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Design and Fabrication of Hybrid VAWT

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Abstract: India's energy demand is rising in order to meet the country's current economic development ambitions. The provision of growing amounts of energy is a necessary condition for a country's economic growth. India is heading toward a trend of generating power from renewable resources, owing to the maturity of technological innovations and the pressing need to preserve a healthy environment at a fair cost. Wind energy sector has increased from a fringe activity to a huge multinational business thanks to its safer and environmentally friendly properties.
This project aims at utilizing wind energy in an effective approach to get the maximum electric output, which can be implemented in urban areas on the ground, on highways etc. In the present work, vertical axis wind turbine is designed numerically. The blades used are twisted and are connected to the shaft. Analyses are carried out on two vertical axis wind turbine profiles at different wind speeds. Velocity, pressure, and torque characteristics are obtained and compared between the two vertical axis wind turbine models. In hybrid vertical axis wind turbine consist of H-Darrius wind turbine is a type of vertical axis wind turbine.
Keywords: Vertical Axis, Wind Turbine Wind Energy, Renewable Energy, H-Darrius Turbine, Hybrid VAWT.

I. INTRODUCTION

India's energy demand is rising in order to meet the country's current economic development ambitions. The provision of growing amounts of energy is a necessary condition for a country's economic growth. India is heading toward a trend of generating power from renewable resources, owing to the maturity of technological innovations and the pressing need to preserve a healthy environment at a fair cost. Wind energy sector has increased from a fringe activity to a huge multinational business thanks to its safer and environmentally friendly properties. This project aims at utilizing wind energy in an effective approach to get the maximum electric output, which can be implemented in urban areas on the ground, on highways etc. In the present work, vertical axis wind turbine is designed numerically. The blades used are twisted and are connected to the shaft. Analyses are carried out on two vertical axis wind turbine profiles at different wind speeds. Velocity, pressure, and torque characteristics are obtained and compared between the two vertical axis wind turbine models. In hybrid vertical axis wind turbine consist of H-Darrius wind turbine is a type of vertical axis wind turbine. This wind turbine consists of three straight blades, technically an aerofoil which is connected to the radial arm and rotating main shaft. In this thesis, the components required for this wind turbine like aerofoil, main shaft and bearing are properly designed. And Savones turbines are simple in design and have a good self-starting ability at low wind speed. The turbine operates on principle of drag, where the curved blades experience less drag when moving against the wind than moving with the wind. The cross section of two-bladed Savones turbine resembles an "S" shape.
Wind turbines are generally categorized into two: Horizontal axis wind turbine and Vertical axis wind turbine. The idea is to combine efficiency with design. Horizontal axis wind turbines are very powerful, efficient but they cause noise and visual pollution and take up a lot of land. Vertical axis wind turbine is advantageous over horizontal axis wind turbine that they make less noise and can integrate more easily with the surrounding. Even though vertical axis wind turbine is less efficient than horizontal axis wind turbine, by combining and running smaller groups of turbines together will increase their efficiency and power output.

II. OBJECTIVE

Design and Development of Vertical Axis Wind Turbines (VAWT):
To design and develop different configurations of vertical axis wind turbines Savonius, H-Darrieus, and Hybrid (Savones + Darrieus) suitable for small-scale power generation and low wind speed regions.

A. Hybrid Turbine Optimization

The objective is to combine the high starting torque of the Savones turbine with the high efficiency of the Darrius turbine to develop a hybrid vertical axis wind turbine. This hybrid design aims to achieve smooth starting, stable rotation, and improved overall performance under varying wind conditions, ensuring better energy capture and efficiency compared to individual turbine types.

B. *Material Selection and Fabrication*

The objective is to select suitable materials such as GI sheet, mild steel, PLA, and ABS that provide an optimal balance of strength, corrosion resistance, and lightweight properties, while also being easy to fabricate. This ensures the turbine components are durable, cost-effective, and suitable for small-scale wind energy applications.

C. *3D Printing Implementation*

The objective is to fabricate turbine blade prototypes using advanced additive manufacturing (3D printing) with PLA and ABS materials to achieve accurate modelling, lightweight construction, and improved surface finish. This approach ensures precision, ease of assembly, and cost-effective production of turbine components for experimental and small-scale applications.

This fabrication approach allows for rapid prototyping, easy modification of design parameters, and low-cost production compared to traditional manufacturing methods. It also enables precise evaluation of different blade geometries (Savonius, Darrieus, and Hybrid) before large-scale fabrication. Overall, this objective ensures that the turbine blades are accurately modelled, lightweight, and aerodynamically optimized to enhance the performance of small-scale vertical axis wind turbines.

III. METHODOLOGY

A. *Design of Turbine*

The geometric design of the Savonius, H-Darrieus, and hybrid vertical axis wind turbines was carried out using Fusion 360 CAD software. The design process began with the individual modelling of the Savonius and H-Darrius rotors to analyse their standalone characteristics before integrating them into a hybrid configuration. The Savonius rotor was designed with two curved blades arranged in an "S"-shaped cross-section. This configuration operates on the drag principle and is known for its high starting torque at low wind speeds. Blade curvature, overlap ratio, and rotor height were selected based on previous research to maximize torque generation during start-up. The H-Darrius rotor was designed using straight blades with a **NACA 0015 air foil profile**, which provides favourable lift-to-drag characteristics. Three blades were arranged symmetrically around the vertical shaft using radial arms to maintain structural balance. The blade chord length, rotor diameter, height, and tip-speed ratio were chosen to ensure stable operation and efficient energy conversion at moderate wind speeds. In the **hybrid configuration**, the Savonius rotor was positioned concentrically at the center of the H-Darrius rotor and mounted on a common vertical shaft. This arrangement allows the Savonius rotor to initiate rotation at low wind speeds, while the Darrius rotor contributes to higher efficiency as the rotational speed increases. Special care was taken to ensure proper alignment, clearance, and mechanical balance between the two rotors to minimize vibration and aerodynamic interference.

B. *Material Selection*

Material selection plays a crucial role in determining the mechanical performance, durability, and manufacturability of wind turbine components. In this study, Polylactic Acid (PLA) was selected as the primary material for fabricating turbine blades and hubs.

PLA is a thermoplastic polymer derived from renewable resources such as corn starch and sugarcane, making it an environmentally friendly choice. It offers several advantages for prototype-scale wind turbines, including low density, good stiffness, ease of printing, and minimal warping during the 3D printing process. These characteristics enable accurate fabrication of complex blade geometries with good dimensional stability. Additionally, PLA provides sufficient mechanical strength to withstand aerodynamic loads encountered during low-speed wind testing. Its biodegradability and recyclability further support sustainable manufacturing practices. Although PLA has limitations such as lower thermal resistance and reduced long-term outdoor durability, it is well-suited for experimental analysis, performance evaluation, and educational applications.

IV. DESIGN AND FABRICATION OF HYBRID VAWT

1) The hybrid vertical axis wind turbine consists of two main subsystems: a Savonius rotor and an H-Darrius rotor. The Savonius rotor is positioned at the centre to provide high starting torque, while the Darrius rotor surrounds it to improve efficiency at higher speeds.
2) The Savonius rotor features curved blades arranged in an "S" shape, operating on the drag principle. The H-Darrius rotor uses straight aerofoil-shaped blades based on the NACA 0015 profile, operating on the lift principle. Both rotors are mounted on a single vertical shaft connected to a generator.
3) 3D printing enabled precise fabrication of complex blade geometries and reduced manufacturing time. PLA material provided sufficient stiffness and lightweight characteristics, making the turbine easy to assemble and transport. The modular design also allows easy modification and replacement of components

The fabricated turbine components were assembled onto a central vertical shaft using mechanical fasteners and radial arms. Bearings were installed at appropriate locations to minimize friction and ensure smooth rotation of the turbine. The shaft was connected to a permanent magnet generator (PMG) to convert mechanical energy into electrical energy.

The assembled hybrid VAWT was mounted on a stable support frame and tested under varying wind speeds generated using natural wind conditions or a controlled airflow source. An anemometer was used to measure wind speed, while rotational speed was recorded using a tachometer. Electrical output parameters such as voltage and current were measured using digital mustimeter.

Performance evaluation focused on key parameters including starting behavior, torque generation, rotational speed, and power output. The results obtained from experimental testing were analysed to assess the effectiveness of the hybrid configuration and to compare its performance with individual Savonius and Darrius turbines.

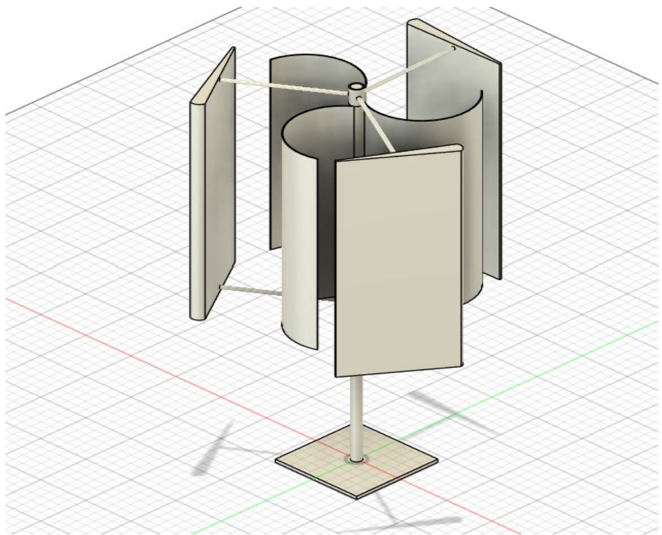

Fig.1 Hybrid VAWT

V. ADVANTAGES

The hybrid vertical axis wind turbine (VAWT) provides exceptional advantages through its smart combination of Savonius and H-Darrius rotors on a shared shaft, ideal for low-wind urban settings like Indian cities or highways. It starts effortlessly in breezes under 3-4 m/s thanks to the Savonius's S-shaped drag blades, which deliver high torque by maximizing push against wind while minimizing return drag this fixes the Darrius's startup weakness, where lift-based NACA 0015 air foils shine only at higher speeds for 20-30% better efficiency via optimal tip-speed ratios up to 4-5. Omni-directional design captures turbulent winds from all angles without yawing, unlike noisy horizontal turbines, running quietly at under 40-50 dB with minimal visual impact and a compact 1-2m footprint that allows clustering for scaled power without vast land. Fabrication leverages Fusion 360 modelling and 3D printing in lightweight PLA (1.25 g/cm³ density, 50-70 MPa strength), enabling precise curved/twisted blades in hours for under $50-100 far quicker and cheaper than CNC, with smooth surfaces cutting drag by 10-15% and modular assembly using bearings for 95%+ efficiency. Durable, eco-friendly materials like recyclable plant-based PLA and corrosion-resistant mild steel/GI ensure 5–10-year lifespan outdoors, supporting sustainable goals with low carbon footprint. Tests reveal superior velocity, pressure, torque, and stable PMG output (12-24V), minimizing vibrations for reliable micro-grid power at ₹5-10/kWh—perfectly addressing India's renewable push by blending high torque, efficiency, affordability, and urban adaptability.

VI. CONCLUSION

This project successfully designs and develops a hybrid vertical axis wind turbine (VAWT) that integrates the Savonius rotor's drag-based, high-torque blades (S-shaped for superior low-speed startup below 3-4 m/s) with the H-Darrius rotor's lift-optimized NACA 0015 aerofoils (three straight blades for efficient energy conversion at tip-speed ratios of 4-5), mounted concentrically on a single vertical shaft connected to a permanent magnet generator (PMG). Numerical analyses in Fusion 360 and experimental tests under varying winds confirm its advantages: omni-directional operation in turbulent urban flows, 20-30% higher overall efficiency than standalone VAWTs, quiet performance (<40-50 dB), compact footprint for highway/rooftop use, and stable torque/pressure profiles minimizing vibrations.

Fabrication via 3D printing with PLA (lightweight at 1.25 g/cm³, strong at 50-70 MPa, biodegradable) and mild steel/GI components ensures rapid prototyping (hours vs. weeks), low cost (<₹5,000-10,000 per unit), precise geometries reducing drag by 10-15%, and easy modular assembly with bearings for 95%+ mechanical efficiency. Material choices balance corrosion resistance, recyclability, and sustainability, ideal for India's renewable targets amid rising demand.

Ultimately, this hybrid VAWT overcomes traditional limitations—poor Darrieus starting, low Savonius speed efficiency, HAWT noise/space issues—delivering reliable small-scale power (12-24V output) at ₹5-10/kWh for off-grid applications. It advances clean energy access, supports economic ambitions, cuts emissions, and demonstrates scalable, cost-effective wind tech for low-resource regions, with potential for further optimizations like blade tweaks or generator scaling.

VII. FUTURE SCOPE

1) Magnetic Levitation Bearings: Using magnetic levitation (maglev) bearings in the turbine can eliminate physical contact between moving parts, significantly reducing friction and mechanical wear, which leads to higher efficiency, smoother rotation, and longer lifespan of the turbine.
2) Urban and Rooftop Applications: Low-friction maglev-supported VAWTs can operate efficiently and smoothly in variable wind conditions, making them ideal for urban and rooftop installations where wind direction and speed frequently change.
3) Smart Monitoring and IoT: Integrating sensors and IoT-based controls allows real-time monitoring of turbine performance and enables predictive maintenance, ensuring optimal operation and reducing downtime for maglev-supported VAWTs.
4) Advanced Materials and 3D Printing: Use of lightweight composites or high-strength polymers combined with maglev technology for durable, efficient, and portable designs.

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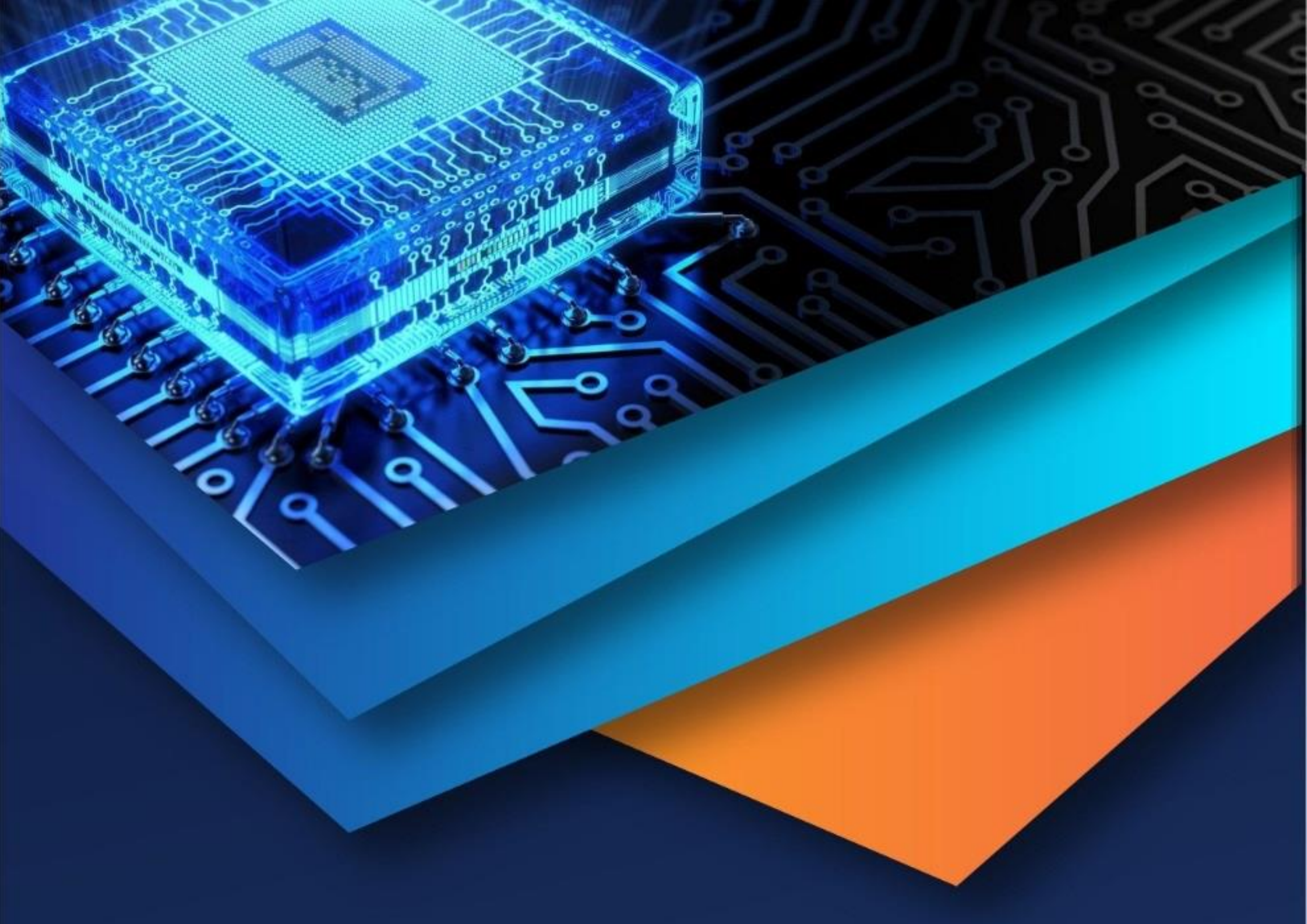

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