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Fabrication and Performance Analysis of Bladeless Wind Turbine using Linear Actuator

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Abstract: *Bladeless Wind Turbine uses a radically new approach to capturing wind energy. Our device captures the energy of vorticity, an aerodynamic effect that has plagued structural engineers and architects for ages (vortex shedding effect). As the wind bypasses a fixed structure, its flow changes and generates a cyclical pattern of vortices. Once these forces are strong enough, the fixed structure starts oscillating, may enter into resonance with the lateral forces of the wind, and even collapse. There is a classic academic example of the Tacoma Narrows Bridge, which collapsed three months after its inauguration because of the Vortex shedding effect as well as effects of flattering and galloping. Vortex-Bladeless is a Spanish SME whose objective is to develop a new concept of wind turbine without blades called Vortex or vorticity wind turbine. This design represents a new paradigm in wind energy and aims to eliminate or reduce..*

Keywords: Fluid-Structure Interaction (FSI), Vortex Bladeless, vortex induced vibrations (VIV), Vortex Bladeless

I. INTRODUCTION

Energy Instead of avoiding these aerodynamic instabilities our technology maximizes the resulting oscillation and captures that energy. Naturally, the design of such device is completely different from a traditional turbine. Instead of the usual tower, nacelle and blades, our device has a fixed mast, a power generator and a hollow, lightweight and semi-rigid fiberglass cylinder on top.

The Bladeless Turbine harness vorticity, the spinning motion of air or other fluids. When wind passes one of the cylindrical turbines, it shears off the downwind side of the cylinder in a spinning whirlpool or vortex. That vortex then exerts force on the cylinder, causing it to vibrate. The kinetic energy of the oscillating cylinder is converted to electricity through a linear generator similar to those used to harness wave energy.

Objectives:

The primary objective of integrating **linear actuators** in **bladeless wind turbines** is to create an efficient, sustainable, and environmentally friendly solution for wind energy conversion. This technology seeks to address the challenges posed by conventional wind turbines while enhancing energy production capabilities. The specific goals of this innovation include.

By implementing this system, the project aims to:

- To increase the efficiency of wind power generation.
- Development of the project so that it can be used on domestic purposes.
- To produce clean energy to meet the increasing demands.
- To make the wind energy economical and efficient.

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II. METHODOLOGY

2.1 Concept & Design

In fluid dynamics, vortex shedding is an oscillating flow that takes place when a fluid such as air or water flows past a bluff (as opposed to streamlined) body at certain velocities, depending on the size and shape of the body.

2.2 Design Phase

Objective: Develop a conceptual model of the bladeless wind turbine system.

Actions: Design the vertical cylindrical or conical structure to optimize vortex shedding.

2.3 Simulation and Analysis

Objective: Validate the design using computational simulations.

Actions: Perform simulations to analyze vortex shedding and oscillatory motion under varying wind speeds

2.4 Prototype Development

Objective: Build a working prototype of the bladeless wind turbine with the linear actuator.

Actions: Construct the turbine structure using selected materials.Integrate the linear actuator with the turbine base and oscillating structure.

2.5 Experimental Testing

Objective: Evaluate the performance of the prototype under controlled and real-world conditions.

Actions: Set up the prototype in a wind tunnel to test functionality under controlled wind speeds. Measure key parameters: oscillation amplitude, frequency, actuator efficiency, and power output.

2.6 Data Analysis

Objective: Assess the prototype's performance based on experimental data.

Actions: Analyze data to determine the efficiency of energy conversion and power output. Compare experimental results with simulation data to validate the model. Identify areas for optimization, such as material improvements or actuator design adjustments.

III. LITERATURE REVIEW

The existing project implemented by students of MIT primarily was intended to convert the energy of transverse structural vibrations into electricity. The main principle was to use linear alternator to convert the structural vibrations into feasible electricity. By using linear alternator, they limited the vibration of the structure in transverse direction which was possible on very high Reynolds number.

Considering the cost and manufacturing constraints we have modified the design to meet the optimum manufacturing conditions. We modified the design by changing the taper ratio thereby making the structure more prone to vibrations and making the structure slenderer to give more amplitude of vibrations. Instead of using linear alternator which had its limited use, we have used piezoelectric crystal which can produce electricity by transverse as well as inline vibrations.

The project claims to reduce manufacture optimize the cost as compared to conventional multi blade wind power generators by removing the most expensive generators associated with the blades and tower.

Pre-1970s: Early Innovations

Scientist: Poul la Cour (Denmark)

Contribution: In the late 19th and early 20th centuries, Poul la Cour, a Danish scientist, pioneered modern wind power by developing wind turbines for electricity generation. He is considered a foundational figure in wind energy research and laid the groundwork for future advancements in wind technology.

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1970s: Commercial Turbines and Renewable Energy Awareness
Scientist: Ulrich Hütter (Germany)
Contribution: Ulrich Hütter's work during the 1960s and 1970s significantly improved turbine efficiency. His research on aerodynamics and light-weight construction of wind turbine blades helped push wind turbines towards commercialization, particularly in the wake of the oil crisis.

1980s: Scaling Up and Efficiency Improvements
Scientist: Henrik Stiesdal (Denmark)
Contribution: Henrik Stiesdal, often called the "father of modern wind power," invented a three-bladed turbine design that became a global standard in the 1980s. His work, particularly with companies like Vestas, helped increase the size and efficiency of wind turbines, making wind energy more viable on a large scale.

1990s: Global Growth and Offshore Wind Development
Scientist: Paul Gipe (USA)
Contribution: An influential figure in wind energy advocacy and technology, Paul Gipe published key works on the economics and potential of wind turbines. His studies emphasized community-based wind projects and helped popularize wind energy globally during this decade.

2000s: Technological Optimization and Smart Grids
Scientist: Dr. James L. Manwell (USA)
Contribution: Dr. James L. Manwell's research at the University of Massachusetts contributed to the optimization of offshore wind farms and the integration of wind energy into the power grid. His work in wind turbine design and renewable energy systems became essential for large-scale wind energy deployment.

2010s: Larger Turbines and Offshore Wind Expansion
Scientist: Dr. Cristina Archer (USA)
Contribution: Dr. Cristina Archer made significant contributions to the understanding of atmospheric science and its implications for wind energy. Her research focused on wind farm optimization and turbine placement, especially for offshore wind, making it more efficient and productive.

2020s: Future Directions and Sustainability
Scientist: Dr. Kathryn Dykes (USA)
Contribution: Dr. Kathryn Dykes, a lead researcher at the National Renewable Energy Laboratory (NREL), focuses on wind turbine systems engineering and optimization. Her research contributes to designing next-generation turbines that are more efficient, sustainable, and cost-effective, addressing future challenges in wind energy.

IV. SCHEMATIC REPRESENTATION

Top View: Showing the Liner Actuator.
Exploded View: Showing the Support Stand.

Figure 1: Top View

Figure 2: Side View

V. ANALYSIS AND CALCULATIONS

Weld ability: Due to the medium-high carbon content it can be welded with some precautions. Hardenability: It has a low hardenability in water or oil; fit for surface hardening that gives this steel grade a high hardness of the hardened shell.

Why Mild Steel C-45 is selected in our project.

Easily available in all sections.

Welding ability

Machinability

Cutting ability

Cheapest in all other metals.

Material = C 45 (mild steel)

Take factor of safety 2

$\sigma_t = \sigma_b = 540/\text{fos} = 270\ N/mm^2$

$\sigma_s = 0.5\ \sigma_t$

$= 0.5 \times 270$

$= 135\ \text{N/mm}^2$

Power capacity

Calculation of Wind Energy and Power

Force = mass x acceleration F = ma (Typical Unit -Newton's)

Energy = Work (W) = Force (F) x Distance (d) (Typical unit – Joules)

Power = P = W / time (t) (Typical unit –Watts)

Power = Torque (Q) x Rotational Speed (Ω)

Kinetic Energy in the Wind

Kinetic Energy = Work = $\frac{1}{2}MV^2$

Where:

M= mass of moving object

V = velocity of moving object Mass of moving air

M = density (ρ) x volume (Area x distance)

$= \rho \times A \times d$

$= (kg/m^3)\ (m^2)\ (m)$

= kg

= 1 x 0.196x 0.5

= 0.098 kg

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Power in the Wind

Power $= \text{Work} / t$

$= \text{Kinetic Energy} / t$

$= \frac{1}{2}MV^2 / t$

$= \frac{1}{2}(\rho \times A \times d)\, V^2/t$

$= \frac{1}{2}\rho A V^2\, (d/t)$ (d/t = Distance/time = velocity)

$= \frac{1}{2}\rho A V^3$

Power in the Wind $= \frac{1}{2}\rho A V^3$

V = 5 meters (m) per second (s) m/s

$\rho = 1.2\ \text{kg/m}^3$

Power in the Wind $= \frac{1}{2}\rho A V^3$

A=Height x Base/2

A = 1.2 x 0.1/2

$A = 0.06\ \text{m}^2$

Given Data:

Power (P) required ………………………………..	10W
Velocity of wind (U)………………………………	5 m/sec
Coefficient of power (Cp)…………………………	0.3
Density of air at sea level (ρ)……….……………..	$1.2\ \text{kg/m}^3$
Viscosity of air (μ)…………………………………	10-5 kg/m-s

Length of turbine = 1200 mm

Top Width of triangle = 100 mm

Material = GI sheet

Weight of blade = 3.5 kg

$P = 0.5 \times A \times \text{density} \times cp \times V^3$

$P = 0.5 \times (0.5 \times 1.2 \times 0.1) \times 1.2 \times 0.3 \times 10^3$

P = 10.8 watt

VI. EXPERIMENTAL RESULTS

1. Mass of moving object 0.098 Kg
2. Power is $1.2\ \text{kg/m}^3$
3. Power generated 1.5 Wat.

VII. DISCUSSION

A **bladeless wind turbine** is a novel approach to harnessing wind energy that eliminates traditional rotating blades. Instead, it relies on **vortex-induced vibrations** or other non-rotational mechanisms to generate electricity. Here's a structured discussion on the topic

Concept and Working Principle

Bladeless wind turbines typically use **a vertical cylinder or mast** that oscillates in response to wind. These oscillations, caused by **vortex shedding**, are converted into electrical energy through **piezoelectric materials** or linear alternators.

Vortex shedding: As wind flows around a cylindrical object, alternating low-pressure vortices are formed on either side, causing the structure to vibrate.

Energy conversion: These vibrations can be harnessed using materials that generate electricity when mechanically stressed

VIII. CONCLUSION

The bladeless wind turbine using a linear actuator offers a safer, quieter, and more compact alternative to traditional turbines. It efficiently converts wind-induced vibrations into electrical energy. This design reduces maintenance costs and environmental impact. Overall, it presents a promising solution for sustainable and urban wind energy generation.

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