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Design and Development of Electricity Generation Using a Bladeless Wind Turbine

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Abstract: *The increasing demand for electricity and the need for sustainable energy sources have encouraged the development of innovative wind energy technologies. This paper presents the design and development of a bladeless wind turbine for electricity generation. The system operates on the principle of vortex-induced vibration, where a cylindrical mast oscillates when wind flows around it. The oscillatory motion is converted into rotational motion using a rack and pinion mechanism connected to a generator. The generated electrical energy is processed through power conversion components for storage and utilization. The proposed system demonstrates the potential of bladeless wind turbines as a low-noise and environmentally friendly alternative for small-scale renewable energy applications.*

Keywords: Bladeless Wind Turbine, Wind Energy, Vortex-Induced Vibration, Renewable Energy, Energy Harvesting

I. INTRODUCTION

The rapid growth of population and industrialization has significantly increased the global demand for electrical energy. Conventional energy sources such as coal, oil, and natural gas are limited and cause environmental pollution. Therefore, the use of renewable energy sources has become essential for sustainable development. Among various renewable sources, wind energy is considered one of the most promising and environmentally friendly options for electricity generation.

Traditional wind turbines use large rotating blades to convert wind energy into electrical energy. Although these systems are widely used, they have several disadvantages such as noise generation, high maintenance cost, and potential risk to birds and wildlife. To overcome these limitations, alternative technologies such as bladeless wind turbines are being explored.

A bladeless wind turbine works on the principle of vortex-induced vibration. When wind flows around a cylindrical structure, alternating vortices are formed which cause the structure to oscillate. This oscillatory motion can be converted into mechanical energy and further into electrical energy using suitable mechanisms

In this research, a bladeless wind turbine prototype is designed and developed to study the feasibility of generating electricity from wind-induced vibrations. The system utilizes a cylindrical mast that vibrates due to wind flow, and the vibration is converted into rotational motion using a rack and pinion mechanism connected to a generator. The developed system demonstrates an innovative approach for small-scale and sustainable energy generation.

II. FIELD OF INVENTION

The present invention relates to the field of renewable and sustainable energy technologies, particularly wind energy conversion systems. More specifically, it focuses on the design and development of a bladeless wind turbine that generates electrical energy using wind-induced vibration instead of conventional rotating blades. Traditional wind turbines generally use large aerodynamic blades to convert wind energy into mechanical rotation and electrical power;

however, these systems often involve complex mechanical structures, higher maintenance requirements, noise generation, and environmental concerns.

The proposed system utilizes the principle of vortex-induced vibration, where wind flowing around a cylindrical mast produces alternating vortices that cause the structure to oscillate. These oscillations are converted into mechanical motion using a rack and pinion mechanism connected to a generator for electricity generation. The generated electrical energy can be processed through power conversion components for storage and practical use. This approach provides a low-noise, eco-friendly, and efficient alternative for small-scale renewable energy generation.

III. NEED OF SYSTEM

The increasing demand for electricity due to rapid population growth and industrial development has created a need for reliable and sustainable energy sources. Conventional energy resources such as coal, oil, and natural gas are limited in availability and contribute significantly to environmental pollution and climate change. Therefore, it has become essential to explore renewable energy sources that are clean, sustainable, and environmentally friendly.

Wind energy is one of the most promising renewable energy sources; however, conventional wind turbines use large rotating blades that can produce noise, require high maintenance, and may pose risks to birds and surrounding environments. In addition, traditional turbines may not operate efficiently at low wind speeds or in small-scale applications. To overcome these limitations, the development of a bladeless wind turbine system is necessary. The proposed system utilizes wind-induced vibration to generate electricity with fewer moving parts, reduced noise, and lower maintenance requirements. This makes the system suitable for small-scale and eco-friendly power generation applications.

IV. LITERATURE REVIEW

Han E. (2024) presented the development of a new type of vortex bladeless wind turbine for urban energy systems in Energy Reports. The study introduced a bladeless turbine that operates using the principle of vortex-induced vibration. The research highlighted that such systems require less maintenance compared to conventional wind turbines and are more suitable for urban environments due to their low noise and compact structure.

Duvellat et al. (2025) investigated the effect of dust and airflow dynamics on the performance of bladeless wind turbines in Renewable Energy Journal. Their research examined real-world environmental conditions and how factors such as dust particles and airflow patterns influence turbine efficiency. The study also provided important insights for improving turbine design and increasing the reliability of vibration-based wind energy systems.

Younis et al. (2022) proposed the design of a vibration-based piezoelectric bladeless wind turbine in IEEE Transactions on Energy Conversion.

The research focused on harvesting energy from vortex shedding vibrations using piezoelectric materials. The system was designed mainly for compact and urban-scale applications where traditional wind turbines are not practical.

Kang et al. (2024) presented a novel small-scale bladeless wind turbine system based on vortex- induced vibrations in Smart Energy Systems. The study proposed a compact turbine design that uses discrete resonance shifting to enhance vibration amplitude and improve energy harvesting efficiency. The research emphasized the importance of optimizing structural design to maximize power output from vibration-based wind turbines.

Zhang et al. (2023) studied vibration-based wind energy harvesting techniques in Renewable Energy. The research focused on improving the efficiency of energy harvesting systems operating at low wind speeds. The study showed that vortex-induced vibration can be effectively used for small- scale power generation, especially in urban and low-wind environments.

Lin et al. (2023) proposed an optimized vortex-induced vibration energy harvesting system in Energy Reports. The research analyzed different structural parameters affecting vibration amplitude and energy output. The results indicated that proper design optimization can significantly improve the performance of bladeless wind turbines.

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Duarte et al. (2022) presented a comprehensive review of energy harvesting technologies in Renewable and Sustainable Energy Reviews. The study discussed various renewable energy
harvesting methods, including vibration-based wind energy systems. It highlighted the advantages of bladeless turbines such as reduced mechanical complexity, lower maintenance, and environmental friendliness.

Wang et al. (2024) investigated the performance of small-scale wind energy harvesting devices in Applied Energy. The research demonstrated that vibration-based wind turbines can provide a viable solution for decentralized power generation in remote and urban areas.

V. RESEARCH GAP

Although several studies have been conducted on bladeless wind turbines and vibration-based energy harvesting systems, many challenges still remain in their practical implementation. Most of the previous research focuses on theoretical analysis, simulation models, or specialized energy harvesting methods such as piezoelectric systems. However, limited work has been carried out on simple mechanical transmission mechanisms for converting vibration into useful electrical energy

In addition, many existing studies emphasize large-scale systems or complex designs that may not be suitable for low-cost and small-scale applications. There is a need for a simple, compact, and cost- effective bladeless wind turbine system that can efficiently convert wind-induced vibrations into electrical energy using easily available components.

Therefore, the present work focuses on the design and development of a practical bladeless wind turbine prototype that utilizes a rack and pinion mechanism connected to generators for energy generation. The proposed system aims to provide a simple and eco-friendly solution for small-scale renewable energy harvesting.

VI. METHODOLOGY

A. Block Diagram

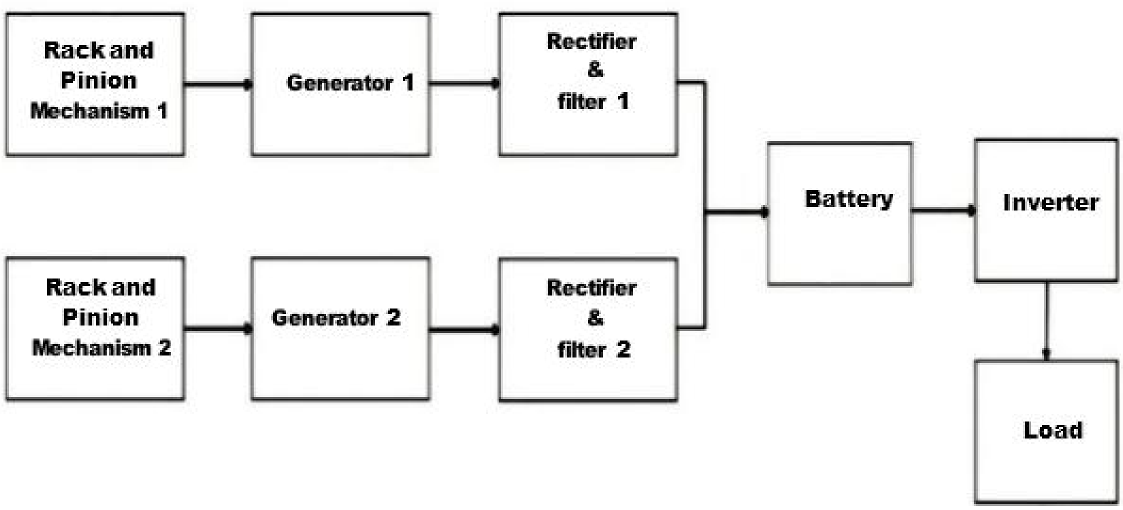

Fig. 1. Block Diagram

B. Working

The proposed bladeless wind turbine works on the principle of vortex induced vibration. When wind flows around the cylindrical mast, alternating vortices are formed behind the structure due to pressure differences in the airflow. This phenomenon is known as vortex shedding and it causes the cylindrical mast to oscillate or vibrate. The vibration of the mast acts as the main mechanical energy source in the system. As the wind speed increases, the intensity of vibration

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also increases, which improves the energy conversion process. This method allows the system to generate energy without using large rotating blades like conventional wind turbines.

The vibration produced by the mast is transferred to a rack and pinion mechanism connected at the base of the structure. The oscillating motion moves the rack in forward and backward directions, and the pinion gear converts this linear motion into rotational motion. This rotational motion drives the generators connected to the system, producing electrical energy. In the prototype, two generators are connected in parallel to improve reliability and maintain operation even if one generator fails. The generators produce AC output, which is then converted into DC using a bridge rectifier and stored in a battery. Finally, an inverter converts the stored DC power into AC so that it can be used to operate electrical loads. This system demonstrates an alternative approach for small-scale wind energy generation using vibration instead of rotating blades.

C. Components Used

Cylindrical Mast (PVC Pipe)   Rack and Pinion
Two DC Generators - 45 watt
Bridge Rectifier
Rechargeable Battery
Converter - 12V / 24V (DC to AC Inverter)   Capacitor - 1000 micro farad / 25V
Supporting Frame

VII. CIRCUIT DIAGRAM

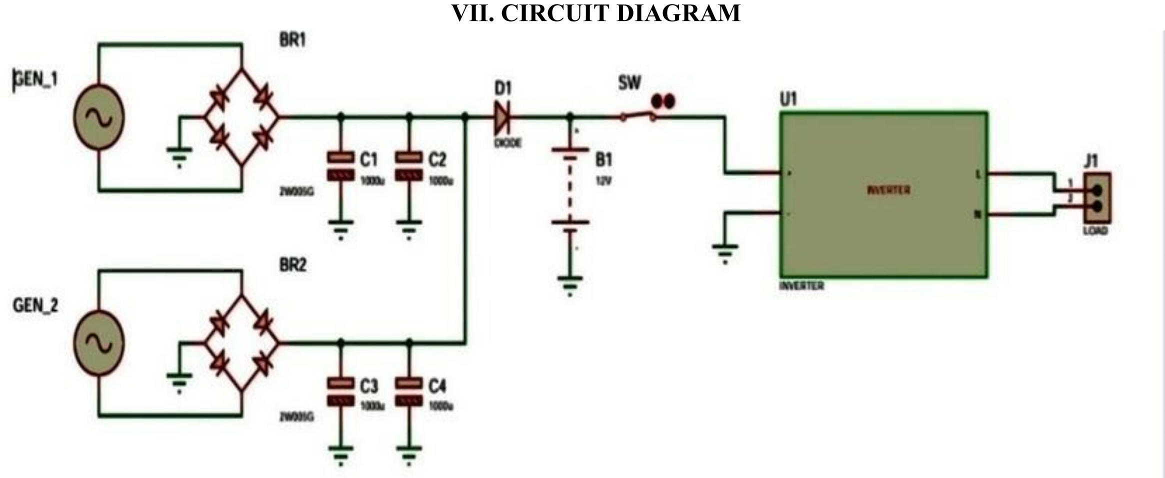

Fig. 2. Circuit Diagram

VIII. CALCULATION

Total Current Calculation :

In parallel connection, current adds up Total Current = 0.25 A+ 0.25 A
Total Current = 0.5 A

Total Voltage:

In parallel connection, voltage remains the same Total Voltage = 6 V

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Power Calculation at 4 m/s
Step 1: Substitute values P=2×1.225 x 0.2 x 43
Step 2: Calculate
P=0.5 x 1.225 x 0.2 × 64
Step 3: Result P7.84 W ≈ 8 Watt

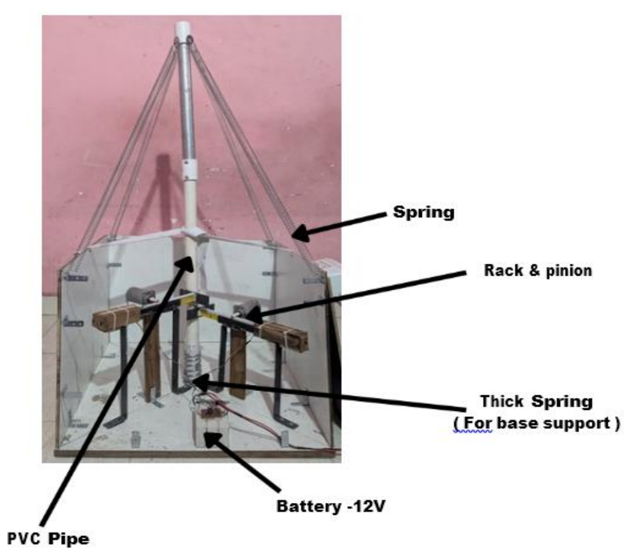
Final Result

At 3 m/s wind speed Power ≈ 3 W At 4 m/s wind speed Power ≈ 8 W Observation: Power generated by wind turbine increases rapidly because it is proportional to V^3 (cube of wind speed).

Wind Power Formula
P = 1/2 *rho *A*V^3 Where:
P = Power (Watt)
ρ = (rho) = Air density = 1.225 kg/m^3 A = Swept Area = 0.2 m^2
V = Wind speed (m/s)
Given Data
Air density (ρ) = 1.225kg / (m ^ 3) Swept Area (A) = 0.2m2
Wind speed (V) = 3 - 4m /s
Power Calculation at 3 m/s
Step 1: Substitute values
P = 1/2 * 1.225 * 0.2 * 3 ^ 33
Step 2: Calculate
P = 0.5 * 1.225 * 0.2 * 27
Step 3: Result
P = 3.30 W ≈ 3 Watt

IX. RESULT AND DISCUSSION

Project Image



Project Model

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9.1. Result

The developed bladeless wind turbine prototype was successfully designed and tested to demonstrate the concept of vibration-based wind energy generation. During the experiment, it was observed that when wind flows around the cylindrical mast, vortex shedding occurs which causes the mast to vibrate. This vibration is transferred to the rack and pinion mechanism, converting linear oscillatory motion into rotational motion. The rotational motion drives the generators connected to the system, producing electrical energy. The system uses two small generators connected in parallel, and during testing the prototype produced an output voltage of approximately 6V to 8 V under available wind conditions.

The generated electrical output was initially in AC form, but due to irregular vibration and changing wind speed, the output contained fluctuations. To overcome this problem, a bridge rectifier circuit was used to convert the AC output into DC power. The DC output was then stored in a battery for energy storage and later converted back to AC using an inverter to run small electrical loads. The experimental results show that although the generated voltage is relatively small, the system successfully demonstrates the feasibility of converting wind-induced vibration into usable electrical energy. The prototype confirms that bladeless wind turbines can be used for small-scale renewable energy generation with advantages such as low noise, simple design, and reduced maintenance compared to conventional wind turbines.

9.2. Discussion

The experimental results show that the bladeless wind turbine prototype is capable of generating electrical energy using wind-induced vibration. When wind flows around the cylindrical mast, vortex shedding causes the structure to oscillate. This vibration is successfully converted into rotational motion using a rack and pinion mechanism, which drives the generators to produce electrical power. The system demonstrates

X. ADVANTAGES, DISADVANTAGES, AND APPLICATIONS

A. Advantages

Low Noise: Bladeless wind turbines produce very little noise because they do not use large rotating blades.
Low Maintenance: The system has fewer moving parts, so maintenance and mechanical wear are reduced.
Environment Friendly: It is safer for birds and wildlife since there are no fast rotating blades.
Compact Design: The structure is simple and can be installed in small spaces such as rooftops.

B, Disadvantages

Low Power Output: The electricity generated is generally lower than conventional wind turbines.
Wind Dependence: Power generation mainly depends on wind speed and vibration intensity.

C. Applications

Residential Power Supply: Can be used for small loads like LED lights and charging devices.
Rooftop Installations: Suitable for buildings and urban areas.
Street Lighting: Can provide power for street lights in windy locations.
Educational and Research Projects: Useful for renewable energy experiments and demonstrations.

XI. CONCLUSION

The proposed bladeless wind turbine system demonstrates an innovative method for generating electrical energy using wind-induced vibrations instead of conventional rotating blades. In this system, the oscillating motion produced by wind is converted into mechanical motion using a rack and pinion mechanism, which then drives generators to produce electrical energy. The generated electrical output is further processed through rectifier and filter circuits for stabilization, stored in a battery, and supplied to electrical loads through an inverter. The developed prototype shows that wind vibration can be effectively utilized for small-scale electricity generation using a simple and compact system design.

In comparison to traditional wind turbines, the bladeless turbine offers several advantages such as reduced noise, lower maintenance, and improved safety for birds and the surrounding environment. The compact structure also allows installation in urban areas or limited spaces where conventional turbines are not practical. Although the generated power is relatively small, the system successfully demonstrates the feasibility of vibration-based wind energy harvesting. With further improvements in structural design, vibration amplification, and generator efficiency, the performance of the system can be enhanced, making it a promising alternative for sustainable and eco-friendly energy generation in the future.

XII. SCOPE OF PROJECT

1. Improved Structural Design:

In the future, the design of the cylindrical mast can be optimized to increase vibration amplitude even at lower wind speeds. A better aerodynamic design will help the structure respond more effectively to wind flow.

2. Use of High-Efficiency Generators:

Higher efficiency generators can be used to improve the electrical output of the system. This will help in generating more power from the same amount of vibration.

3. Advanced Materials:

Using lightweight and strong materials can increase the flexibility of the structure and improve vibration performance, which will enhance overall energy generation.

4. Power Electronics Integration:

Improved rectifier circuits, voltage regulators, and smart controllers can be integrated to stabilize and manage the generated electrical power more efficiently.

5. Large-Scale Implementation:

With further research and development, the system can be scaled up for larger installations in urban areas, highways, or open fields to generate more electrical energy.

6. Hybrid Renewable Energy Systems:

The bladeless wind turbine can be combined with other renewable energy sources such as solar panels to create hybrid energy systems for continuous and reliable power generation.

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