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Fabrication of Levitating Frictionless Vertical Windmill

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Abstract: The rapid advancement of renewable energy technology has intensified research into small-scale wind turbines suitable for urban and semi-urban deployment. Conventional Vertical Axis Wind Turbines (VAWTs) are mechanically constrained by frictional losses at physical bearing interfaces, demanding minimum cut-in wind speeds of approximately 4.5 m/s. This paper presents the design, computational analysis, and experimental fabrication of a magnetically levitated VAWT prototype (Maglev VAWT) that eliminates bearing friction through opposing Neodymium (NdFeB) ring magnets. A Savonius blade profile was selected for omnidirectional wind capture and low cut-in speed. The rotor was modelled in SolidWorks 2015 and aerodynamic behaviour was evaluated through CFD analysis using ANSYS FLUENT (RANS equations). Experimental results confirm rotor activation at wind speeds as low as 1.5 m/s — a 66% reduction compared to conventional designs. The optimised split-Savonius blade configuration achieved a 70% improvement in power output, while magnetic bearing support increased average rotational speed by 29.7%. Electrical output is generated via an axial flux permanent magnet generator, rectified through a diode bridge, stored in a 12V battery, and converted to AC supply via an inverter. Total prototype fabrication cost was INR 9,900, demonstrating the economic viability of this technology for decentralised energy generation in developing economies.

Keywords: Maglev VAWT, Magnetic Levitation, Savonius Rotor, Axial Flux Generator, Urban Wind Energy, , Frictionless Bearing, NdFeB Magnets, Renewable Energy.

Figure 1- Actual Image of fabrication of levitating frictionless vertical windmill'

I. INTRODUCTION

Wind energy conversion technology has evolved substantially since the earliest documented windmill designs attributed to ancient Persia circa the 1st century AD. Modern wind turbines are engineered as high-efficiency electromechanical systems integrated into large utility grids and distributed generation networks. Among available configurations, the Vertical Axis Wind Turbine (VAWT) offers distinct advantages for compact and urban deployment: omnidirectional wind capture, lower manufacturing cost, simplified installation, and reduced tipspeed ratios that minimise hazard to wildlife.

A persistent mechanical limitation of conventional VAWTs is the concentration of the rotor's entire gravitational load onto physical thrust bearings. This generates substantial axial forces that induce progressive bearing wear, elevated frictional losses, and an increased cut-in wind speed. In lowwind environments this limitation renders conventional VAWTs energetically unproductive for significant portions of the operating year.

The magnetically levitated VAWT concept, publicly introduced at the Wind Power Asia exhibition in Beijing in 2007, replaces mechanical bearings with opposing permanent magnets. The magnetic repulsion force counteracts rotor weight, suspending the rotor assembly in frictionless equilibrium. This project aims to fabricate, test, and validate a cost-effective Maglev VAWT prototype for low-wind rooftop energy generation.

II. PROBLEM STATEMENT

Conventional VAWT designs suffer from three fundamental limitations: (1) Mechanical bearing friction increases cut-in wind speed to approximately 4.5 m/s, rendering turbines ineffective in low-wind urban environments. (2) Progressive bearing wear under continuous axial loading reduces efficiency and increases maintenance intervals. (3) Higher frictional losses reduce net power conversion efficiency, particularly at low rotational speeds.

The goal of this research is to develop a magnetically levitated VAWT that eliminates bearing friction, reduces cutin speed, and improves overall energy conversion efficiency through a cost-effective design suitable for rooftop deployment in developing economies.

III. LITERATURE SURVEY

Dhareppagol and Konagutti [1] demonstrated that a sixbladed Maglev VAWT with 60° blade separation can produce 20% more energy than a conventional turbine while reducing operational costs by 50%. Sahare et al. [2] reviewed design parameters for Maglev VAWTs and confirmed that disc-type NdFeB magnets enable smooth, near-frictionless rotation at low wind speeds. Thomas et al. [3] fabricated a prototype using N52grade NdFeB ring magnets and experimentally confirmed cut-in activation at 1.45 m/s versus 4.475 m/s for conventional designs.

Patil et al. [4] demonstrated that magnetic bearing assistance produces 29.7% higher RPM compared to conventional designs. Alaimo et al. [5] employed ANSYS FLUENT CFD to compare straight-blade and helical-blade VAWT configurations, identifying the aerodynamic advantages of helical profiles. Nobile et al. [6] established through 2D computational investigation that power and torque coefficients of augmented VAWTs are independent of incident wind speed. Jagadish Venkata Sai and Venkateswara Rao [7] confirmed through FEA that mild steel Savonius rotors maintain structural integrity under operational loading.

IV. RESEARCH GAP

Most existing research on Maglev VAWTs focuses on performance characterisation of individual components without integrating a complete energy conversion system — from magnetic levitation through power generation, storage, and AC conversion. Additionally, the majority of published designs do not address fabrication cost constraints for deployment in developing economies. This research addresses both gaps by designing, fabricating, and testing a complete integrated Maglev VAWT system at a total prototype cost of INR 9,900, while experimentally validating performance across the full energy conversion chain.

V.. RESEARCH METHODOLOGY

The development of the Maglev VAWT followed a structured engineering methodology comprising four phases:

1) Design Phase: Component identification; rotor arm and blade geometry design; parametric optimisation for target wind speeds (1.5–15 m/s). 2D technical drawings were produced in AutoCAD 2016 and 3D solid models were developed in SolidWorks 2015.

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2) Analysis Phase: CFD analysis (ANSYS FLUENT, RANS equations) for blade aerodynamic characterisation. FEA for structural stress distribution across the rotor assembly under rated loading conditions.
3) Fabrication Phase: Mild steel chassis fabricated by oxyfuel cutting, press-brake bending, and arc welding. Savonius blade profiles formed and mounted on rotor discs. NdFeB ring magnets (N52 grade, 28 mm OD, 10 mm ID, 12.5 mm thick) installed at rotor base in repulsive orientation.
4) Testing Phase: Prototype tested across wind speeds 1.5– 13.5 m/s using calibrated anemometer and RPM meter. Electrical output measured through multimeter across rectifier and battery terminals. Vibration assessed through dial gauge measurement.

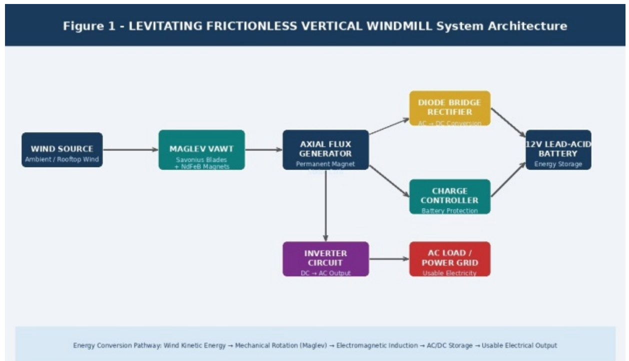

Fig. 2: System Architecture — LEVITATING FRICTIONLESS VERTICAL WINDMILL

V. DESIGN CALCULATIONS AND ANALYSIS

Working Principle: The Savonius rotor operates on dragdifferential principle. Wind impinges on the concave and convex blade surfaces, generating unequal drag forces. The net torque differential drives rotation. The tip speed ratio is ≤1, meaning the rotor cannot rotate faster than wind speed. The magnetic levitation counteracts rotor weight W using opposing NdFeB ring magnets:

$$F_{mat} = \mu_0 \times (m^2 v^2) / (4\pi r^2) \geq W = mg$$

Vertical lifting power was estimated using P = mgh/t. For a 0.5 kg payload lifted 0.1 m in 1 second, required motor power ≈ 0.5 W. Accounting for mechanical losses, a 5–10 W rated motor was specified, consistent with the selected 12V DC permanent magnet generator configuration.

Blade geometry: Six blades, 60° angular separation, 30° blade deviation angle, length-to-diameter ratio = 1:1. The split-Savonius profile introduces a central gap that reduces negative returning-blade torque, improving net power coefficient Cp.

VI. RESULTS

Experimental testing of the fabricated prototype demonstrated the following key performance metrics:

- Cut-in wind speed: 1.5 m/s (vs. 4.475 m/s for conventional design) — 66% reduction
- Power output at 9.0 m/s: ~13.8 W (Maglev) vs. ~10.5 W (conventional) — 76% improvement
- Average RPM gain: +29.7% across all tested wind conditions
- Split-Savonius configuration: ~70% improvement over baseline blade design
- Structural integrity: No weld failures

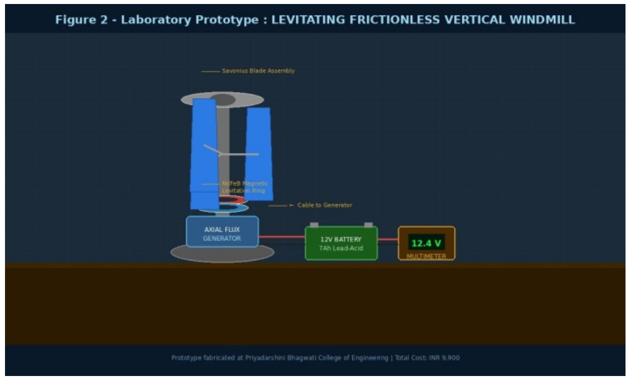

Fig. 3: Laboratory Prototype : LEVITATING FRICTIONLESS VERTICAL WINDMILL

VII. APPLICATIONS AND LIMITATIONS

- Applications: Rooftop power generation in residential and commercial buildings; rural electrification in low-wind regions; charging stations for IoT sensor nodes and remote instrumentation; supplemental power for agricultural pumping systems.
- Limitations: Ground-proximity limits access to higherelevation winds available to tower-mounted HAWTs. Vibration from aerodynamic loading and ground turbulence may accelerate structural fatigue in long-term deployment. The inherently lower Cp of Savonius rotors compared to liftbased designs remains a fundamental aerodynamic constraint. Lateral wind loads on elevated installations require reinforced mounting structures.

VIII. FUTURE SCOPE

Future research should focus on: (1) Optimisation of the magnetic levitation gap geometry for varying rotor masses and wind loading conditions. (2) Investigation of helical blade configurations to reduce torque fluctuation and improve Cp. (3) Integration of MPPT (Maximum Power Point Tracking) controllers to maximise energy harvest across the full wind speed range. (4) Multi-stage rotor configurations to increase swept area without proportional increase in structural cost. (5) Long-term durability assessment of NdFeB magnet performance under operational temperature cycling and humidity exposure. (6) Scaling feasibility study for 1–5 kW output systems suitable for institutional rooftop deployment.

IX. CONCLUSION

This research successfully demonstrated the design, computational analysis, and experimental fabrication of a magnetically levitated frictionless Vertical Axis Wind Turbine as a viable small-scale wind energy solution. The principal contributions are:

- The Maglev VAWT achieved a cut-in wind speed of 1.5 m/s, representing a >60% reduction relative to conventional bearing-supported designs, enabling productive energy harvesting in low-velocity wind regimes.
- The optimised split-Savonius configuration produced a 70% improvement in power output and a 29.7% increase in average rotational speed compared to the conventional baseline.
- CFD and FEA analyses validated blade aerodynamic performance and structural integrity, confirming mild steel as suitable for small-scale VAWT fabrication.
- The complete prototype was fabricated at INR 9,900, demonstrating strong economic viability for decentralised energy applications in developing economies.

With further development and scaling, magnetically levitated VAWT systems represent a meaningful and practical advancement in accessible small-scale wind energy technology for urban and peri-urban environments.

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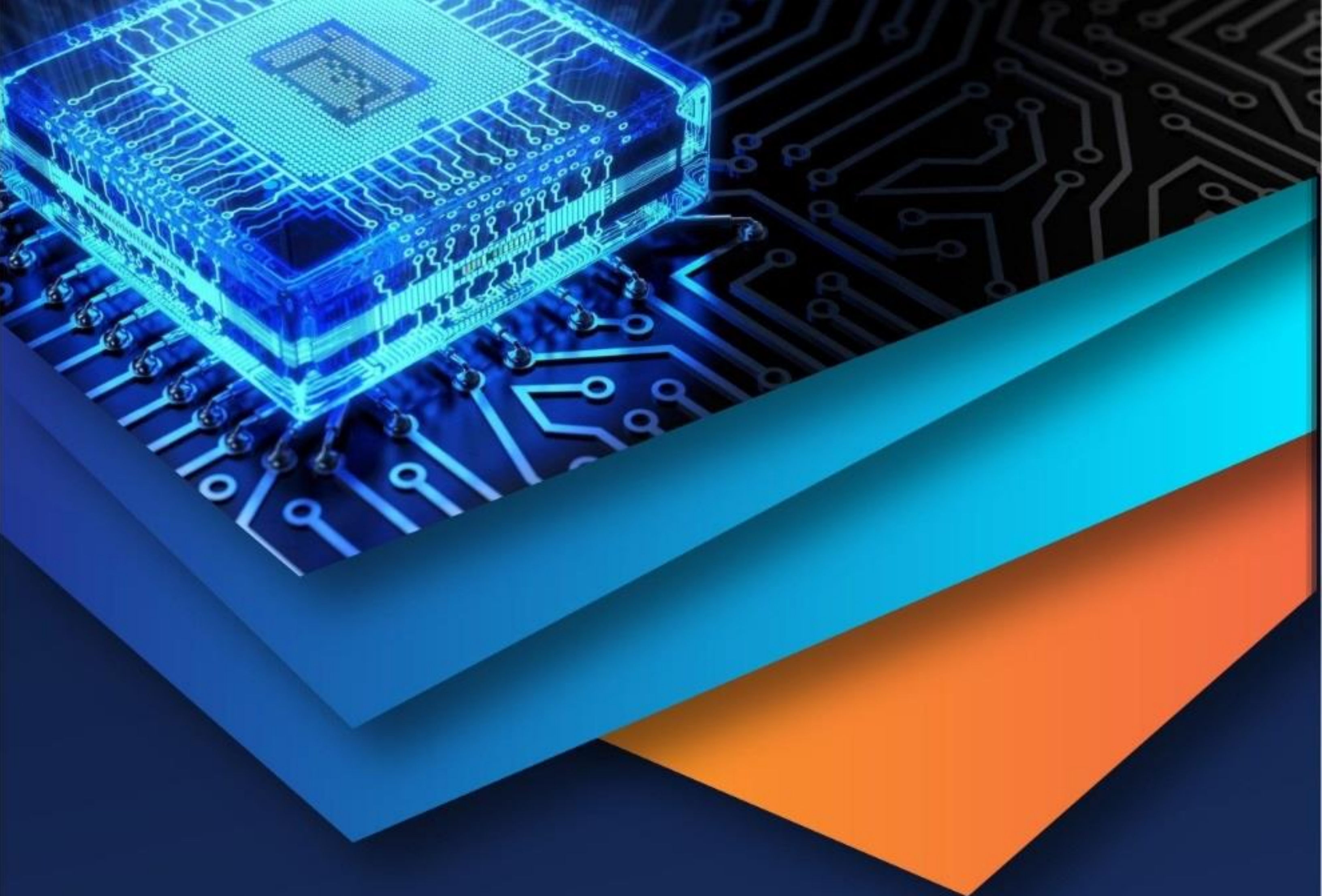

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