Prototype of Small Savonius Wind Turbine

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ABSTRACT

Green energy likely wind energy, solar energy, biomass energy, and tidal energy, with the characteristics of being free, natural, and free from pollution problems, and renewable. In this research, we used air conditioner with split (AC Split) model has a large energy potential that could be utilized, from exhaust air velocity in the outdoor unit which reaches 2-6 m/s. A simple prototype is designed using a wind turbine and generator as the main components in energy production. The design of a wind turbine prototype with a Savonius vertical axis wind turbines (VAWT) has several advantages such as low wind speed to drive the rotor. We used method consists of five stages. Firstly, is literature study; secondly design and modelling using computational fluid dynamics software; thirdly is manufacturing and assembly; next stages is measurement and data collection; and the last stages is testing, which is evaluating the performance of wind turbine as possible modifying tools if needed. This simple prototype has been evaluated with two models of Curvature angles, is the blade with single angle of curvature of 46.5o within four-blade model that is curved, and blades with double curvature angles of 45o and 30o of the curved three-blade model. The results of test used a reducer with there-blades as staring test, we found the rotation speed was dramatically increased from 20 to 90% was reaches less than 60 seconds. Also the net power extracted by double of curvature angle is maximum reaches from 13% to 36% of turbine power (Watt), it should not be addressed for the power extraction capability of single curvature angle model. We suggested with this result could as a simple prototype in the future. It's slightly possible to be applied as an alternative solution in green energy industries.

Keywords: *Green Energy, Prototype, Savonius VAWT, Curvature angles, Turbine power*

1. INTRODUCTION

Today, energy consumption and environmental pollutants have to become serious problems for this earth. Find and develop as a new alternative energy is an urgently needs. Although, found many alternative fuel resources have been developed to replace fossil energy and as brief solve for the crisis energy problem, because this energy has gave waste likely pollutant gases that has the potential to broke the environmental safety. According [4], he said a new type of energy alternative is needed that produces less pollutant gases or that what call as Green Energy. This energy can replace energy from fossils such as wind energy, solar energy, biomass energy, and tidal energy with the characteristics of being to free came from nature also no pollution problems and renewable resources. The green energies are best suited for contemporary needs.

In this time problem [7] is mostly focused on the development of wind energy and [6] solar energy. These energy [4] have quite different for developing cost, wind energy is much lower than solar energy, so the wind energy have a main advantage. The results [2] showed the exhaust dry air from air conditioner type split has great energy potential that can be utilized. The energy potential is air velocity from outdoor unit has reaches from 2 to 6 m/s. By designing a wind turbine by utilizing the potential dry air velocity generated by the outdoor unit, it has the potential for the application of energy conservation into electrical energy.

The main reaches for this research is firstly the air flow modeling using Computational Fluid Dynamics (CFD) to obtain the energy kinetic value from the exhaust fan of outdoor unit (air conditioner type split); Secondly, design of the blade shape and material of the Savonius wind turbine to produce a maximum value of drag force that produces kinetic head at constant air velocity of the outdoor split air exhaust also analyzing wind power with variations forced flow generated by the Generator; thirdly is generating electrical energy and performance evaluation, to have the sustainability of this prototype will be developed so that it can be applied as an alternative green energy solution.

The result of this work has been carried out because it has benefits and urgency in the fulfillment of sustainable alternative energy. A simple prototype of a Savonius wind turbine utilizing exhaust air from outdoor Split AC is useful for users, especially to tropical countries such as Indonesia. In consequence from cooling purpose has become the main requirement of urban and rural communities. Hence, it will give massive desire as a secondary need for the availability of sustainable green energy.

1.1. Related Work

According to the generation type of assumptions, we divided the existed work into two stages.

1.1.1. Momentum (drag force) theory

According to Betz the maximum amount of energy that can be absorbed from the wind is only 0.59259 of the available energy. Meanwhile, this can also be achieved with a very well designed leaf turbine with a leaf circumference at the top of the leaf at 6 times the wind speed.

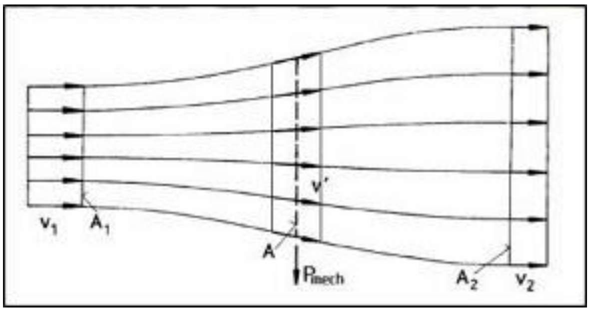

Figure 1. Fluid flow model by Beltz's momentum theory

Figure 1 illustrated in [5] the power coefficient resulting from the conversion of wind power to turbine mechanical power depending on the ratio of the wind speed before and after being converted. If this relationship is illustrated in a graph, it can be seen that the power coefficient reaches a maximum at a certain wind speed ratio as shown in Figure 2

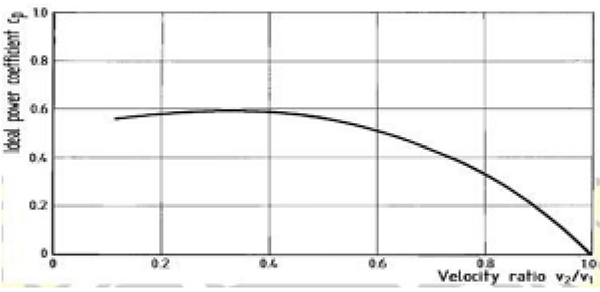

Figure 2. Power coefficient VS velocity ratio in flow fluid speed

He [5] found the amount of theoretical or maximum efficiency of the Cp wind turbine is:

$$C_p = \frac{v_2}{v_1} = \frac{16}{27} = 0{,}593 \quad (1)$$

Its mean the wind turbine can covert no more than 60% of total wind power to usable power.

1.1.1. Momentum (drag force) theory

The maximum wind power (Watt) that can be extracted by a wind turbine with a rotor sweep area A can be found by equation 2.

$$P = \frac{16}{27}\frac{1}{2}\rho A V^3 \ (W) \quad (2)$$

Due to the presence of friction losses and losses at the blade tip, the aerodynamic efficiency of the rotor, the η of this rotor will be even smaller that is around the maximum value of 0.45 for a very well designed blade, the wind turbine rotor efficiency can be found in equation 3.

$$\eta_{rotor} = Cp = Pt/\frac{1}{2}\rho A v^3 \quad (3)$$

Wherein:

Pt = turbine power (watt)
Cp = power coefficient
ρ = wind density (kg/m³)
A = square are of air flow (m²)
v = wind velocity (m/s)

1.2. Our Contribution

This paper presents some improvements based on the related our framework in Rusmaryadi et al [8]. They have Modelling conducted by shows that the aerodynamic performance of the egg-beater Darrieus wind turbine increased by 0.19% compared to the H type.

2. METHOD AND PROCEDURE

2.1. Methods

In this research the methods that will be used include observations, study literature, modelling air flow, design of sample material for Savonius rotor, collect the data and testing of the prototype also evaluating the performance of wind turbine. The order of research can be explained by the flow chart in Fig 3. The majority of this research was carried out at the CAD-CAM workshop in Mechanical Engineering and Renewable Power plant Laboratory in Electrical Engineering Department of Politeknik Negeri Sriwijaya for six months.

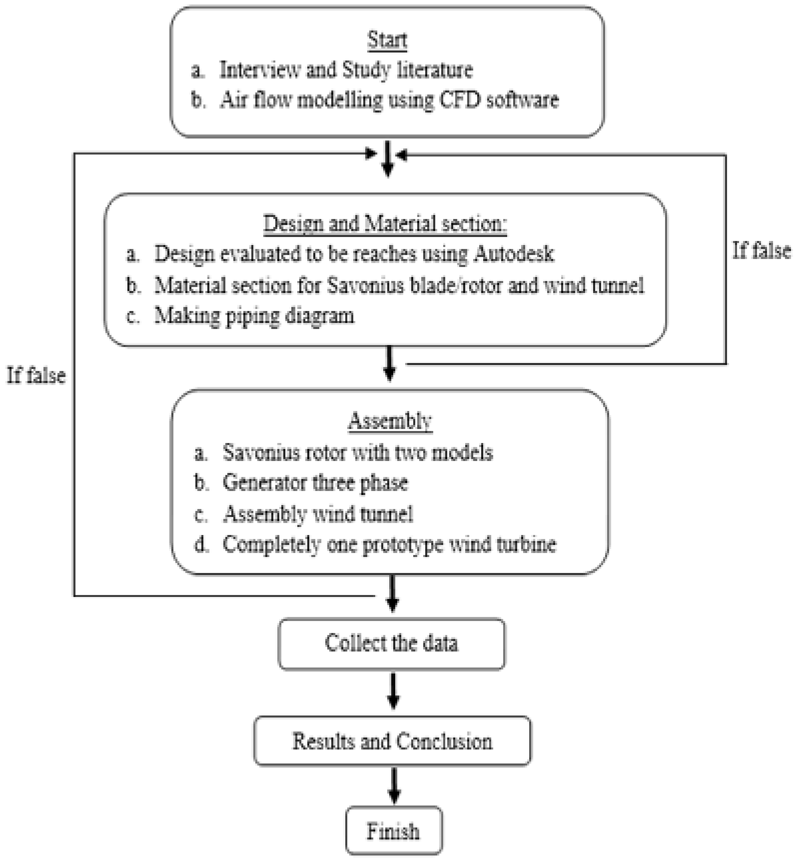

Figure 3. Design of Research flowchart

2.2 Procedure

The research was conducted in the design of a Savonius wind turbine, by simulating the fluid flow in the wind tunnel / ducting and the design of the blade shape of the wind turbine. The minimum height and dependence on power conversion on the height of machine and analyse the performance of the system using CFD [10]. Figure 4 illustrates the air flow velocity in a wind tunnel without and with a reducer, where the inlet is the exhaust air from the outdoor split AC unit which has an air flow velocity of 3 m/s, with a wind tunnel length of 50cm.

Figure (4a) shows the flow modelling, it can be seen that the air velocity driving the turbine blades is 3.724 m/s. While in (4b) using a reducer, the air velocity that drives the turbine blades was reaches to 7.601 m/s. In Figure 5, describes the component layout of the prototype wind turbine Savonius

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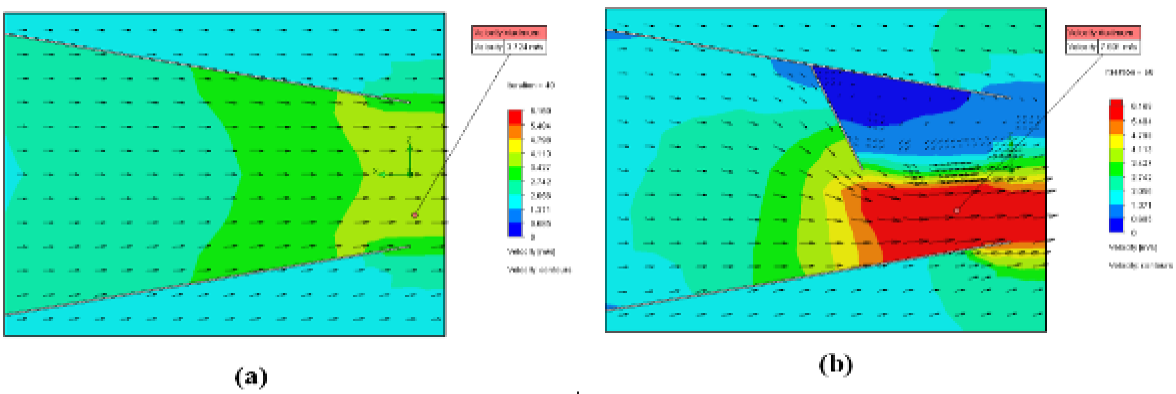


Figure 4. Modelling of airflow path in wind tunnel using CFD simulator (a) without reducer, (b) using reducer

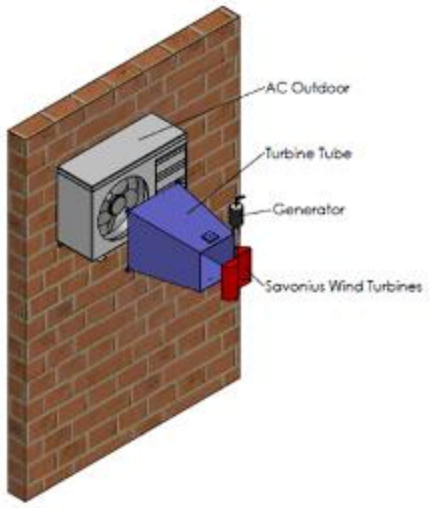


Figure 5. Design layout of Savonius wind turbine

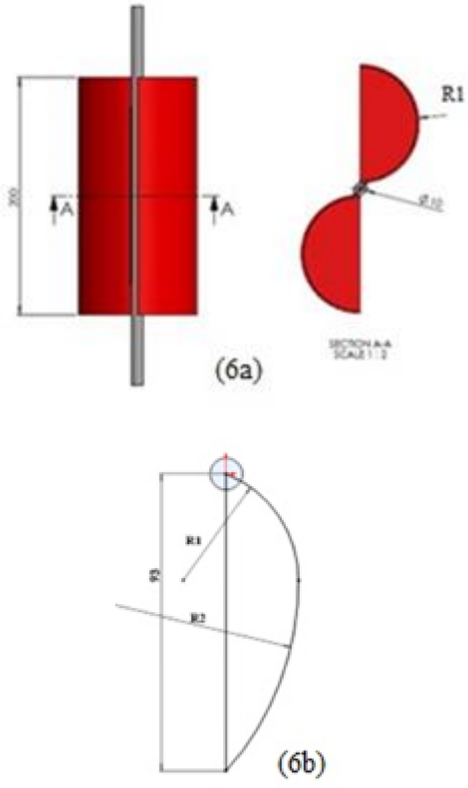


Figure 6. Blades of Savonius wind turbine models

In this prototype, we used two models of turbine blades, is the blade with single angle of curvature of 46.5o from four-blade model that is curved, and blades with double curvature angles of 45o and 30o of the curved three-blade model. The fig 6 was shows a savonius blades models; (6a) with four-blade with single angle (R1 = 46.5o) and (6b) three-blade with double angle (R1=45o, R2=30o). In this research, we made selection material for the Savonius blades. Based on Fatahul et al [3], he suggest the material selection is very important to calculated and analysed for the static load. To convert wind energy into electrical energy, a wind turbine is need to be connected a generator. Wind turbines are generally divided into two, vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). VAWT and HAWT have different advantages and characteristics [1].

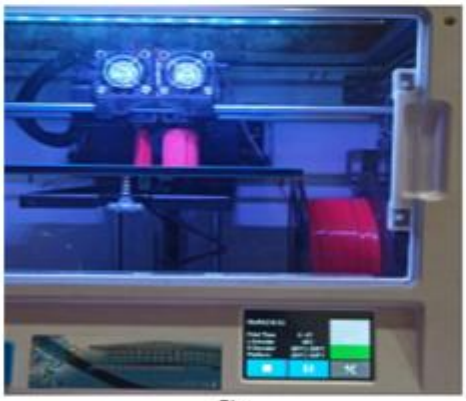
3. RESULTS AND DISCUSSION

The final result of this prototype is obtained for configuration of Savonius blade models for two model with curvature angle at wind velocity 3.0 m/s, 4.0 m/s, 5.0 m/s and 6.0 m/s. We used a permanent magnet generator as a 24VAC in three-phase power generated.

3.1 Assembly

This research was conducted in a dry-air at temperature of average to 310 K and using an exhaust fan from outdoor unit of air conditioning machine with a modifying to control of wind velocity as a device to simulate wind flow and we used a reducer as close loop. The closed loop and reducer is used to increase the head speed of Savonius rotation. In fig 7, the construction of the vertical axis wind turbines (VAWT).

7a.



7b.

Figure 7. Assembly process (a) a completely prototype (b) Production of Savonius blades and shaft used 3D filaments machine printing.

3.2. Self-starting test

Figure 8 illustrates the starting characteristics of Savonius blade models. From this figure, it's seen that the maximum speed that could reach by single angle is slightly lower than the double angle model. These figure showed the result test with two models; at wind velocity 6 m/s, the double angle (three-blade) can reach the maximum rotation speed within 180 seconds at 954 rpm. Further, at wind velocity 4m/s, the single angle (four-blade) was poorly to self-starting within 306rpm at 180 seconds. That opposite at wind 3m/s was quite reach to self-staring in 310rpm. The results are as follows. At the wind 6 m/s in less than 60 seconds the wind turbine reaches 350 rpm, and the wind speed of 3 m/s wind turbine is able to get 95 rpm. In other hand, four-blade in similarly time-run, just reaches 301 rpm at 6m/s and 50 rpm at 3 m/s. By using the there-blades as staring test, we found the rotation speed was dramatically increased from 20 to 90%.

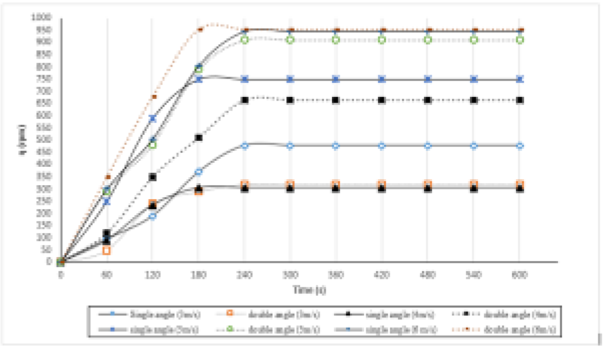


Figure 8 illustrates the starting test of Savonius blade models.

3.3. Power Capability (Turbine power)

. Figure 9 illustrates the power characteristics of Savonius blade models, single and double of curvature. From this figure, it's seen that the net power capability by single angle of curvature lower than that could reach by double angle. These results were showed the four-blade (single angle of curvature) in comparing with the three-blades model (double angle of curvature) was mounted on the main shaft with directly to permanent magnet generator gives power reduction at wind velocity 6 m/s, 5.0 m/s, 4 m/s and 3m/s are 13%, 16%, 36 % and 35% respectively.

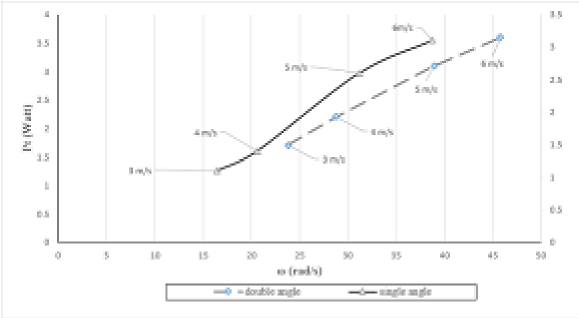


Figure 9. Power capability characteristics of Savonius blade models.

4. CONCLUSION

A prototype of small Savonius wind turbine have been design, assembly and testing to self-starting and power capability. These prototype with two models single and double of angle curvature within four-blade and three blade model. The results of testing showed the starting ability of the double angle of curvature was increased to 90%. In Saha et al, 2006 [9] was provided the optimal performance at a curvature angle of 15o from a three-blade turbine model with a curved mount. As conclusion that type of model, we found the net power extracted by double of curvature angle is slowly reaches from 13% to 36% of turbine power (Watt).

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REFERENCES

[1] Akwa, J.V., Vielmo, H.A., and Petry, A.P., 2012, "A review on the performance of Savonius wind turbines", Renewable and Sustainable Energy Reviews, Elsevier, Vol. 16 (5): 3054–3064

[2] Ching-Song Jwo, Zi-Jie Chien, Yen-lin Chen and Chao-Chun Chine, "Development of a Wind Directly Forced Heat Pump and Its Efficiency Analysis", International Journal of Photo energy, vol. 2013, pp.1-7, doi: http://dx.doi.org/10.1155/2013/862547.

[3] Fatahul Arifin et al, 2020, "Studi analisis simulasi kekuatan beban pada alat bantu pembuatan lubang dengan sudut kemiringan 45o", Jurnal Polimesin, 18(2), pp.116-123.

[4] H. Holttinen, 2005, "Optimal electricity market for wind power," Energy Policy, vol. 33, no. 16, pp. 2052–2063.

[5] Hua Erich, 2006, “Wind Turbines Fundamentals Technologies, Application, Economics”, 2nd Edition, Springer.

[6] L. Q. Liu, Z. X.Wang, H. Q. Zhang, and Y. C. Xue, 2010, “Solar energy development in China—a review,” Renewable and Sustainable Energy Reviews, vol. 14, no. 1, pp. 301–311.

[7] M. Esteban and D. Leary, 2012, “Current developments and future prospects of offshore wind and ocean energy,” Applied Energy, vol. 90, pp. 128–136.

[8] Rusmaryadi, H., Sahim, K., & Homzah, O. F, 2018, “Model Perencanaan Performansi Aerodinamika Turbin Angin Darrieus dengan Metode Multiple Streamtube”. Mechanical, 9(1), pp.1–6.

[9] Saha, U.K., Rajkumar, M.J., 2006, On the Performance Analysis of Savonius Rotor with Twisted Blades, Renewable Energy, vol 31, pp. 1776–1788, Elsevier.

[10] Srinivasan, C., Ajithkumar, G., Arul, S., Arulprasath, G., dan Dharunbabu, T.M., 2017, "Design of Combined Savonius-Darrieus Wind Turbine", (IOSR-JMCE), e-ISSN: 2278-684, p-ISSN: 2320-334X, Volume 14: 60-70.