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Design and Construction of a Wooden Shaped Portable Mini Vertical Axis Wind Turbine Using a Bicycle Wheel Pulley and Car Alternator

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Abstract - This publication presents the design, construction and preliminary performance evaluation of a portable mini vertical axis wind turbine developed using locally available materials. The project was motivated by the continuous rise in the cost of fuels in Nigeria and the growing national and global quest for renewable and sustainable energy sources. The system employs a vertical rotor mounted on a plywood structural frame shaped as a compact enclosure, with mechanical power transmission achieved through a bicycle wheel used as a pulley. Electrical energy conversion is performed using a car alternator coupled to a battery storage system through a charge controller and inverter. The aim of this research is to demonstrate a simple and affordable renewable energy solution suitable for small-scale off-grid power generation, particularly in developing regions. Basic engineering calculations are provided to estimate wind power capture, mechanical transmission ratio and expected electrical output. Results indicate that the prototype can generate useful electrical energy at low wind speeds, making it suitable for rural and urban applications.

Keywords: Vertical Axis Wind Turbine, Bicycle Wheel Pulley, Car Alternator, Renewable Energy, Low-Cost Turbine.

I. INTRODUCTION

The rising cost of fuels in Nigeria, coupled with frequent power shortages and environmental concerns, has intensified the search for alternative and renewable energy sources. Dependence on petrol and diesel generators for electricity generation has become economically burdensome for households and small businesses. Consequently, renewable energy technologies such as wind and solar power are increasingly being explored as sustainable solutions. Wind energy is one of the most mature and widely adopted renewable technologies worldwide. Conventional horizontal axis wind turbines dominate commercial applications. However, vertical axis wind turbines offer advantages such as simplicity of construction, omnidirectional wind acceptance, and suitability for low wind speed environments. In many developing regions, including rural communities in Nigeria, access to grid electricity remains limited. Locally fabricated wind turbines like this can provide a viable small-scale power solution using readily available materials. This research carried out by mechanical engineers at National space research and development Agency (NASRDA), focuses on the development of a mini portable vertical wind turbine constructed using a bicycle wheel as a pulley system and a car alternator as the electrical generator.

The system integrates a battery, charge controller, battery indicator, and a 3000 W inverter to supply usable alternating current (AC).

The objective of this study is to design and analyze a low-cost wind energy conversion system motivated by the need to reduce dependence on fuels, lower energy costs, and promote renewable energy utilization in Nigeria.

The paper presents a locally fabricated portable wooden (coffin shaped) designed vertical wind turbine with mechanical drive aided with the use of belt, transmitting Power through an alternator to a battery storage and dispensed by an inverter

II. LITERATURE REVIEW

Extensive research has been conducted on vertical wind turbine aerodynamic optimization and modeling.

Sarneje et al. (2025) reviewed aerodynamic optimization and hybrid integration strategies across 80 peer-reviewed works, identifying major trends and research gaps, although without practical implementation. Morgan et al. (2025) investigated blade inclination and chord distribution, demonstrating their significant influence on aerodynamic efficiency and structural loading. Gupta et al. (2025) studied variable blade pitch systems and reported improvements in torque and lift under varying wind conditions.

Alina et al. (2025) employed Computational Fluid

Dynamics (CFD) analysis to compare Savonius, Darrieus, and spiral VAWT configurations, identifying suitable designs for low-wind urban environments. Similarly, Roga et al. (2025) demonstrated that CFD simulations provide a cost-effective approach for evaluating VAWT performance. Zakıs et al. (2025) proposed improved blade shapes optimized for low wind speed applications, while Zhang et al. (2024) investigated self-starting enhancement devices for vertical axis turbines.

Hameed and Afaq (2013) modeled blade parameters for small VAWTs targeted at achieving 1 kW output. Jin et al. (2015) highlighted the advantages of Darrieus VAWTs over Horizontal Axis Wind Turbines (HAWTs), particularly under turbulent wind conditions. Srivastava (2022) reviewed aerodynamic challenges and computational tools used in wind turbine analysis. Mohammed et al. (2021) developed hybrid Darrieus−Savonius turbines integrated into buildings, while Rusianto et al. (2023) investigated generator integration in small-scale VAWTs. Su et al. (2020, 2023) further improved blade design and aerodynamic performance of vertical axis turbines.

Several researchers have also investigated the design and development of portable and small-scale wind power generators with emphasis on low cost, efficiency, and user-friendly operation. Augus et al. (2021) developed a low-cost portable hybrid wind−hydro power source for emergency charging of small batteries in disaster scenarios, demonstrating the feasibility of combining renewable energy inputs for portable applications.

Md Zakir et al. (2023) and Joyeshree Biswas and Suman Das (2024) evaluated portable wind generators utilizing airflow from moving vehicles. Their studies established a relationship between wind speed and power output, confirming that vehicular-induced airflow can be harnessed for renewable electricity generation. Kristel et al. (2024) designed and field-tested a portable wind turbine power bank for charging small electronic devices such as lamps and smartphones in remote outdoor environments.

Rodriguez Martinez (2025) used simulation techniques to estimate the performance of do-it-yourself portable wind turbine blades, emphasizing the importance of blade geometry in improving output efficiency. Achmad and Muslim (2021) demonstrated portable wind generators through simulation-based models, illustrating the conversion of mechanical motion into renewable electrical energy. Adegbenro et al. (2022) proposed an improved portable wind turbine system using concentric wound coils as an alternative to permanent magnets in alternators.

Chengyu et al. (2021) investigated triboelectric nanogenerators for wind energy harvesting and concluded that low-speed wind can effectively be utilized through material-based energy conversion methods. Prajzendanc (2025) reviewed emerging technologies in wind turbine generators, including axial-flux machines and superconducting generators for portable and hybrid micro-grid systems. Ajike and Akinlolu (2023) designed a compact portable wind turbine integrated with solar panels for USB charging applications.

Further contributions include Mthethwa et al. (2024), who integrated portable wind turbines into mobile cooling systems for agricultural transport, and Patel and Kumar (2016), who developed a low-wind-speed portable turbine suitable for rural electrification. Rahman and Al-Hadhrami (2014) demonstrated that Vertical Axis Wind Turbines (VAWTs) perform better under turbulent and multidirectional winds, making them suitable for portable systems. Singh and Verma (2015) emphasized the importance of portable wind energy systems in reducing dependence on fossil fuel generators in rural areas.

UNIQUENESS OF THE PRESENT STUDY

While previous studies focused on portable wind turbines for charging small devices, vehicular airflow harvesting, hybrid solar–wind systems, or micro-scale generators, the present work introduces a distinct design approach. The uniqueness of this project lies in the use of a specially designed wooden (plywood) structural enclosure combined with a vertical axis rotor and mechanical pulley transmission using a bicycle wheel and car alternator.

Unlike many fixed or tripod-mounted designs reported in literature, the proposed system is fully portable and movable, allowing it to be transported and deployed in different locations according to wind availability and power demand.

Furthermore, the system is configured to operate in a manner similar to a portable fuel generator, in which it can be relocated from one point to another as required. This portability, combined with its low-cost locally available materials, distinguishes the present prototype from existing portable wind turbine designs and enhances its suitability for rural electrification, emergency power supply, and off-grid renewable energy applications.

System Description

The mini wind turbine consists of the following major components:

Vertical Rotor Assembly – Four vertical blades mounted on a circular base, designed to capture wind from any direction.

Mechanical Transmission System – A bicycle wheel fixed to the rotor shaft acting as a large pulley.

Generator Unit – A car alternator connected to the bicycle wheel using a belt drive.

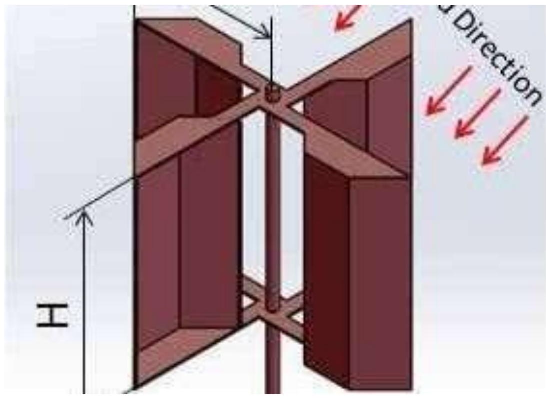
Energy Storage and Conditioning – A battery, charge controller, battery indicator, and a 3000 W inverter.

Structural Frame – A plywood enclosure shaped as a compact box (coffin-like geometry) for housing mechanical and electrical components.

The turbine operates by converting wind kinetic energy into mechanical rotation of the vertical shaft. The bicycle wheel increases torque transmission to the alternator through belt coupling. The alternator produces DC electricity which is regulated by the charge controller and stored in the battery. The inverter converts stored DC power to AC for end-use applications.

III. DESIGN METHODOLOGY

3.1 Rotor Design



The rotor is a vertical axis type with four blades arranged symmetrically around a central shaft. The effective swept area (A) of the turbine is defined as:

$$A = H \times D$$

where: H = height of the rotor (m) D = diameter of the rotor (m)

For a prototype with H = 0.6 m and D = 0.5 m:

$$A = 0.6 \times 0.5 = 0.30 \text{ m}^2$$

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3.2 Mechanical Transmission

A bicycle wheel of diameter 0.6 m is used as the main pulley, while the alternator pulley

diameter is approximately 0.05 m. The speed ratio is given by: Speed ratio = D_large / D_small
Speed ratio = 0.6 / 0.05 = 12

This means that for every 1 revolution of the turbine shaft, the alternator rotates approximately 12 times, increasing the generator speed to a usable range.

3.3 Electrical System

The alternator charges a 12 V battery through a charge controller. A battery indicator monitors charge level, and a 3000 W inverter converts DC to AC (220–240 V).

IV. THEORETICAL POWER ANALYSIS

4.1 Available Wind Power

The theoretical wind power available is given by:

$P\_w = 0.5 \times \rho \times A \times v^3$

where: ρ = air density (1.225 kg/m³) A = swept area (0.30 m²) v = wind speed (m/s)

Construction Materials

Plywood sheets (for enclosure and base) Bicycle wheel (pulley)
Rubber belt Car alternator
Vertical steel shaft Bearings
Charge controller 12 V battery Battery indicator
3000 W inverter

V. WORKING PRINCIPLE

Wind flows across the vertical blades, causing the rotor to spin. The rotating shaft turns the bicycle wheel pulley. Through belt transmission, the alternator rotates at higher speed, generating DC electricity. The charge controller regulates the voltage and current supplied to the battery. The inverter converts stored DC electricity into AC power suitable for domestic appliances.

VI. RESULTS AND DISCUSSION

Initial testing of the prototype shows that the turbine begins rotation at low wind speeds due to its vertical axis configuration. The pulley system significantly increases alternator rotational speed. Although the measured power output is modest, it demonstrates feasibility for charging small batteries and powering low-load devices such as LED lamps and phone chargers.

Losses occur due to friction in bearings, belt slippage, and inefficiency of the car alternator at low speeds. Improved blade design and use of a permanent magnet generator could significantly enhance performance.

VII. APPLICATIONS

Rural Electrification

Educational demonstration of renewable energy systems

Battery charging stations

Low-power household devices

CONCLUSION

This research demonstrates the successful design and construction of a mini vertical axis wind turbine using a bicycle wheel pulley and car alternator. The system is low-cost, easy to fabricate, and suitable for small-scale renewable energy generation. Theoretical calculations confirm that useful electrical output can be achieved under moderate wind conditions. Further work will focus on blade optimization, improved generators, and structural reinforcement.

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