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An Expository Review of Components Used in a Portable Wind Turbine in Centre for space innovation and development, NASRDA

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Abstract- This paper presents an expository review of selected components and materials used in the construction of a portable Vertical Axis Wind Turbine developed at the Centre for space innovation and development in National Space Research and Development Agency (NASRDA) using locally available resources. The study examines the characteristics, functions, material selection, and suitability of the major components incorporated into the turbine system. These include plastic rotor blades, a bicycle wheel pulley mechanism, shaft, bearings, car alternator, battery storage unit, charge controller, inverter, and supporting wooden frame structure. Particular attention is given to the reasons for selecting each component and material, considering factors such as availability, affordability, ease of fabrication, mechanical strength, durability, maintainability, and suitability for low-speed wind energy conversion. The study further explains how the individual components interact to facilitate the conversion of wind energy into mechanical energy and subsequently into electrical energy for storage and utilization. The findings demonstrate that locally available materials and repurposed components can be effectively incorporated into the construction of a portable vertical axis wind turbine, providing a practical and cost effective approach to small scale renewable energy generation. The study provides useful technical information for researchers, students, engineers, and other practitioners interested in the design, fabrication, and application of portable vertical axis wind energy systems.

Keywords: portable wind turbine; vertical axis wind turbine; wind energy; renewable energy; wind turbine components; mechanical components; electrical components; energy storage; automotive alternator; bicycle wheel pulley.

I. INTRODUCTION

The growing demand for electrical energy, coupled with the rising cost of fossil fuels and frequent power outages, has increased the need for alternative and renewable energy sources worldwide. In many developing countries such as Nigeria, access to reliable electricity remains a major challenge, particularly in rural and remote communities. Renewable energy technologies, especially wind energy systems, have become attractive solutions due to their environmental friendliness, sustainability, and ability to operate independently of the national grid.

Wind turbines convert the kinetic energy of moving air into electrical energy. Among the various turbine designs, the vertical axis wind turbine is suitable for low wind speed environments because of its simple construction, omnidirectional wind acceptance, and ease of maintenance. Portable wind turbines further provide flexibility, mobility, and convenience for small-scale power generation.

This study focuses on the exposition of the components and materials used in the construction of a portable vertical axis wind turbine fabricated with locally sourced materials. The system utilizes a bicycle wheel as a pulley mechanism and a car alternator for electrical energy conversion. Other supporting components include wooden blades, shaft, bearings, battery, charge controller, inverter, and structural support frame. The selection of these materials was based on affordability, availability, strength, lightweight properties, and operational efficiency.

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II. AIM AND OBJECTIVE

The aim of this paper is to explain the functions and significance of the selected components and materials in the design and operation of the portable wind turbine system. To demonstrates how locally available resources can be effectively utilized to develop low cost renewable energy technologies capable of supporting small-scale electricity generation in developing regions.

III. COMPONENT BASED CITATION

Rotor/blades: Özer et al. (2026)
Bicycle wheel: Ocheja et al. (2026); Ahmed et al. (2026)
Shaft: Ocheja et al. (2026)
Bearing: Martin-del-Campo et al. (2019)
Alternator: Ani et al. (2014)
Battery: Drouilhet et al. (1995)
Charge controller: Ndiaye et al. (2014)
Inverter: Ocheja et al. (2026)
Wooden frame/material: Ahmed et al. (2026)

IV. LITERATURE REVIEW

Muljadi (1995), in Optimizing Small Wind Turbine Performance in Battery Charging Applications, explained that batteries are essential for storing electrical energy generated by small wind turbines and supplying power during periods of low or no wind. He emphasized the importance of matching the generator with the battery bank to maximize charging efficiency.

De Broe, Drouilhet and Gevorgian (1999) further showed that proper battery charging and power tracking significantly improve the energy output of small wind turbine systems.

Lubitz (2014), in Small Wind Power Generation Using Automotive Alternator, investigated the use of automotive alternators in small wind turbines and concluded that, with appropriate gearing, they can effectively generate electricity for battery charging at relatively low cost.

Muljadi (1995) also discussed the application of permanent magnet alternators in battery-charging wind turbines and their performance characteristics.

Martin-del-Campo, Sandin and Strömbergsson (2019), in Dictionary Learning Approach to Monitoring of Wind Turbine Drivetrain Bearings, reported that bearings are among the most critical components of wind turbines, as their condition directly affects efficiency, reliability, and maintenance requirements.

Ocheja Joseph, David C. Udeabor, Kabiru Nuhu Umar, Ejiga A. Ejiga and Obiora Agbo (2026) used a 600 mm bicycle wheel as the transmission mechanism in a stand-mounted vertical axis wind turbine integrated with an automotive alternator and battery storage.

Abduljafar Ahmed, Ramatu Dangogo, Esomu Emanoke, Oyewole Omotayo O. and Vivian O. Akanbi (2026) also reported the use of a bicycle wheel pulley in the construction of a portable mini vertical axis wind turbine because of its low cost, availability, and ease of fabrication.

Early studies established the importance of power electronics in wind energy systems. Slootweg and Kling (2003) demonstrated that inverter-based wind turbines improve grid compatibility, power quality, and system controllability. Bhadra, Kastha and Banerjee (2010), Burton et al. (2011), Ackermann (2012), Patel (2005), Rashid (2014), and Heier (2014) further explained that inverters regulate voltage and frequency, enable maximum power point tracking (MPPT), improve energy conversion efficiency, reduce mechanical stress, and ensure reliable integration of wind-generated electricity into the power grid.

Research on Vertical Axis Wind Turbines has also progressed significantly. Bhutta et al. (2012) reviewed various VAWT configurations, highlighting their advantages, limitations, and the use of Computational Fluid Dynamics (CFD) for aerodynamic optimization. Hameed and Afaq (2013) developed an optimized blade design for small VAWTs, while Jin et al. (2015) compared Horizontal

Axis Wind Turbines (HAWTs) and VAWTs, concluding that although HAWTs dominate the industry, VAWTs offer promising alternatives for low-speed and urban environments.

Experimental and numerical studies have further enhanced VAWT performance. Agbormbai and Zhu (2020), Su et al. (2020), Mohammed Ibrahim et al. (2021), Srivastava (2022), Rusianto and Huda (2023), and Zhang et al. (2024) investigated hybrid Darrieus–Savonius turbines, auxiliary blades, generator integration, aerodynamic behaviour, CFD modelling, and self-starting mechanisms. Their findings showed improved power coefficient, torque, generator performance, and energy capture, especially under low wind speed conditions.

Recent investigations have focused on advanced optimization techniques. Samjeje et al. (2025) reviewed approximately 80 peer-reviewed studies on aerodynamic optimization, hybrid integration, and control strategies. Morgan et al. (2025), Gupta et al. (2025), Giri Ajay et al. (2025), Zakis et al. (2025), Roga et al. (2025), Alina et al. (2025), and Huan Liu and Richard D. James (2025) examined blade inclination, variable blade pitch, wake prediction, CFD simulations, comparative rotor configurations, machine-learning optimization, and hybrid VAWT designs. These studies consistently reported significant improvements in aerodynamic efficiency, power output, structural performance, and offshore deployment potential.

Supporting studies by Su et al. (2023), Le Fouest and Mulleners (2022), Ouro and Lazennec (2020), and Hand and Cashman (2020) further investigated serrated blade designs, dynamic stall behaviour, wake interactions, and the historical evolution of VAWTs, providing valuable guidance for future turbine optimization.

Regarding mechanical power transmission, several researchers have demonstrated the effectiveness of pulley and belt drive systems in small wind turbines. Ajayi (2012), Ravi Anant Kishore et al. (2013), Alex Van den Bossche (2013), Vivek Kumar and Verma (2015), Gebreel Abdalrahman et al. (2017), Abdullah Alsuhaim (2017), Rizky Brillian Yuliandi et al. (2018), Sarwono et al. (2020), Madhan Mohan Cheepinapi et al. (2023), Shreya N. Wishwakarma et al. (2023), Radon Dhelika et al. (2023), Davin Tjandra et al. (2025), and Ihat Solihat and Dimas Abimanyu (2026) successfully applied bicycle wheels, pulleys, belts, chains, timing belts, and gear trains to transmit rotational motion and increase generator speed. These studies confirmed that pulley belt systems provide a simple, cost-effective, reliable, and efficient means of power transmission, making them highly suitable for portable and low-cost wind turbine designs.

The performance, durability, and efficiency of a portable wind turbine depend largely on the appropriate selection of its components and construction materials. The prototype was designed using locally available, affordable, and durable materials to minimize production cost while maintaining satisfactory performance. The major components are discussed below.

V. METHODOLOGY

The methodology adopted for this study was based on an expository examination of the selected components and materials used in the construction of the portable Vertical Axis Wind Turbine developed at the National Space Research and Development Agency (NASRDA). Each selected component was examined individually to establish its material composition, physical characteristics, function, method of integration, and contribution to the successful operation of the turbine system.

The study focused on the major components, including the plastic rotor blades, bicycle wheel pulley mechanism, shaft, bearings, car alternator, battery storage unit, charge controller, inverter, and supporting wooden frame structure. For each component, its specific function within the system was identified and explained, while consideration was given to why the particular material or component was selected. Factors such as availability, cost, strength, durability, ease of fabrication, maintenance, and suitability for the operating conditions of the turbine were also considered.

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The interaction between the individual components was subsequently examined to determine how they collectively contributed to the conversion of wind energy into mechanical energy and ultimately into usable electrical energy. Particular attention was given to the transmission of rotational motion from the rotor through the pulley and shaft arrangement to the alternator, followed by electrical regulation, energy storage, and power conversion through the charge controller, battery, and inverter.

The methodology therefore involved a component-by-component functional and material assessment, supported by observations made during the fabrication, assembly, and operation of the portable . This approach provided a systematic basis for explaining the role and significance of each selected component and material in achieving the intended performance of the complete system.

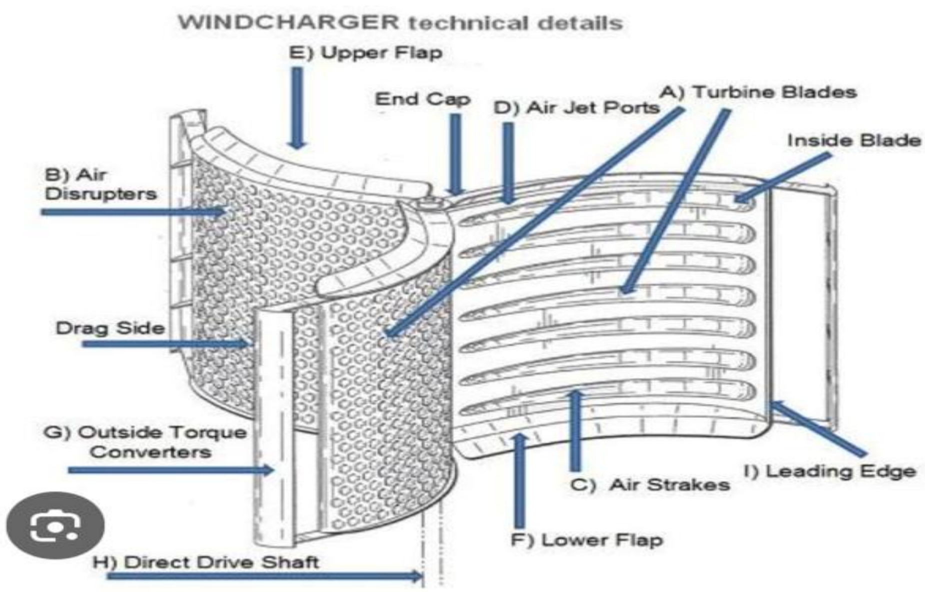
VI. DISCUSSION

Mechanical Components

The mechanical components of the portable Vertical Axis Wind Turbine are responsible for capturing wind energy, producing rotational motion, and transmitting the mechanical power generated by the rotor to the electrical generating unit. The major mechanical components examined in this study include the rotor blades, bicycle wheel pulley mechanism, shaft, bearings, and supporting wooden frame.

6.1 Plastic Rotor Blades

The plastic rotor blades constitute the primary wind-catching element of the turbine. They were fabricated from locally available wood selected for its accessibility, ease of shaping,



relatively low cost, and adequate strength for the intended application. The blades are arranged around the vertical axis of the turbine so that they can interact with wind approaching from different directions.

The principal function of the rotor blades is to convert the kinetic energy of moving air into rotational mechanical energy. As wind acts on the surfaces of the blades, aerodynamic forces are produced, causing the rotor to rotate about its vertical shaft. The use of plastic also makes the blades relatively easy to fabricate, modify, and repair using locally available tools. However, proper finishing and protection of the plastic are necessary to reduce the effects of heat, weathering, and prolonged exposure to outdoor conditions.

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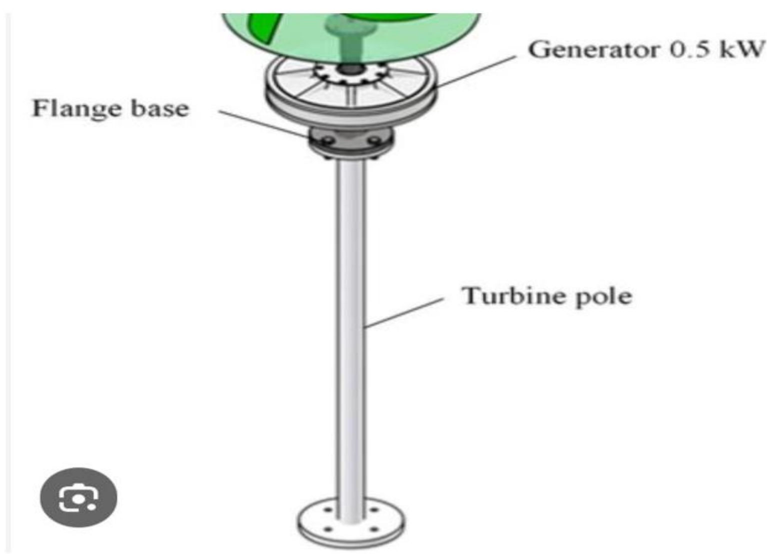
6.2 Bicycle Wheel Pulley Mechanism

A bicycle wheel was incorporated into the system as part of the mechanical power transmission arrangement. The wheel provides a practical and readily available means of transferring rotational motion from the turbine rotor to the alternator.

Its function is to facilitate the transmission and, depending on the pulley arrangement, appropriate adjustment of rotational speed between the turbine shaft and the alternator. The use of a bicycle wheel demonstrates the possibility of adapting readily available and discarded mechanical components for renewable-energy applications. This approach reduces fabrication costs while providing a relatively simple mechanism that can be assembled and maintained locally.

6.3 Shaft

The shaft serves as the central rotating member of the turbine assembly. It connects the rotor to the mechanical transmission system and transfers the torque produced by the rotating blades.



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During operation, the shaft is subjected to rotational forces and must therefore possess sufficient mechanical strength and rigidity to withstand the transmitted torque without excessive bending or deformation. Its proper alignment is essential because misalignment can increase vibration, friction, and bearing loads, thereby reducing the efficiency and reliability of the system.

6.4 Bearings

Bearings were incorporated to support the rotating shaft and reduce friction between the shaft and its stationary support structure. Their function is particularly important because the turbine must rotate freely in response to relatively low wind forces.

Properly positioned bearings allow smooth rotation while maintaining the alignment of the shaft. They also reduce mechanical losses and vibration, thereby improving the transfer of available wind energy to the alternator. The selection and installation of suitable bearings therefore contribute significantly to the smooth and reliable operation of the turbine.

6.5 Supporting Frame

The supporting wooden frame provides the structural foundation for the mechanical and electrical

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components of the turbine. It supports the rotor assembly, shaft, bearings, pulley mechanism, and other associated components while maintaining their relative positions.

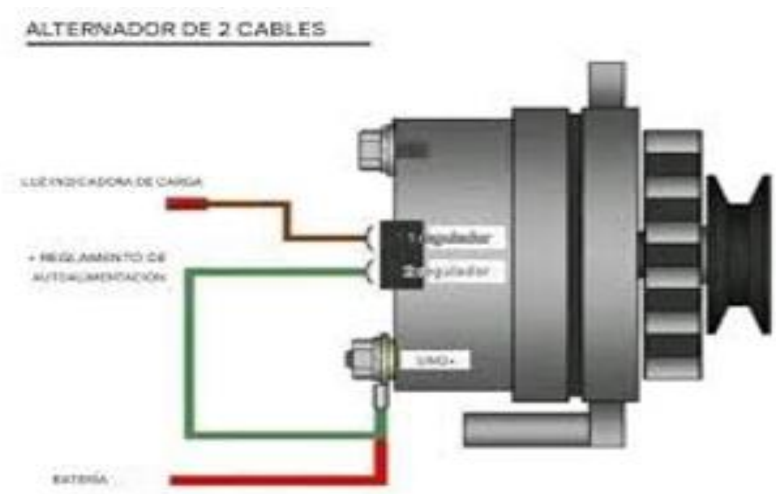
VII. ELECTRICAL COMPONENTS

The electrical components are responsible for converting the mechanical rotation produced by the turbine into electrical energy, regulating the generated electricity, storing the energy, and making it available for useful applications. The principal electrical components examined are the car alternator, charge controller, battery storage unit, and inverter.

7.1Car Alternator

The car alternator serves as the electrical generating unit of the portable VAWT. Mechanical rotational energy transmitted from the turbine rotor through the shaft and bicycle wheel pulley mechanism drives the alternator.

The alternator converts the mechanical energy supplied to its rotating shaft into electrical energy through electromagnetic induction. The use of a readily available automotive alternator provides a relatively affordable alternative to purchasing a purpose-built small wind generator. Its successful application, however, depends on achieving sufficient rotational speed and maintaining an appropriate mechanical connection between the turbine and the alternator.



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7.2 chararge Controller

The charge controller regulates the electrical energy supplied from the alternator to the battery storage system. Its principal function is to control the charging process and protect the battery from inappropriate charging conditions.

The charge controller also helps to ensure that the generated electrical energy is delivered to the battery in a controlled manner. Its inclusion in the system is important for protecting the energy-storage unit and improving the reliability and useful life of the battery.

7.3 Battery Storage Unit

The battery provides an energy-storage facility for the electrical power generated by the turbine. Since wind availability is variable, the turbine may not continuously produce electricity at the required level. The battery therefore stores generated electrical energy for subsequent use when wind power is insufficient or unavailable.

A 12 V rechargeable battery stores the electrical energy generated by the alternator. Energy storage enables continuous power availability even when wind speed decreases or becomes unavailable. Deep-cycle batteries are preferred because they are designed for repeated charging and discharging cycles.

The storage unit also provides a more stable source of electrical energy for the inverter and connected loads.

Its capacity and condition influence the amount of energy that can be stored and subsequently supplied to the user.

7. 4 Inverter
The inverter is used to convert the direct-current (DC) electrical energy stored in the battery into alternating-current (AC) electrical energy suitable for compatible AC loads. This component makes the stored energy from the renewable-energy system more useful for conventional electrical appliances.

The inverter therefore forms the final stage of the energy-conversion process in the prototype. Its capacity must be appropriate for the intended electrical load to prevent overloading and ensure reliable operation.

7.5 Fasteners
Bolts, nuts, washers, screws, and metal brackets were used to secure all components firmly together. These fasteners allow easy assembly, maintenance, adjustment, and replacement of individual parts whenever necessary.

The successful operation of the portable VAWT depends on the coordinated interaction of its mechanical and electrical cmponents. Wind first acts on the wooden rotor blades, causing the vertical rotor to rotate. The resulting mechanical rotation is transmitted through the shaft and bicycle wheel pulley mechanism to the car alternator. The alternator converts the mechanical rotational energy into electrical energy, which is subsequently regulated by the charge controller and stored in the battery.

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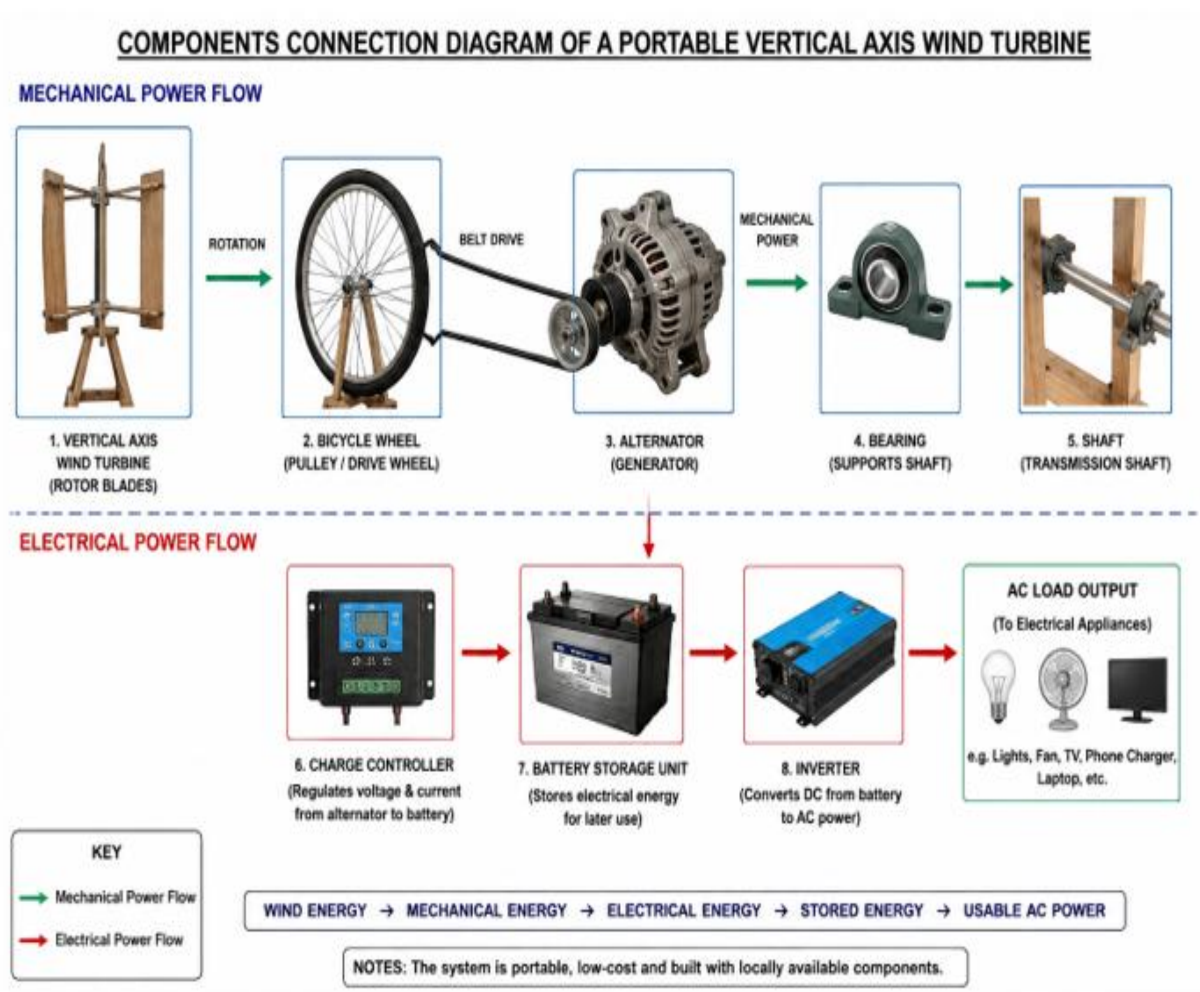
When electrical power is required for an AC load, the stored DC energy from the battery is supplied to the inverter, where it is converted into AC electricity. The supporting wooden frame and bearings maintain the structural stability and smooth rotation required throughout the process.

Thus, the effectiveness of the prototype does not depend on a single component but on the proper selection, fabrication, alignment, and integration of the individual mechanical and electrical components. The study of these components provides an understanding of how locally available and repurposed materials can be combined to produce a functional portable wind-energy conversion system.

8 Flow chart diagram of components parts



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8 Flow chart diagram of components parts

VIII. CONCLUSION

This expository study has examined the selected components and materials used in the construction of a portable vertical-axis wind turbine, with particular attention to their functions, suitability, availability, and contribution to the overall performance of the system. The study established that the successful construction and operation of a small portable wind turbine depend not only on the design of the rotor but also on the appropriate selection and integration of both mechanical and electrical components.
The mechanical components, includes plastic rotor blades, bicycle wheel, shaft, bearings, and supporting wooden frame, provide the structural and rotational arrangement required for the conversion of wind energy into mechanical energy. The plastic blades provide a lightweight and relatively inexpensive means of capturing wind, while the bicycle wheel serves as a practical hub and pulley mechanism for transferring rotational motion. The shaft transmits the rotational force from the rotor to the alternator, while the bearings support the shaft and reduce friction during rotation. The supporting wooden frame provides stability and maintains the alignment of the major components during operation.

The electrical components, particularly the automotive alternator, charge controller, battery storage unit, and inverter, provide the means of converting, regulating, storing, and utilizing the electrical energy generated by the turbine. The alternator converts the mechanical rotational energy of the rotor into electrical energy, while the charge controller regulates the charging process and protects the battery from inappropriate charging conditions. The battery stores the generated electrical energy for subsequent use, and the inverter converts the stored direct current into alternating current suitable for powering appropriate electrical appliances.

The study further demonstrates that the use of locally available and relatively inexpensive materials such as wood, bicycle components, and an automotive alternator can make the construction of a portable wind turbine more affordable and accessible, particularly for experimental, educational, and small-scale renewable-energy applications. However, the performance and durability of the system depend on proper fabrication, alignment, material selection, component compatibility, maintenance, and the prevailing wind conditions.

Overall, the study concludes that each selected component performs a complementary function within the portable vertical-axis wind turbine, and that the integration of these components determines the effectiveness of the complete system. The successful combination of simple mechanical materials with conventional electrical components provides a practical approach to developing a low-cost portable wind-energy system. The study therefore demonstrates the potential of appropriately selected locally available materials and components for the development of small-scale renewable-energy technologies.

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