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# DEVELOPMENT OF VERTICAL-AXIS WIND TURBINE MODELS AS STRENGTHENING FOR SUSTAINABLE RENEWABLE ENERGY

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**ABSTRACT**

The use of electricity in the world continues to increase over time, the main source of producing electricity in the world is coal which is a basic material that takes a long time to form. Since 2021, British patrol has recorded that coal supplies in the world are available at 1,074,108 million tonnes. In Indonesia, coal still provides 60% of the country's electricity supply and the other 40% uses other energy such as water, steam, gas and other energy. New renewable energy development goals through the Sustainable Development Goals (SDG) in utilizing wind energy through vertical axis wind turbines. The research made three turbine models with different shapes, which then collected voltage data with an air compressor. The experimental results show that the average voltage generated by the two turbine models is 240 mV and 229 mV respectively. For the third model using two sampling methods obtained 353 mV and 292 mV. The use of vertical shaft wind turbines can be used in urban areas, especially in some tall buildings and parks. Research can still be developed by adding several other factors such as wind speed, turbine rotation speed and the aerodynamics of the turbine shape. and using a dc generator that requires a small torque so that it can increase the electric power produced. (KS)



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## 1. INTRODUCTION

Over time, the use of electrical energy in the world continues to increase. As the use of electric power increases, many resources are used throughout the world for electricity generation including wind, water, steam engines, nuclear, solar, diesel and other resources. The main source of electricity in the world is coal, based on the International Energy Agency, the highest demand for coal will occur in 2024 due to a reflection that will occur in 2021 (International Energy Agency, 2021). Based on British Petroleum or abbreviated as BP (British Petroleum PLC, 2021), coal reserves that are still available in the world are 1,074,108 million tons.

In Indonesia, the use of coal as a source of electrical energy is still 60% and the other 40% comes from other energy sources. In 2019, there were 64,843 MW of electricity generated by power other than coal

(Badan Pusat Statistik, 2021), the percentage of this electricity can be seen in Figure 1 and a map of the distribution of power plants can be seen in Figure 2.

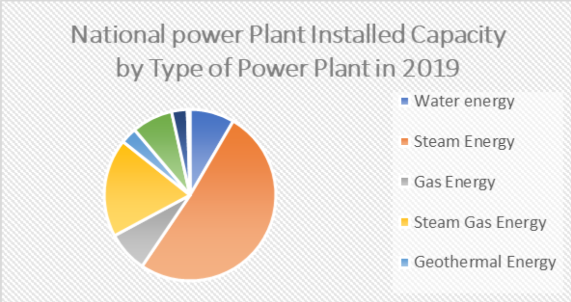



**Figure 1.** National Power plant Installed Capacity by Type of Power Plant in 2019

**Figure 2.** Power Plant Distribution Map

The development of wind energy potential has begun to be traced in Indonesia, one of which is wind energy development carried out by Lubis, Lubis & Harahap (Lubis, Lubis, & Harahap, 2019). Where in this study converts wind energy into electrical energy using a car alternator. In this study, data was collected with wind speeds of 8 to 16 meters per hour (mph) and a gear box to combine the low-speed rotor shaft and the high-speed rotor shaft. the results of this study provide an average voltage of 1.74 V and an average current of 0.424 A at a rotational speed of 100 rpm. The voltage and current generated by the generator section of the power plant have parallel results and follow the received rotation speed.

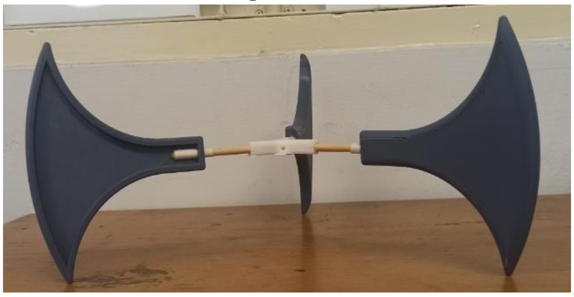
Many studies lean more towards horizontal axis wind turbine research than vertical axis wind turbines, this is due to a number of factors, including because they less reliable and current commercial versions of vertical turbines cannot produce as much power as horizontal turbines. According to the researchers, the efficiency of vertical turbine technology can be increased by deploying vertical turbines in clusters, in addition to the fact that the use of vertical turbines can be used in urban areas (Hui, Cain, & Dabari, 2018).

In this study, the researcher's idea to develop a vertical turbine was due to several factors such as the size, location and position of the vertical turbine that could be used. Moreover, with the uneven wind direction in Indonesia, vertical axis wind turbines have the advantage of receiving wind because they are not limited by one wind direction like vertical axis wind turbines. should provide ideas and ideas for the community to use wind energy around them. And provide ideas for renewable energy researchers to implement vertical well PLTB on Indonesian territory.

## 2. RESEARCH METHODS

### 2.1 Materials and parameter

The Following are the turbine models used for measurement and their parameters



(a)

(b)

(c)

**Figure 3.** Turbine Models (a) Model 1 (b) Model 2 (c) Model 3

**Table 1**. Dimension of Turbine Models

| Turbine Models | Measurement | | | | |
|---|---|---|---|---|---|
| | Height (cm) | Length (cm) | Number of Blades | Blades Position (°/blade) | Blades tilt (°) |
| **Model 1** | 14 | 16,25 | 3 | 120 | 0 |
| **Model 2** | 15 | 11,65 | 3 | 120 | 0 |
| **Model 3** | 16 | 8.75 | 3 | 120 | 72 |

**Table 2**. Weight of turbine models

| Turbine Models | Weight (g) | |
|---|---|---|
| | Single blade | Full Model |
| **Model 1** | 20 | 66.2 |
| **Model 2** | 29.5 | 99.4 |
| **Model 3** | 22.6 | 72.3 |

There are three turbine models will be used for experiments, wind turbine model 1 is the result of a design that has been done independently with the shape of a fairly large wind basin and gives some depth to the design to help drive the blades of the 'turbine- wind turbine'. While the geometry of turbine models 2 and 3 are turbine models that have been used in some previous studies and used commercially as a learning or independent production material, namely the Savonius wind turbine high resistance for model 2 and Darrieus helical turbine for model 3. High resilience to wind Savonius The turbine is resistively driven, but a small lift also adds power. Traction usually accelerates. Greater wind loads will be generated if traction is not converted to torque. The shield used to reduce negative moment on the convex side of the blade by directing the wind into the concave side tends to increase the wind load, while the deflector plate increases efficiency by 27%. For this soap turbine propeller, the frontal area of the turbine will not change if strong winds arise. For the Darrieus helical turbine, a turbine design proposed by Gorlov in 1995, the advantages of the Darrieus helical turbine design over the straight design are increased self-starting, lower peak voltage across the impeller, low noise, longer propeller life. Blade acceleration in unshielded areas and reduced angle of attack increase self-start (Kumar, et al., 2019).

### 2.2 Data Collection

Data Collection were done by connecting a multimeter to a dc dynamo which is used as a turbine generator, each turbine model will be connected to a generator and then voltage data is taken by shooting wind into the turbine. The test location is carried out in a closed lab with only one wind source which is air compressor.

## 3. RESULT AND DISCUSSION

There are 2 results for the experiments, the first results are taken from several spots on turbine model 1, the following figure show the test spot on turbine model 1.

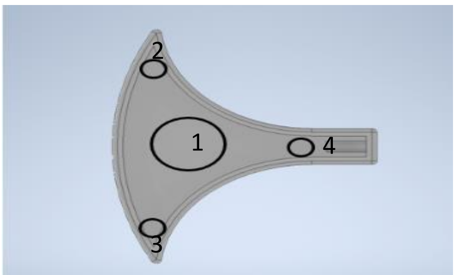



**Figure 4.** Turbine model 1 test spots

**Table 3.** Voltage Result on model 1 test spot 1

| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 272 | 207 | 158 |
| **Test 2** | 281 | 209 | 148 |
| **Test 3** | 261 | 199 | 150 |
| **Test 4** | 246 | 200 | 153 |
| **Test 5** | 260 | 210 | 157 |

**Table 4.** Voltage Result on model 1 test spot 2

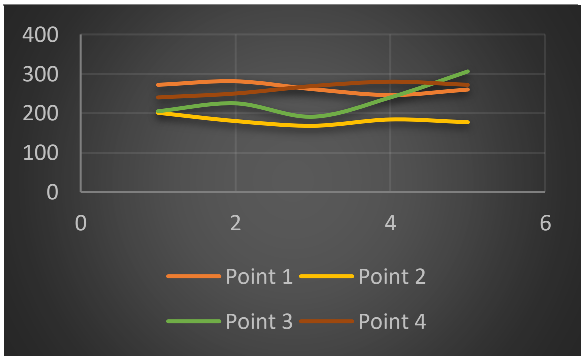
| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 201 | 183 | 135 |
| **Test 2** | 180 | 158 | 110 |
| **Test 3** | 168 | 138 | 100 |
| **Test 4** | 184 | 148 | 105 |
| **Test 5** | 177 | 140 | 117 |

**Table 5.** Voltage Result on model 1 test spot 3

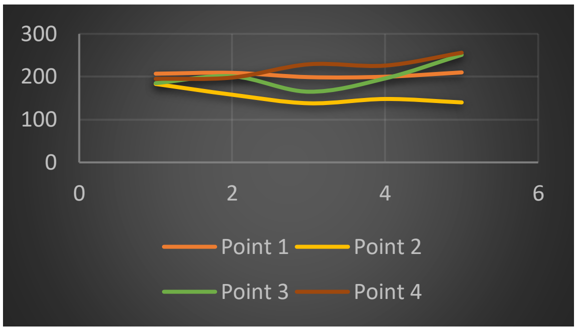
| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 240 | 195 | 150 |
| **Test 2** | 250 | 198 | 178 |
| **Test 3** | 269 | 229 | 160 |
| **Test 4** | 280 | 226 | 180 |
| **Test 5** | 272 | 256 | 162 |

**Table 6.** Voltage Result on model 1 test spot 4

| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 205 | 185 | 141 |
| **Test 2** | 225 | 201 | 179 |
| **Test 3** | 191 | 165 | 147 |
| **Test 4** | 240 | 196 | 155 |
| **Test 5** | 306 | 251 | 199 |




(a)

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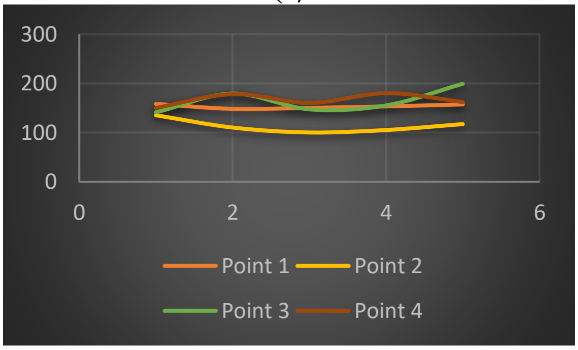



(c)

**Figure 5.** Voltage graph of each wind condition (a) 111,5 psi (b) 60 psi (c) 30 psi

Based on Figure 5, it can be seen that from the voltage generated from 5 times of experiment, stable results can be obtained if the experiment is performed using the midpoint of turbine model 1 because the area of turbine blades catches the wind at point 1. This is the largest among others and provides feedback from the turbine's depths to help power the thrust that the turbine generates after not picking up the wind. In addition, the center point also provides stability in the load distribution of the generated power so that the thrust of the propellers does not meet the weight at other points that could impede the turbine.

The second result is from testing 3 turbine models, The test results in this section measure the voltage across the turbine using an air compressor directed directly at the turbine, and then record the amount of voltage at three points as a function of the pressure applied to the compressor. The results of the measurements taken can be viewed in Table 3, Table 4, Table 5, and Table 6.

**Table 7.** Voltage Result on Model 1

| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 272 | 207 | 158 |
| **Test 2** | 281 | 209 | 148 |
| **Test 3** | 261 | 199 | 150 |
| **Test 4** | 246 | 200 | 153 |
| **Test 5** | 260 | 210 | 157 |

**Table 8.** Voltage Result on Model 2

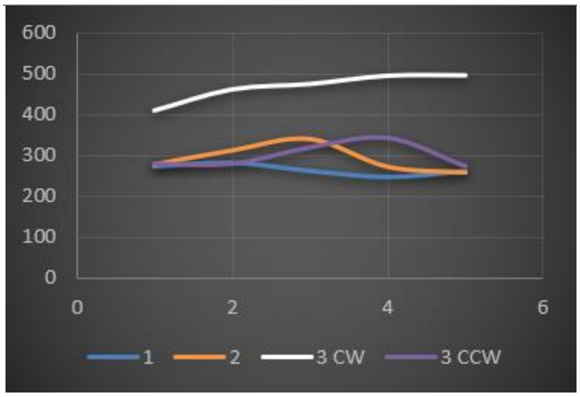
| Model 2 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 280 | 250 | 217 |
| **Test 2** | 314 | 245 | 213 |
| **Test 3** | 342 | 295 | 276 |
| **Test 4** | 274 | 200 | 153 |
| **Test 5** | 260 | 210 | 157 |

**Table 9.** Voltage Result on Model 3 Clockwise

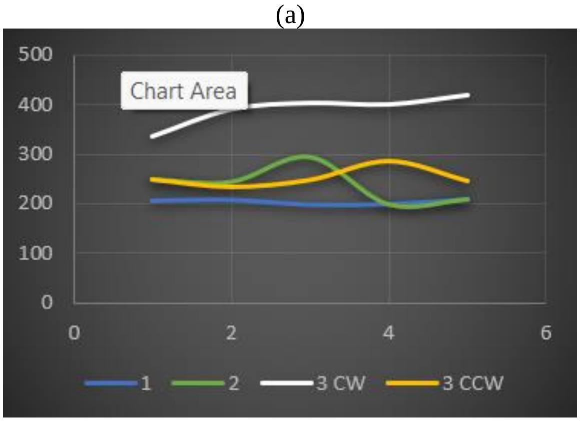
| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 411 | 335 | 274 |
| **Test 2** | 462 | 390 | 337 |
| **Test 3** | 475 | 403 | 335 |
| **Test 4** | 495 | 400 | 322 |
| **Test 5** | 496 | 419 | 354 |

**Table 10.** Voltage Result on Model 3 Counter-Clockwise

| Model 1 Test | Voltage (mV) | | |
|---|---|---|---|
| | Full Compressor (111.5 Psi) | Refilling Compressor (60 Psi) | Full Compressor (111.5 Psi) |
| **Test 1** | 280 | 250 | 217 |
| **Test 2** | 280 | 235 | 180 |
| **Test 3** | 319 | 249 | 213 |
| **Test 4** | 342 | 287 | 276 |
| **Test 5** | 274 | 247 | 222 |




(a)

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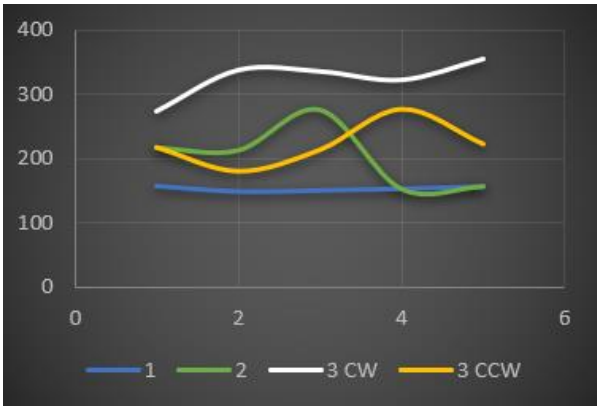


(c)

**Figure 6.** Voltage graph of each wind condition (a) 112 psi (b) 60 psi (c) 30 psi

Based on Table 7 to table 10, data collection using model 1 blade height 14 cm wide 10 cm can generate average voltage in each condition of air compressor is 264mV, 205mV and 153mV. The Model 2 turbine has a blade width of 6 cm and a height of 15 cm, which can generate average voltages of 294 mV, 240 mV and 203 mV. In model 3, an experiment is performed twice by pulling the wind through two different points i.e. low point of turbine and high point of turbine, two points producing different rotation directions where the lower point rotates in opposite directions. clockwise and the upper point rotates clockwise. The average voltages obtained in each condition are 467 mV, 389 mV and 324 mV while the average results are 299 mV, 253 mV and 221 mV in each condition of the air compressor. Based on Figure 6, it can be seen that the model 3 turbine rotating clockwise has a higher voltage than the other models, this is due to the design of the model 3 turbine where the resulting resistance of the turbine lower than other models. model and aerodynamics because of the propeller-like shape, where the wind at the top of the turbine will blow down creating thrust to help rotate the turbine resulting in higher tension than in model 1 and model 2. Tension in model 1 is smaller than the other models due to the larger wind resistance surface compared to the surface of model 2, in addition, model 1 does not have aerodynamic support on the flat surface of the wind resistance while model 2 still has a convex shape to help distinguish split the wind as the turbine rotates. In addition, the length and angle of position of the turbine model blades also affect the amount of wind captured, and the revolutions per minute (RPM) of the turbine is related to the amount of voltage generated. Each model has a different spacing on each blade. length is shown in table 11.

**Table 11.** Blade Distance for each Turbine Models

| Turbine Models | 1 | 2 | 3 |
|---|---|---|---|
| Blade Distance (cm) | 34,02 | 24,39 | 18,32 |

From the table above, it can be seen that the turbine of model 1 has quite a distance between the blades compared to models 2 and 3, which affects the amount of voltage even though it has more surface than other turbine models. The width of the turbine model affects the area that the blades can use to capture wind as kinetic energy to drive the DC generator.

## 4. CONCLUSION

Experiments were conducted by building three different models of turbine blades and igniting them at full pressure with an air compressor. This result indicates that the generated voltage follows the generated wind speed. In terms of tension stability, the Model 3 turbine produces more stable tension and higher tension due to excess aerodynamics. A limitation of Model 3, however, is that the wind must pass through the turbine to provide more thrust. This research is currently in the early stages of development. For further research, we recommend adding variables such as wind speed, rotational speed, and aerodynamics to each blade. The data acquired should take into account different conditions at different points in time, such as skyscrapers, undeveloped land, and coasts. Additionally, vertical axis wind turbine optimization can be complemented by using multiple statistical tools such as reaction surfaces and Taguchi methods for quality control.

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