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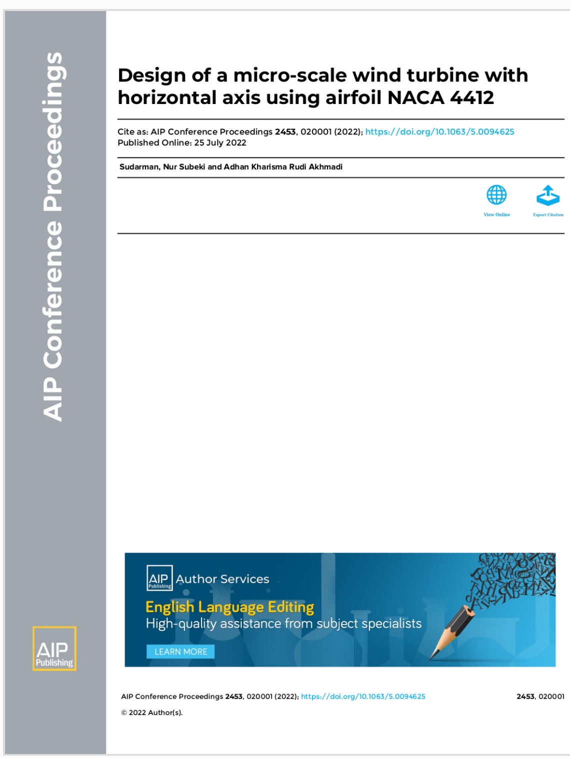
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Design of A Micro-Scale Wind Turbine with Horizontal Axis using Airfoil NACA 4412

Sudarman[a)], Nur Subeki, Adhan Kharisma Rudi Akhmadi

Department of Mechanical Engineering, Universitas Muhammadiyah Malang, Malang, Indonesia

[a)]Corresponding author: [a)]sudarman@umm.ac.id

Abstract. The high demand for electrical energy leads to the depletion of fossil fuel reserves. Therefore, alternative energy is required to overcome the scarcity of fossil fuels. Regardless of the fact that natural resources are renewable as alternative energy such as wind, water, ocean waves, and sunlight. Wind on the south coast of Malang, Indonesia provides good potential as alternative energy. The design in this paper is focused on designing a horizontal axis wind turbine with 4 blades with a length of 50 cm utilizing the NACA 4412 Airfoil profile. The wind turbine is designed utilizing a low-speed permanent magnet generator around 500-1000 rpm to produce a design power of 100-125 Watt and the maximum power of the generator of 270 Watt. The wind turbine that has been designed has a tower-shaped support that uses iron pipes and is pulled by 4 steel ropes that are plugged in each pointing to the 4 cardinal directions.

INTRODUCTION

The existence of global fossil energy reserves is currently low, one of which is oil, capable of limited supply for 53 years. This left amount includes all existing oil reserves in the world today and is calculated based on the total of all oil reserves in the world in 2012, under 200,000 million tons. Coal reserves in the world are currently available for another 109 years, and natural gas is available for another 55 years. With the existing reserves and production levels as in 2012, it is estimated that global coal is capable of supplying for 109 years, and natural gas is available for 55 years. The global demand for energy in the world continues to sharply increase along with the growth of the world economy annually [1].

National energy reserves are currently small with a population of 3.5% worldwide, Indonesia solely has oil reserves of 0.5%, gas 1.4%, and coal 0.89%. For this reason, it is necessary to describe short-, medium-, and long-term national energy. Short-term national energy covers aspects of efficiency, intensification, indexation, and diversification. Medium-term national energy includes reducing dependence on fuel and increasing gas use, while long-term national energy is by developing alternative energy in accordance with regional potential. (bumn.go.id, 2014)

The use of energy, especially electrical energy, is required by developing in large or small quantities [3]. Lots of alternative energy from nature is utilized to generate electricity, currently presenting great potential to be developed as wind energy. Wind energy provides clean energy, in which the production process does not pollute the environment. Wind is regarded as a form of renewable energy sourced from the sun due to uneven heating of the earth's atmosphere and irregularities in the surface and rotation of the earth [4].

Indonesia is an archipelagic country comprising 17,500 islands with a coastline of more than 81,290 kms. Indonesia additionally has a very large wind energy potential, which is around 9.3 GW [5]. The development of wind energy in Indonesia remains relatively low, due to the low wind speed, hindering the generation of electricity on a large scale. However, the wind potential in Indonesia is annually available, creating the possibility to develop small-scale power generation systems.

Independent energy is defined as energy resulting from the ability of a device to provide independent electrical energy, such as the utilization of wind kinetic energy, converted into mechanical energy in blades and generators to produce electrical energy. A wind turbine is a device for converting the kinetic energy of the wind into usable electrical energy. The working principle of a wind turbine as a power plant occurs if the wind blows and causes the propeller to rotate utilizing wind energy to drive an electric generator [6]. Based on data from BMKG (Meteorology, Climatology and Geophysics Agency) the average wind speed in Malang Regency, East Java, is around 10 - 20 km/hour (3 - 4 m/s), fluctuating (different for everyday fluctuation).

Referring to the aforementioned description, it is thus necessary to design the engineered small-scale wind turbines for the use of wind energy. Therefore, this study novelty lies in the "Design of Horizontal Axis Wind Turbine Models

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for Coastal Lighting", provided that the turbine provides an efficient means of alternative along with the material availability on the market for long-term manufacturing and maintenance.

Hence, the purpose of this design is to produce a wind turbine design for beachside lighting and the target of this design is to craft a wind turbine design.

METHOD

Design contains an initial activity in the manufacturing process, which is necessary for the basics of stepping or working, generally presented in the form of flow diagrams as a method of design and planning.

In the general manufacture of a machine, especially turbine engines, the design aspect plays a significantly important role. Prior to the preparation and testing of the tool, the tool design serves as the initial requirement for tool-making description. The provided design contains the shape of the tool, the used machine component, the possible drawbacks, the critical points, the relationships with other machines and the mechanism of the tool, which presents as the basis for the next step in tool making.

RESULTS AND DISCUSSION

Windmills are regarded as one type of environmentally friendly renewable energy to supply the community's electrical energy needs. In general, the design and manufacture of HAWT (Horizontal Axis Wind Turbine) types are more complex than VAWT (Vertical Axis Wind Turbine) types. The HAWT windmill was selected based on the existing studies, meanwhile the wind characteristics in the southern coastal area of Malang Regency are laminar. Laminar winds are indicated by the shape of the trees leaning in one direction, suitable for the wind characteristics which are laminar, not turbulent. The blade type was selected based on research conducted by Kale and Varma explaining that the NACA 4412 Airfoil Profile is appropriate in micro scale wind turbines, as illustrated in Figure 1 [8].

To simplify the design process, the coastal area in the south of Malang Regency was selected. According to the conducted study, the wind speed in coastal area X is 3 - 7 m/s. To simplify the calculation, it is assumed that the wind speed is = 3 m/s, taking the minimum value, anticipated that if the speed is at the lowest value, the rotor could still rotate [9].

In the design, it is expected that the windmill can produce an output power of about 100 Watts at wind speed (V) = 3 m/s. Although the power is relatively small, it is sufficient to be used to turn on some lights on the beach that do not require a large amount of electricity. Considering the efficiency of the generator which cannot reach 100%, it is assumed that the generator efficiency value is (g) = 50%. While the maximum gearbox efficiency value is 95%, it is assumed that the generator efficiency value is (ηb) = 80%.

Based on Betz's theory, not all mechanical power of windmills is convertible into electrical energy, thereby considering the efficiency of the windmill or the coefficient of performance (Cp) not exceeding 60%, the convertible mechanical power into electrical energy is Assumed (Cp) = 20%.

FIGURE 1. Blades design of NACA 4412.

The International Standard Atmosphere (ISA) states that the standard air density (ρ) is 1.225 kg/m^3, but at an altitude of 3-5 meters, the density of air decreases to 1.145 kg/m^3. TSR in windmills contains the ratio between the tangential speed of the blade tip and the actual wind speed [10]. The rotor is designed to rotate at n = 300 rpm. Then the angular speed of the rotor in.rad/second is 31.4 rad/s and the TSR calculation determines the number of blades of 3.34.

Chrome SCr 5 steel is utilized as a shaft because it has b = 100 kg/mm^2, in the ASME standard, the safety factor reaches 5.6 for SF material with guaranteed strength, while for SC material with the influence of mass and alloy steel, having a safety factor of 6.0. The factor is expressed by Sf_1, while considering the effect of stress concentration hardness. Thus, it is necessary to consider a factor expressed as Sf2 with a value of 1.3 to 3.0. In this calculation, the minimum value of Sf_2 is arranged to 1.3, preventing the excessive diameter of the shaft, as shown in Figure 2.

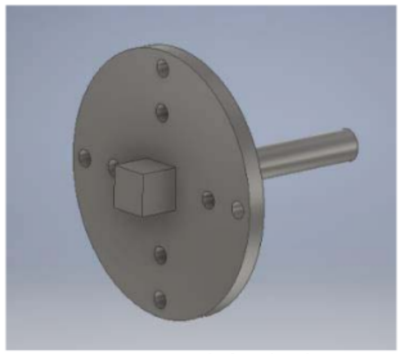

FIGURE 2. Shaft and Hub

The utilized transmission in this wind turbine is more feasible with a gear transmission, in which the generator requires 500 to 1000 rpm, while the wind turbine rotation is 300 rpm. The wind turbine generator is selected with the required specifications, including low rpm and DC current and obtaining a generator with a speed of 500-1000 rpm, suitable for micro-scale wind turbines. A realistic size for the tail fin cross-sectional area comprises between 5% to 10% of the rotor sweep area, where in this design, a tail cross-sectional area is utilized approximately 10%. The steering tail design is illustrated in Figure 3.

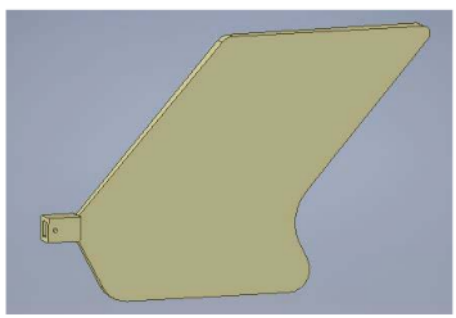

FIGURE 3. Steering Tail Design

The tail rod, centred on the axis of the rotor shaft, is determined by assuming one-third of the rotor diameter. The choice of tower poles is in accordance with the availability in the market, commonly utilized for low-voltage electricity poles, by employing thick aluminium material with a diameter of 3 inches or about 7.62 cm, and a pole length of 4 meters. The tower is helds with 4 steel ropes attached to the hook. Bars with concentric loads that were originally straight and the fibres, remain elastic until buckling occurs generating a small bend. The tower could carry a larger axial load even though it has flexed, but the tower begins to flex when reaching a load called buckling load.

At the end of the critical load, a column having a constant cross section could be in any direction. The critical force (Pcr) is theoretically obtained from the Euler formula. The load that occurs at the end of the tower is due to the nacelle, perpendicularly and symmetrical installed to the tower, in which maximum moment lies in the middle of the tower stem. The general wind turbine design is presented by technical drawing in Figure 4.

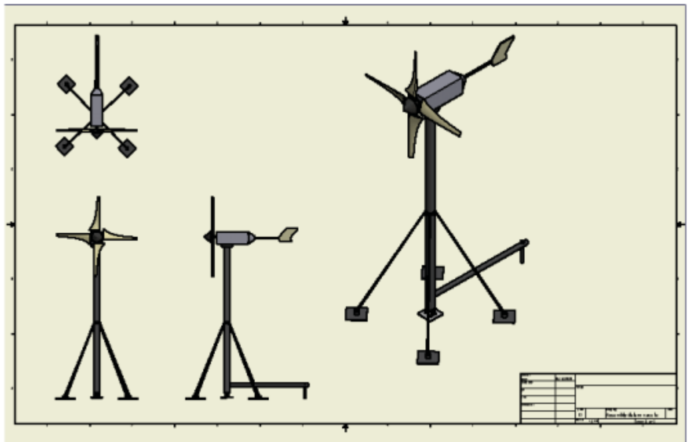

FIGURE 4. Wind Turbine Design

CONCLUSION

The design of the wind turbine utilizes a horizontal axis wind turbine (HAWT) type. The designed wind turbine blades consist of the 4 pieces using the NACA 4412 Airfoil profile which has a length of 50 cm. The wind speed becoming the reference in this design is located on the edge of the south coast which has wind speeds of around 3 m/s. The generator used in this design is classified in the type of low rotation generator, ranging from 500 to 1000 rpm with a maximum power of 270 Watt, while the planned output power is 100 - 125 Watt. The wind turbine is designed to have a tower-shaped support utilizing iron pipes, pulled by 4 steel ropes and plugged in each pointing to the 4 cardinal directions.

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