Simulation and Performance Test Giromill Type Wind Turbine; Case Study Muara Enim, South Sumatra, Indonesia

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ABSTRACT

This research examines the dynamic load resistance of the Giromill type wind turbine to the variable wind speed, which is converted to the value of the force received by the wind turbine blades. The analysis was carried out numerically using Autodesk Inventor Professional 2019 software. The variations in wind speed used were 2.5 m/s with a force value of 0.195 N for the Giromill turbine, at a speed of 3.5 m/s with a force value of 0.274 N, at 4.5 m/s with a Force value of 0.352 N and a wind speed of 5.5 m/s with a force rating of 0.430 N. From the simulation results using the Autodesk Inventor Pro 2019 software, the effect of gravitational force is greater than the wind force in, so stress analysis is mainly caused by gravity while the wind force has no significant impact. The simulation results also have a characteristic that the higher the wind speed, the lower the stress value. In addition to the dynamic load simulation, the author also tries to implement the Giromill wind turbines in Muara Enim district, South Sumatra, Indonesia. The wind turbine blade rotation will be faster, and the Wind Generator will produce a greater voltage if it is supported by sufficient wind speed.

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1. INTRODUCTION

Electricity needs in various regions of the world, especially developing countries, are still predominantly sourced from fossil fuels such as coal and oil. However, the energy transition to a low-carbon energy system with the use of renewable energy has become a global agenda and trend in the framework of mitigating climate change, promoting sustainable development, and energy security [1]-[4]. The reduced production of fossil energy, especially oil, and the global commitment to reducing greenhouse gas emissions, has encouraged the Government to continuously increase the role of new and renewable energy as part of maintaining energy security and independence. According to PP No. 79 of 2014 concerning National Energy Policy, the target for the new and renewable energy mix in 2025 is at least 23% and 31% in 2050. Indonesia has a large enough potential for new and renewable energy to achieve the primary energy mix target, as shown in Table 1 Renewable Energy Potential [5]-[8], [26]-[28].

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New and Renewable Energy (RE) is a non-fossil energy source that is environmentally friendly and has a vital role because of its contribution in reducing climate change and global warming given its low emission and sustainable nature. However, fossil energy is still dominating the use of domestic energy, and RE is only an alternative energy source. Even though Indonesia has the potential for renewable energy resources that are relatively large that can be utilized, one of which is the use of wind energy [9]-[13].

Table 1. Renewable Energy Potential [1]

Energy Type	Potential
Hydropower	94.3 GW
Geothermal	28.5 GW
Bioenergy	PLT Bio : 32.6 GW dan BBN : 200,000 Bph
Sun	207.8 GWp
Wind	60.6 GW
Ocean Energy	17.9 G

The Government's policies, which continuously encourage EBT, will significantly contribute to increasing energy security. EBT is also considered to be more friendly to the environment because it can reduce the impact of climate change and global warming and has the prospect of sustainability so that public acceptance of the development of the Wind Power Plant (PLTB) development is very positive [14]-[18].

Based on wind prospecting data, Muara Enim District, the research area in South Sumatra, has an average wind speed of 3.4 m/s throughout the year, as shown in Fig. 1 [1].

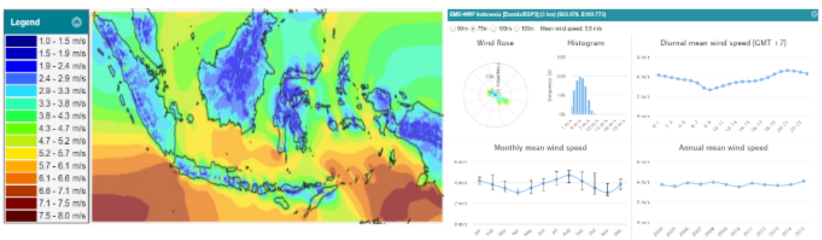


Figure 1. Average Wind Speeds in Kelurahan Air Lintang Muara Enim
(Resource: Indonesia.windprospecting.com)

Fig. 1 illustrates the average wind speeds in Kelurahan Air Lintang Muara Enim. This data is used to try to make a simulation with variation wind speed by using Autodesk Inventor Pro 2019.

2. RESEARCH METHOD

The design of this study used the Giromill type vertical axis wind turbines. This research will be conducted under the actual conditions. The vertical wind turbine Giromill will be installed on a tower with a height of 2.2 meters and placed on a residential building as high as 5 meters above ground level. Illustration of wind turbine installation at the research location (Fig 2). Besides analyzing the resistance of turbine blades to dynamic loads using the Professional Inventor 2019 software, it is expected that the simulation results are the effectiveness of the types of turbine blades.

Figure 2. Research Location in Muara Enim Regency (South Sumatera, Indonesia)

From Figure 2, it shows the components of the Giromill type wind turbine and their functions:

1. Giromill blades, serve to catch the wind that converts mechanical energy into kinetic energy.
2. Rotor, serves for the blade construction holder connected to the generator
3. Wind Generator, serves as electronic equipment that converts mechanical energy into electrical energy.
4. Tower, serves as the main tower or wind turbine construction.

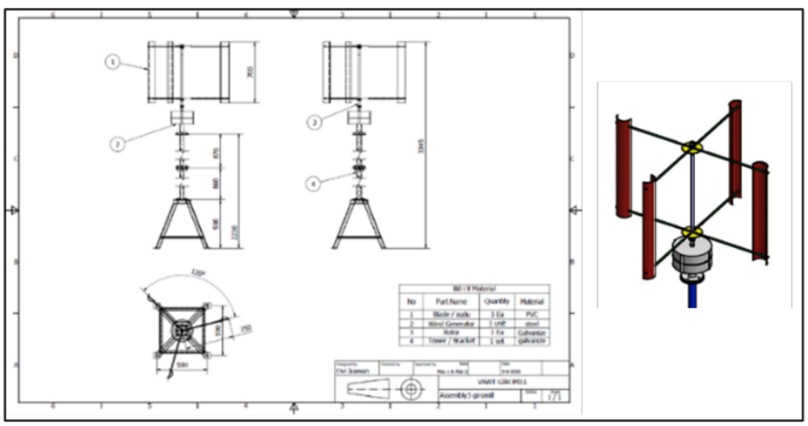


Figure 3. Design of Giromill Wind Turbine

Figure 3 illustrates that the Giromill blade uses PVC pipe material with a diameter of 4” and a length of 700 mm. The turbine blades are connected to the rotor using galvanized pipe material with a diameter of 20 mm and a mild steel plate with a thickness of 2 mm.

Figure 4. Fabrication Process of Giromill Wind Turbine

In this study, the wind turbine was built on a 2.2 meter high tower with a diameter of 2". The tower construction is made portable, making it easier to move locations on the Residential Building (Figure 4). Because the construction uses segments, it is possible to increase the tower height.

This study aims to get an analysis of the strength of the Giromill Wind Turbine Blade. This research examines the dynamic load resistance of the Giromill type wind turbine to the variable wind speed, which is converted to the value of the force received by the wind turbine blades. The analysis was carried out numerically using Autodesk Inventor Professional 2019 software [29],[30]. The conversion of wind speed to the value of the force can be done using the equation:[19]

$$F = Cp\,\frac{1}{2}\,\rho\,A\,v^2 \quad \text{.......... (1)}$$

Force Value converted from the Wind speed Force (N), **ρ** is air density (1.225 kg/m^3), **Cp** is power coefficient (0.4), **A** is turbine swept area (m^2), and v is wind velocity (m/s).

3. RESULTS AND DISCUSSION (10 PT)

This simulation examines the dynamic load resistance of the Giromill wind turbine to the variable wind speed, which is converted to the value of the force received by the wind turbine blades. The analysis was carried out numerically using Autodesk Inventor Professional 2019 software. In this simulation, variations in wind speed were used, namely 2.5 m/s, 3.5 m/s, 4.5 m/s, and wind speed of 5.5 m/s. The simulation of these types of wind turbine blades uses PVC for the Giromill turbine blade material. The mechanical properties are shown in the following Table 2.

Table 2. Physical properties of the Giromill Turbine Blade Material (PVC)

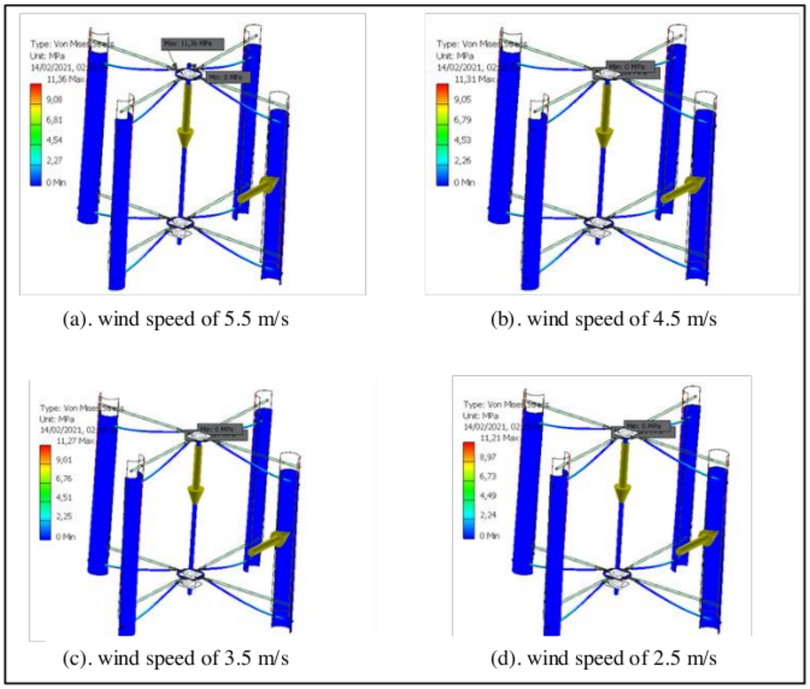
Material	Giromill (PVC)
Density	1.4 g/cm^3
Mass	0.26 kg
Area	249936 mm^2
Volume	185152 mm^3
Yield Strength	46.5 MPa
Ultimate Tensile Strength	52.3 MPa

Based on the results of the Stress Analysis of the Autodesk Inventor Pro Software. 2019 was obtained as following Table 3.

Table 3. Stress analysis at variations Wind Speed

	5.5 m/s wind speed		4.5 m/s wind speed		3.5 m/s wind speed		2.5 m/s wind speed	
	Min	Maks.	Min	Maks.	Min	Maks.	Min	Maks.
Von Mises Stress(Mpa)	0	11.35	0	11.31	0	11.27	0	11.21
Displacement (mm)	0 mm	0.555746	0	0.555265	0	0.5554862	0	0.554433
Safety Factor(ul)	15	15	15	15	15	15	15	15

Table 3 shows the analysis of PVC material stress on wind speed variations that have been converted to the force value received by the turbine blade. Table 3 shows that PVC material is safe enough to withstand dynamic loads because the value of the safety factor required for the material to withstand dynamic loads is 2-3. To more easily illustrate the stress analysis on wind speed variations, it can be seen in Figure 5.



(a). wind speed of 5.5 m/s
(b). wind speed of 4.5 m/s
(c). wind speed of 3.5 m/s
(d). wind speed of 2.5 m/s

Figure 5. Von Misses stress on the Giromill Type wind turbine blades at variations wind speed

From Figure 5, it can be seen in the simulation, variations in wind speed are converted into force values and how they affect the resistance of the turbine blades. Variations in wind speed from 5.5 m/s, 4.5 m/s, 3.5 m/s, and 2.5 m/s have no significant effect on the blades because the value of the force received over the turbine blades is smaller than the gravitational force. Besides that, the safety factor of PVC material is also still above the required value of 2-3 so that the turbine blade material is suitable, effective, and safe to implement. From the simulation, it can be seen that the range of von misses voltage values is between 0-11.36 MPa for a wind speed of 5.5 m/s; 0-11.31 MPa for wind speed 4.5 m/s; 0-11.27 MPa for a wind speed of 3.5 m/s and 0-11.21 for a wind speed of 2.5 m/s which are shown in blue to red. An indication of a safe condition is shown in blue.

Based on the simulation analysis results, the author tries to implement the manufacture of a turbine blade in a residential in the Muara Enim area, South Sumatra, Indonesia. Giromill Wind Turbine Performance test took the wind turbine data and wrote the results in a table 12th of December 2020 starting at 08.00 WIB until 18.00 WIB with time intervals every 30 minutes. The Research result vertical axis wind turbine Giromill type, it can be seen from Fig. 6.

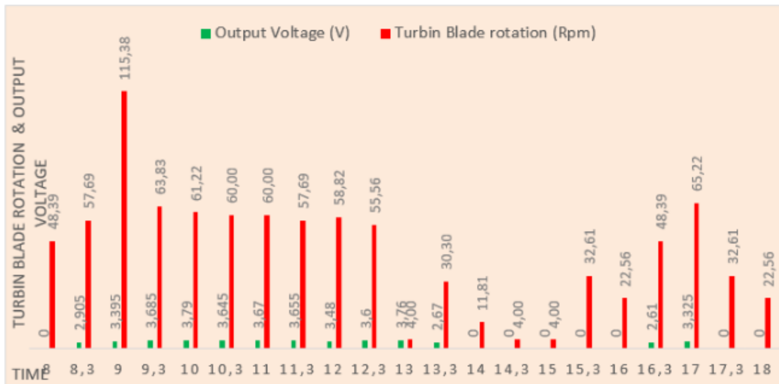


Figure 6. Turbine rotation (rpm) VS voltage (volts) of Giromill wind turbines

From Figure 6, the maximum rotation of the wind turbine can be seen at 78.9 rpm and produces a voltage of 3.76 volts, while the lowest turbine rotation of 34.88 rpm can produce an electrical voltage of 2.61 Volts. The resulting voltage is unstable and always fluctuates depending on the turbine rotation very much, the higher the turbine rotation, the greater the voltage generated.

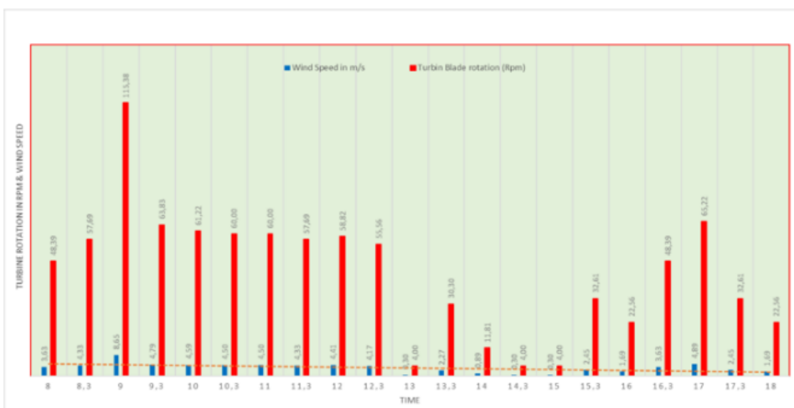


Figure 7 Wind speed in m/s vs turbine rotation in rpm of Giromill wind turbines

From Figure 7, the maximum turbine rotation obtained is 115.38 rpm at a wind speed of 8.65 m/s and the lowest turbine rotation is 4 rpm at a wind speed of 0.4 m/s. The graph above shows that the turbine rotation is very dependent on the wind speed. The higher the wind speed, the higher the turbine rotation too.

4. CONCLUSION

In the simulation using Autodesk Inventor Pro 2019 software, the effect of gravitational force is greater than the wind force in the Giromill type turbine blade, so stress analysis is mainly caused by gravity while the wind force has no significant effect. The simulation results also have a characteristic that the higher the wind speed, the lower the stress value. In this condition, it can be concluded that the turbine blades are still effective in terms of resistance to wind forces. Based on the Giromill type wind turbine graph, the wind turbine rotation, the value of the voltage, and the current generated depends on the wind speed. The wind turbine blade rotation will be faster, and the Wind Generator will produce a greater voltage if it is supported by sufficient wind speed.

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