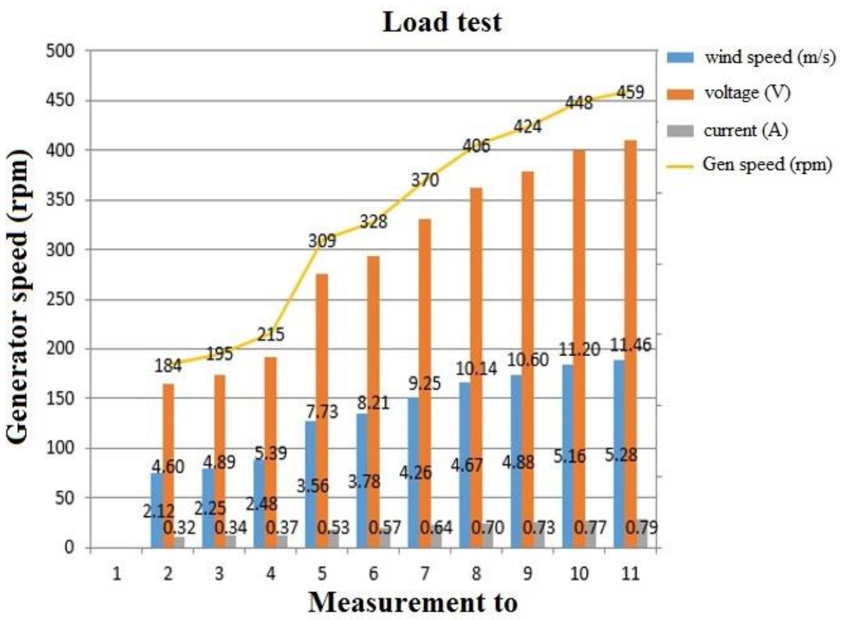

Figure 11 - Loading test results

5. Conclusion

Modification of the roof ventilator as an alternative mini electrical power plant has been successfully developed and tested at the location of engineering lecturer housing of the Indorama polytechnic. The results gave the relationship between wind speed and voltage and electric current generated by the generator. The lowest wind speed at that location is 2.12 m/s and produces generator speed, electrical voltage and electric current are 184 rpm, 4.60 V and 0.32 A respectively. The highest wind speed is 5.28 m/s. It produces the generator speed is 459 rpm and generated the electric voltage is 11.46 V and the electric current is 0.79 A. This test is carried out on the generator is loaded.

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