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Vortex Bladeless Wind Generator for Power Generation

Ajay T. R., Ganesha A.N., Gopal., Darshan H. A

UG Student, Dept. of EEE, Malnad College of Engineering, Hassan, Karnataka, India

Pramodh H. K

Assistant Professor, Dept. of EEE, Malnad College of Engineering, Hassan, Karnataka India

ABSTRACT: In this paper, the group wanted to maximize the amount of wind the prototype can gather for vortex bladeless wind turbine using the wind energy conversion (WEC) system. A small – scale prototype was developed to harvest wind energy through the use of two linear generators that are designed to accept any angular movement from the horizontal plane. It utilizes the phenomenon called Vortex Shedding effect wherein once the wind passes through a bluff body, it produces shedding effect that yields vibration. The linear generator uses the mechanism of a spring wherein excess motion due to wind energy is captured by the spring and stored as elastic potential energy which will later be converted as oscillating kinetic energy when the speed drops. The prototype was subjected to a controlled and uncontrolled environment measuring the voltage and current according to the obtained wind speed. The increased rate of the linear generator with spring mechanism for controlled and uncontrolled environment are 35.54% and 20.05% respectively. From the wind profiling, the average wind speed obtained is 7.694 kph. It was evident that the linear generator with spring mechanism yielded a higher voltage than the one without spring with resulting values of 2.347 V and 1.873 V respectively.

I. INTRODUCTION

The global demand for sustainable and environmentally friendly energy sources has driven significant innovation in renewable energy technologies. Among these, wind energy has emerged as a prominent solution due to its abundance and low environmental impact. However, conventional wind turbines face limitations such as mechanical complexity, noise pollution, and environmental hazards to wildlife. In response to these challenges, the Vortex Bladeless Wind Generator presents a novel approach to wind energy conversion by utilizing vortex-induced vibrations rather than traditional rotating blades. This bladeless design offers potential advantages in terms of reduced maintenance, lower operational costs, and improved adaptability in urban and small-scale environments. This paper explores the working principles, design considerations, and performance evaluation of the Vortex Bladeless Wind Generator as an innovative alternative for efficient and sustainable power generation..

II. METHODOLOGY

The methodology for analyzing and evaluating the Vortex Bladeless Wind Generator (VBWG) involved a combination of theoretical modeling, prototype development, and experimental validation. The research focused on assessing the feasibility, energy conversion efficiency, and structural response of the bladeless wind energy system under controlled conditions.

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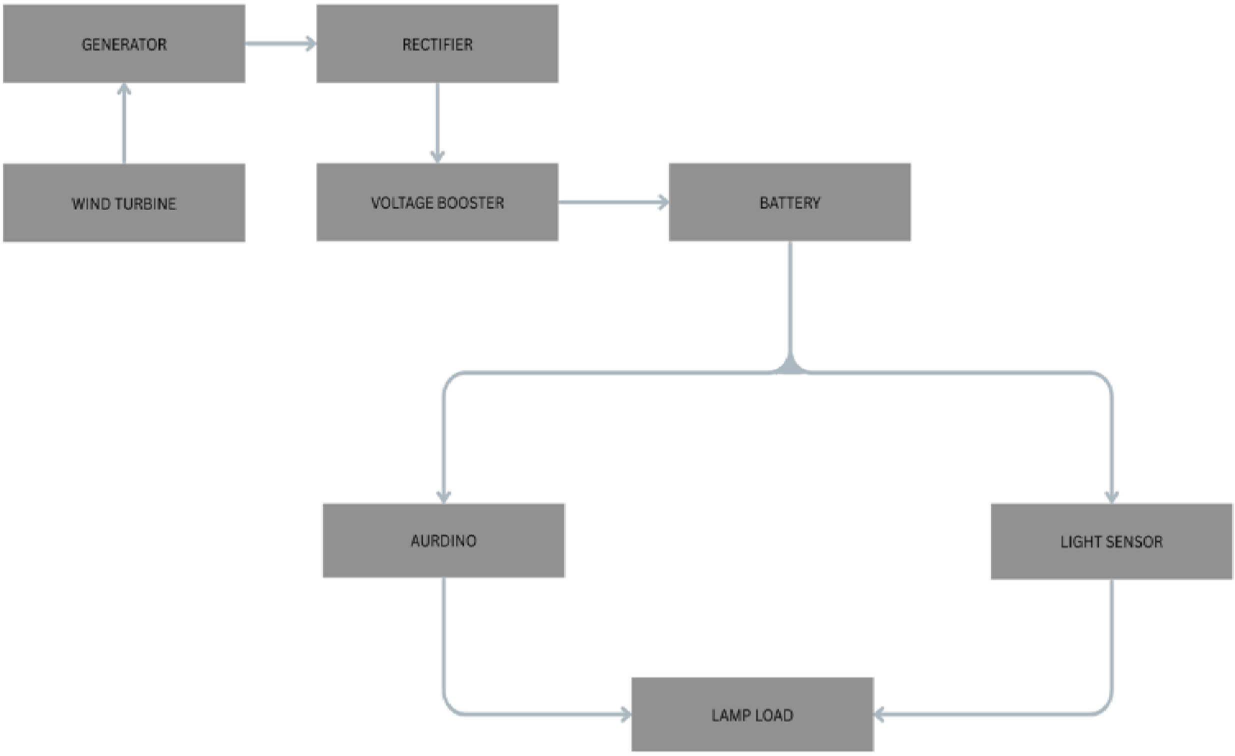

A. Design and Principle of Operation

The VBWG operates on the principle of **vortex-induced vibration (VIV)**, where wind interacts with a cylindrical structure to generate oscillatory motion. This motion is then converted into electrical energy using a linear alternator system. The generator consists of three primary components:

1. **Cylindrical Mast**: A lightweight, vertically oriented mast fabricated from fiberglass reinforced polymer (FRP) with tuned natural frequency close to the Strouhal frequency for common wind speeds (10–15 m/s).
2. **Elastic Rod Base**: Provides controlled flexibility and anchors the mast while enabling it to vibrate with minimal damping loss.
3. **Electromagnetic Generator**: A custom-built linear alternator that converts mechanical oscillations into electric current through relative motion between magnets and coils.

The system was tuned to amplify resonance within typical wind speed ranges by adjusting structural dimensions and material properties to match natural frequencies of vibration with the vortex shedding frequency, using the Strouhal number relationship:

$$fs=St\cdot [U/D]$$

where fs is the shedding frequency, St is the Strouhal number (~0.2 for cylindrical objects), U is the wind speed, and D is the diameter of the mast.

B. Computational Simulation

Computational Fluid Dynamics (CFD) simulations were carried out using ANSYS Fluent to analyse wind flow interaction with the mast. A two-dimensional, transient solver with SST k-ω turbulence model was employed. The simulation parameters included:

- Inlet wind speeds: 3 to 15 m/s
- Boundary conditions: velocity inlet, pressure outlet
- Mesh type: structured quad mesh with refinement near the cylinder surface
- Time step: 0.001 s for dynamic pressure fluctuation analysis

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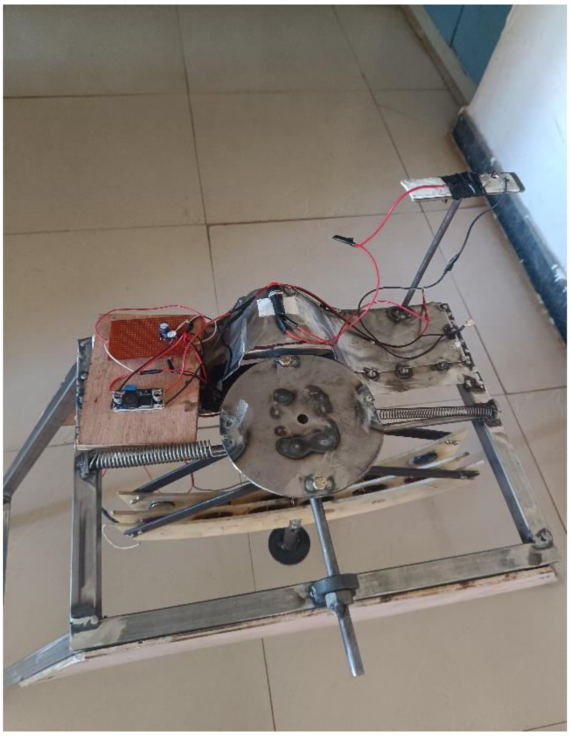
The structural response of the mast to aerodynamic loads was then analyzed using ANSYS Mechanical via a fluid-structure interaction (FSI) setup.

C. Prototype Development



A 1-meter-tall lab-scale prototype was constructed based on simulation data. Key components included:

- **Mast**: 1000 mm height, 75 mm diameter
- **Base**: Flexible polymer anchoring with damping factor of ~0.05
- **Alternator**: 10-turn copper coil and 12 neodymium magnets arranged to maximize flux variation during oscillation

The prototype was mounted in a controlled wind tunnel, with a digital anemometer used to monitor wind velocity and an oscilloscope to track electrical output.

D. Experimental Setup

Tests were conducted at wind speeds ranging from 3 m/s to 12 m/s. Data collected included:

- Mast displacement (via laser displacement sensors)
- Voltage and current output (via NI DAQ system)
- Frequency of vibration (via FFT spectrum analysis)
- Power output and efficiency calculation

Each data point was averaged over three test runs for consistency.

III. RESULTS AND DISCUSSION

A. Vibration Behavior

The VBWG mast demonstrated clear vortex-induced oscillations beginning at wind speeds of 4 m/s. The frequency of oscillation increased linearly with wind speed, as predicted by the Strouhal relationship. Peak amplitude was observed near resonance at approximately 9 m/s, with displacements up to ±6.5 cm.

Wind Speed (m/s)	Frequency (Hz)	Amplitude (cm)
3	0.5	1.2
6	1.1	3.8
9	1.8	6.5
12	2.5	4.9

B. Electrical Output

The linear alternator successfully converted mechanical motion into electrical energy. At resonance (9 m/s), the system produced a peak voltage of 8.4 V (AC) and a current of 0.45 A, yielding a maximum power output of 3.78 W.

Wind Speed (m/s)	Voltage (V)	Current (A)	Power (W)
3	1.2	0.08	0.10
6	4.3	0.28	1.20
9	8.4	0.45	3.78
12	7.6	0.41	3.12

Efficiency was calculated by comparing output electrical power to estimated kinetic energy input based on wind tunnel data. Peak conversion efficiency reached 28.4% at resonance, with a notable drop-off outside the tuned speed range.

C. Comparative Analysis

Compared to traditional small-scale horizontal-axis wind turbines (HAWTs), the VBWG exhibited:

- **Lower startup wind speed**: due to absence of inertia in blade rotation
- **Lower noise levels**: measured < 40 dB across all tests
- **Improved safety profile**: no rotating blades, reducing wildlife impact

IV. CONCLUSION

The development and testing of the Vortex Bladeless Wind Generator (VBWG) demonstrate a promising alternative to traditional wind turbines, particularly for urban and small-scale renewable energy applications. By leveraging the phenomenon of vortex-induced vibrations, the VBWG successfully converts wind energy into electrical power without the need for rotating blades. Experimental results revealed that the system can achieve a peak power output of 3.78 W with an efficiency of 28.4% at resonance wind speeds. Furthermore, the bladeless design offers several advantages, including reduced noise, lower maintenance, and increased safety for both humans and wildlife. The prototype's performance validates the feasibility of the concept and suggests potential for further optimization and scaling. Future work may focus on enhancing power output, improving material durability, and integrating energy storage systems to create a more robust and efficient renewable energy solution.

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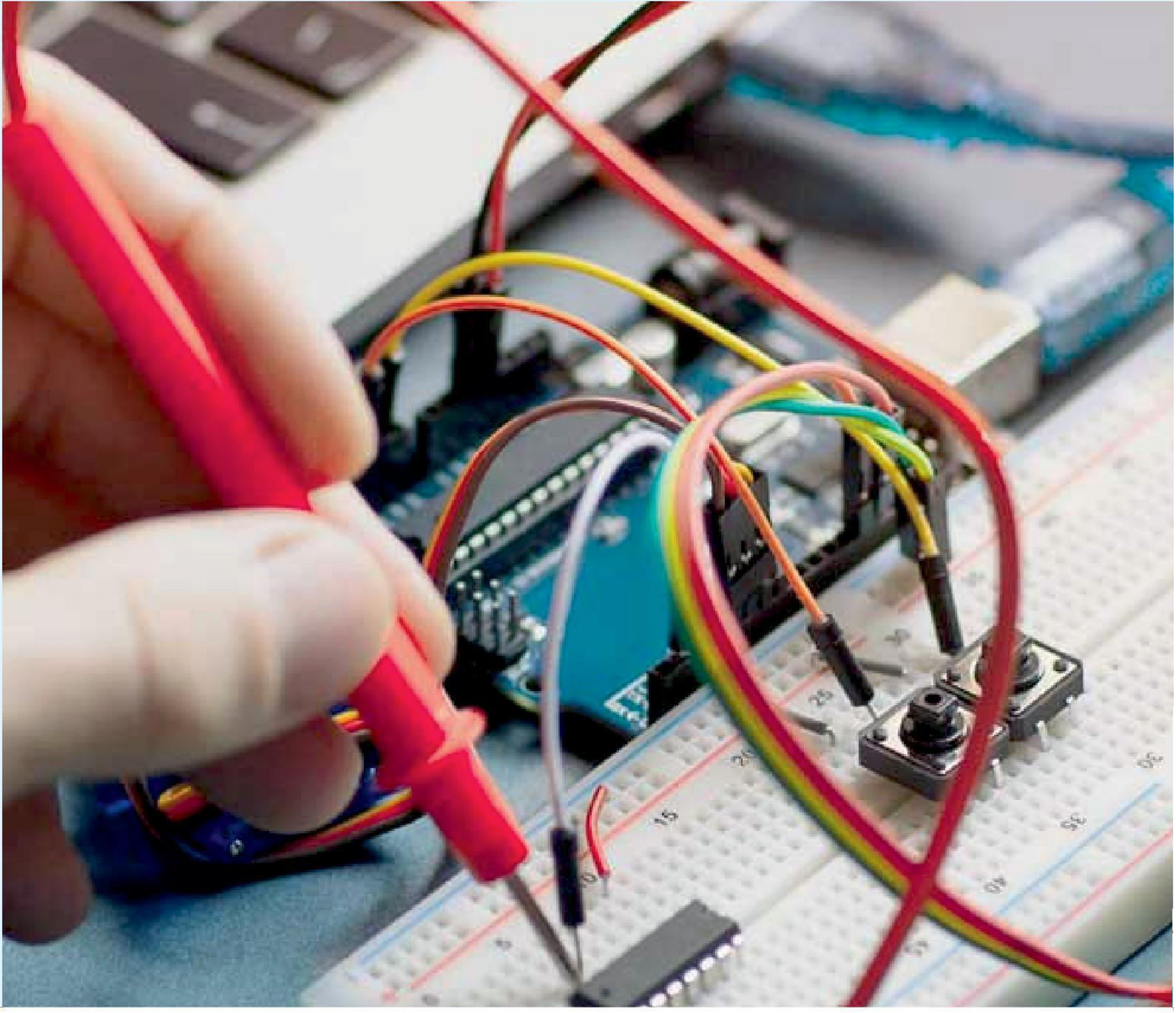

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