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WinP (Wind Innovation for Localized Power): A Vertical Axis Wind Turbine Design for San Roque, Maco, Comval Province

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Abstract. This study proposed the development of a renewable energy system named WinP (Wind Innovation for Localized Power) tailored for the localized data of San Roque, Maco, Compostela Valley (Comval) Province. The specific objectives included: 1) Simulating a design that converted wind power to electrical power, meeting the minimum average wind speed of San Roque, Maco, Comval Province using software; and 2) Generating a minimum of 100 watts of electrical power from the system. The design focused on achieving a minimum power output of 100 watts, informed by actual testing data and records from the Agro-Meteorological Research Station-University of Southeastern Philippines (USeP) Tagum Campus. The choice of a vertical wind axis was apt for the recipient community characterized by low-speed winds. The propeller, constructed from aluminum alloy, featured a 13-inch radius (equivalent to 0.33 meters) and was 31 inches long (equivalent to 0.8 meters). During actual testing, the propeller exhibited free rotation at a wind speed of 2.5 m/s, indicating the ideal torque at this velocity. Furthermore, analysis of the testing data revealed that wind speeds ranging from 3.8 m/s to 5.3 m/s successfully achieved the target power output of at least 100 watts. This research bridged the gap between simulation and practical application, demonstrating the viability of the WinP design in harnessing wind energy for sustainable power generation in San Roque.

Keywords. VAWT, renewable, wind energy, localized power, sustainability

1. Introduction

Wind energy is a globally recognized and significant technological advancement that plays a crucial role in the shift to renewable energy sources. It is dedicated to promoting sustainability ideals and aims to replace traditional fossil fuels. One promising device that is gaining traction in this field is the Vertical Hub Wind Turbines. These turbines are designed to efficiently capture wind energy from multiple directions, eliminating the need for complex systems like yaw mechanisms or downwind coming. While it is worth

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noting the benefits of having electrical generators located at ground level, some specific designs may not have the capability to start operating automatically [1].

The focus of this study is specifically on Vertical Axis Wind Turbines (VAWTs), as they can significantly contribute to meeting the world energy demand [2]. In contrast to the frequently employed Horizontal Axis Wind Turbines (HAWTs), Vertical Axis Wind Turbines (VAWTs) demonstrate a predilection for low wind velocities and provide adaptability in selecting appropriate installation locations. The primary objective of this study is to enhance the design and functionality of Vertical Axis Wind Turbines (VAWTs) to enhance its appeal, effectiveness, and durability.

The Philippines has emerged as a key participant in the field of wind energy, surpassing other members of the Association of Southeast Asian Nations (ASEAN) in terms of installed capacity. The nation presently owns a functional wind energy capacity of 400MW and has established ambitious goals to increase this capacity to 1,600 MW within the next 2-3 years [4]. The Philippines anticipates a significant surge in the need for power to propel its economy. This underscores the imperative to augment the capability for electricity production, embracing both traditional fossil fuel-based sources and environmentally viable renewable sources. The predominant concentration of wind farm power output is now observed in Bangui, Ilocos Norte, where it exhibits a noteworthy capacity of 17,181.576 MWh – 19,742.881MWh [5].

This paper is focused on a specific geographical setting, namely Barangay San Roque in Maco, Comval Province. The aim of this study is to design a wind propeller (WinP) that is suitable for the prevailing wind patterns in a particular geographic region. This study concentrated on the vertical design of a wind turbine since it is more suitable for areas characterized by low wind velocities [6]. Moreover, the turbine has been engineered with a focus on achieving economic efficiency by including easily producible components.

The primary objective of this study is to develop and validate a vertical axis wind propeller design, to address the specific energy requirements of San Roque, Maco, Comval Province. The primary aims of this study endeavor encompass the simulation of the design with the purpose of efficiently transforming wind energy into electrical energy, while guaranteeing its compliance with the minimum average wind velocity documented in San Roque, Maco, Comval Province. This objective will be accomplished by employing suitable software. In addition, it is anticipated that the system under consideration will have the capability to produce a minimum of 100 watts of electrical power. The set of objectives presented here establishes a cohesive framework for the research, guaranteeing its congruence with the unique energy demands of Barangay San Roque as its special local setting.

2. Methodology

2.1. Theoretical and Conceptual Framework

Figure 1 presents a theoretical framework describing a wind energy conversion system, wherein wind is considered the input variable containing kinetic energy. The rotor utilizes the kinetic energy of the wind to facilitate the rotation of the shaft, with the gearbox serving a vital function in transforming the low rotational speed caused by the wind into high torque, enhancing the generator's efficiency. Subsequently, the generator converts mechanical energy into electrical energy, yielding a pristine 100-watt output that is accessible in both direct current (DC) and alternating current (AC) formats. The present system effectively gathers, transforms, and distributes renewable energy, smoothly integrating various components to ensure reliable power generation.

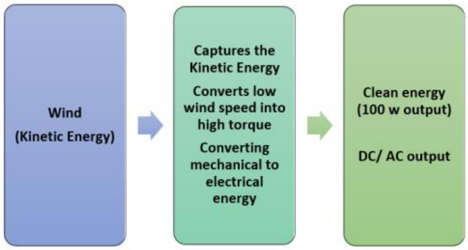

Figure 1. Theoretical Paradigm of variables

The system design process is depicted in Figure 2. The turbine blades, engineered explicitly for low-speed spinning, sustain a uniform lateral flow field across different blade heights. When wind encounters opposed surfaces, it applies specific forces. The gearbox enhances the torque of the prime mover's output shaft speed while the vertical wind turbine rotates. Subsequently, the mechanical energy is transformed into electrical power by the alternator. Following this, the inverter converts the alternating current output of the generator into a direct current. At the same time, the charge controller maintains a stable connection during operation, mitigating potential problems such as over-speeding or low-speed performance, particularly in high wind conditions. Simultaneously, it observes the voltage of the battery, a crucial aspect for storing collected energy, power generation, and providing a consistent load of no less than 100 watts.

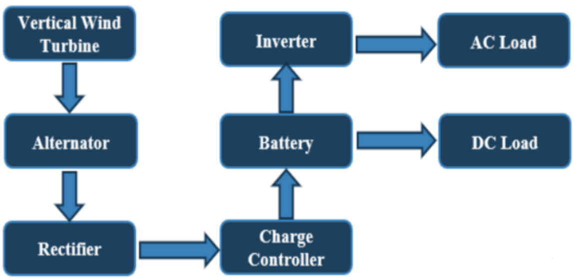

Figure 2. Conceptual framework

2.2. Research Process

The researchers adhered to a systematic methodology encompassing the stages of Planning, Organizing, Implementing, Controlling, and Evaluating. During the first planning stage, a propeller was conceived to operate efficiently at low wind speeds and produce a minimum power output of 100 watts. The examination of materials preceded the structure of the conceptual framework, and a 3D design (Figure 3, Figure 4, Figure 5 and Figure 6) was developed as the desired component for the system. The primary emphasis was placed on modeling the three-dimensional design using Analysis System

(ANSYS) software to achieve optimal performance before the physical construction of the system.

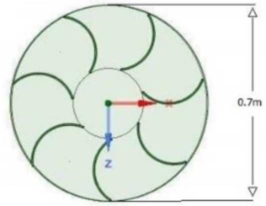

Figure 3. ANSYS design of propeller (top view).

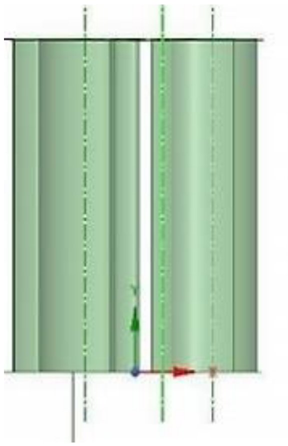

Figure 4. ANSYS design of propeller (side view).

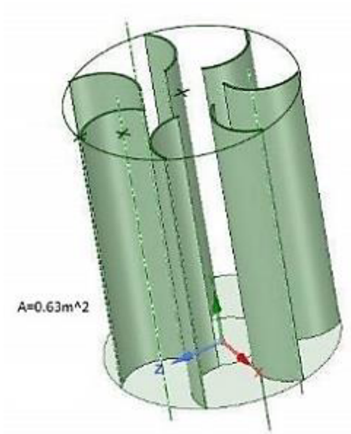

Figure 5. ANSYS design of propeller (3D view).

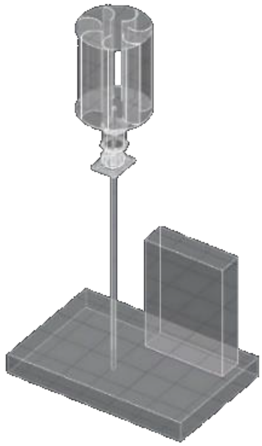

Figure 6. ANSYS design of prototype.

During the implementation phase, construction activities were initiated after a comprehensive examination of materials and connections under the guidance of the tangible outcomes derived from the simulation. The researchers used control measures by conducting weekly monitoring of the building of the prototype, thereby promoting collaboration among team members to facilitate ongoing improvements in the design. The research study yielded a favorable result, as evidenced by the inclusion of Figure 5, which showcases the 3D design.

The chosen research site was in San Roque, located in Maco, Compostela Valley. This location was selected because of its abundant wind resources as it is close to the shoreline. The objective was to design a wind energy system capable of generating clean electrical power to benefit both end-users and the natural environment. Valuable insights were offered by respondents affiliated with the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), confirming the collected data and furnishing essential information for constructing a vertical axis wind turbine.

The researchers utilized the Digital Wind Speed Meter Anemometer as their data collection tool, facilitating the acquisition of accurate wind speed data for their study. The hardware specifications of the vertical axis wind propeller intended for localized data collection within the same vicinity encompass a Savonius-type Vertical Axis Wind Turbine characterized by a significant diameter of 1500mm. Additionally, the WInP is equipped with a configuration consisting of seven semi-circular bladed rotors. The research design includes the utilization of a gearbox featuring a ratio of 1:4, an Alternator with a power rating of 120 watts, a current rating of 10A, and a rated voltage of 12V.

Furthermore, the system is equipped with a charge controller that has a rated voltage of 12 volts direct current (VDC) or 24 volts direct current (VDC) and a maximum current of 40 amperes (A). It also includes an inverter specifically built as a sine wave inverter, operating at 12VDC, and producing an alternating current (AC) of 220 volts (VAC). The inverter has a power rating of 600 watts. The proposed energy storage system entails the utilization of a deep cycle battery. Regarding software applications, ANSYS is employed for system simulation, generating preliminary outcomes based on computed dimensions. At the same time, AUTOCAD is utilized to create an optimal three-dimensional depiction of the project design.

3. Results and Discussion

In this section, the researchers presented a comprehensive collection of data and observation. This encompasses the outcomes derived from computer simulations as well as the actual load output of the system. The researchers have proposed the adoption of a Vertical Axis Wind Turbine (VAWT) due to its suitability for regions with low wind speeds [7]. The following paragraphs will expound on additional details regarding the research findings.

3.1. Design Simulation Output

The development of the Vertical Axis Wind Turbine entails a comprehensive design procedure conducted via computer simulation utilizing ANSYS, a widely recognized engineering simulation software known for its ability to forecast the practical performance of designs correctly [8].

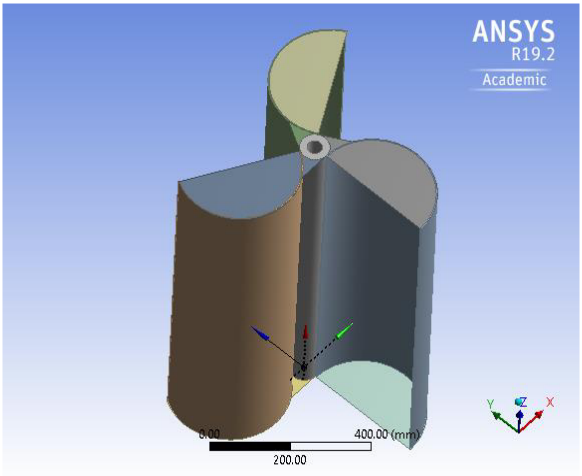

Figure 7. Isometric view of the wind propeller.

Following a series of modifications and drawing insights from multiple trials, the researchers ultimately arrived at a design incorporating a vertical-axis wind turbine with three blades. Figure 7 presents an isometric perspective, showcasing the intricate composition of our propeller. The strategic choice to utilize a three-blade configuration for the propeller is intended to improve its maneuverability through weight reduction and ensure efficient rotation per the available wind speed data.

The top view of the propeller design shown in Figure 8 shows the simple structure designed by the researchers. Aluminum alloy is used to make the propeller, which will be further explained on the latter part of this study. In the simulation, the propeller is more harmonized with the wind speed when the blades are bended 180 degrees. The propeller designed by the researchers has 13-inch or equivalent to 0.33- meter radius and it is 31-inch long or equivalent to 0.8- meter, shown in Figure 8 and Figure 9 respectively.With this structure and its respective dimensions, the proponents proceeded into the computer simulation. The maximum and minimum speed of the area is inputted, and the researchers came up with torque outputs.

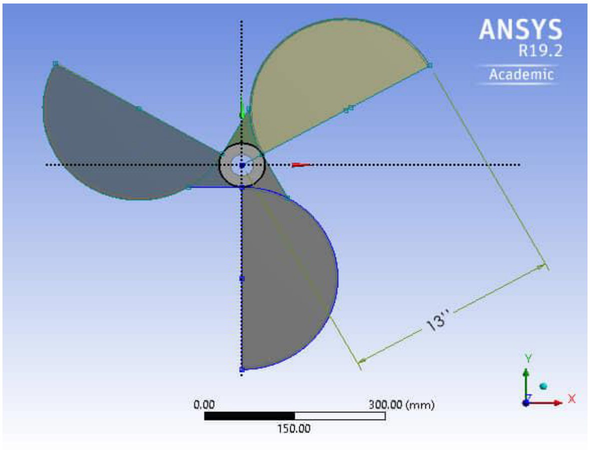

Figure 8. Top view of the wind propeller.

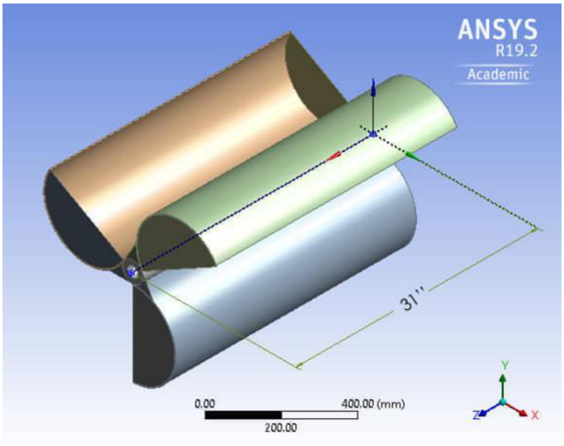

Figure 9. Isometric view of the wind propeller's length.

3.2. Simulation Results vs Actual Results

The results shown in Table 1 presents that the structure is convenient with the wind speed of the San Roque, Maco, Comval Province. On the research done by the proponents, it is said that the output of a rotating body is obtained from Equation 1.0.

$$P = Tw \tag{1}$$

where P is the output power in watts and T stands for Torque induced with unit of N-m and w is the angular speed with unit of radian per second.

To use Eq. (1), the researchers converted first the wind speed into angular speed by dividing the wind speed over the radius. Then the angular speed is multiplied to the torque output from the simulation which leads with these results shown in Table 1.

The attachment of the alternator is excluded from this simulation which may affect the output of the simulation and the real-life environment. To make everything functional, the researchers decided to use aluminum alloy to make the propeller. Aluminum alloys are one of the lightest metals; they are often used on making a bicycle frame [9]. The shaft that is connected to the alternator is also made from the aluminum alloy. The proponents used a permanent magnet three-phase alternator because it is more effective working with turbines [10].

Table 1. Torque and power input

Wind Speed	Torque	Power Input
2.5 m/s	18.9 N-m	143.68 watts
9.7 m/s	51.4 N-m	1509.93 watts

The researchers proceed to the actual testing of the system. Table 2 shows the data gathered on a five-day span. The current read will be multiplied into three because the testing of current is measured on one line of the three-phase alternator. The table above reflects that the minimum wind speed (1 m/s to 3.1 m/s) does not provide the target output stated on one of the objectives. Hence, the wind speed at 3.8 m/s to 5.3 m/s achieved the target of load of at least 100 watts.

Table 2. Actual data from test

Wind Speed (m/s)	Revolutions per Minute (rpm)	Current Output (amperes)	Voltage Output (volts)
1	105	0.82	10.6
1.4	130	1.26	11.82
2.5	195	1.93	12.34
3.1	235	2.21	12.53
3.8	285	2.62	12.72
4.2	347	2.81	12.91
4.8	365	2.97	13.02
5.3	438	3.12	13.66
1	105	0.82	10.6

On the actual testing, the propeller freely rotates with the speed of 2.5 m/s. Thus, the ideal torque at 2.5 m/s (based on the computer simulation), is surpassed by the actual torque produced during the actual testing.

Figure 10. Final structure of the design.

Figure 10 shows the final structure of our design. The propeller above is the exact replica from the computer simulation performed by the researchers. The system has a height of approximately 15 feet.

4. Conclusion

During the system design period, the researchers utilized computer simulations with ANSYS software to determine the exact measurements corresponding to the specific environment's localized wind data. The researchers conducted tests to replicate the hardware dimensions and determined that the system effectively rotates following the wind characteristics of San Roque, Maco, Comval Province.

Under the influence of significant wind speeds, namely ranging from about 4 to 6 m/s inside the designated area, the voltage measurements exhibited a range between 12 and 12.8 V. These voltage readings were accompanied by a similar current range of 2.5 to 2.8 A, as observed on a singular line of the three-phase alternator. Based on the data, the researchers propose improving the project's design by eliminating the propeller's sleeve, thereby mitigating its weight. It is anticipated that a lighter propeller will exhibit more consistent rotation in the low wind speeds that are commonly observed in the region. Recognizing the fundamental significance of maintaining a steady and robust wind resource for the efficacy of a wind-based renewable energy system, the researchers suggest deploying such systems in areas characterized by a dependable and suitably high wind speed, ideally ranging from 4 m/s to 6 m/s consistently.

Further studies may focus on enhancing the performance of WinP through the exploration of design parameter variations, including blade shape, materials, and dimensions. Moreover, thorough lifecycle analyses and environmental impact assessments could be undertaken to guarantee the sustainability of WinP throughout its entire life cycle, spanning from manufacturing to decommissioning. Investigating the scalability of WinP and exploring strategies for mass production is essential, as is its integration into smart grid systems to enable effective load management and ensure grid stability.

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