DESIGN AND DEVELOPMENT OF LIGHTER THAN AIR HYBRID POWER GENERATION SYSTEM FOR ELECTRIC VEHICLE CHARGING

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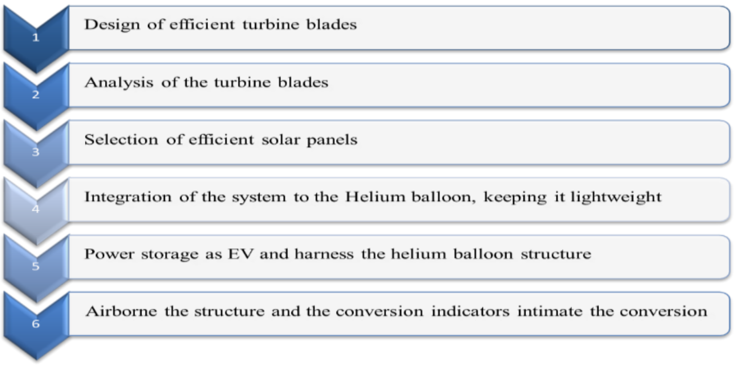
Introduction/Background

The Lighter than Air (LTA) Wind Turbine system harnesses high-altitude winds for electricity generation. Suspended by tethers, it rotates about its axis, activating an onboard AC generator. The generated current is transferred to the ground, where it undergoes conversion from alternating to direct current. The system's envelope and wing design allows operation with wind from two directions, and its spherical envelope enhances stability in turbulent weather, leveraging the Magnus effect. Particularly effective in metropolitan areas with limited space for conventional turbines, LTA systems hold significant potential for building a sustainable future. This project serves as a step toward realizing this potential, presenting an alternative that can be further developed into a viable solution. The move towards electric vehicles (EVs) promises green transportation, necessitating a robust charging infrastructure. In India, a significant opportunity exists for developing such infrastructure. To meet energy needs sustainably, this project proposes an airborne hybrid power generation system using tethered helium balloons with small wind turbines and flexible monocrystalline photovoltaic panels. This innovative system eliminates the requirement for large towers, operates efficiently at lower wind velocities, and taps into higher wind speeds at higher altitudes. Overcoming challenges such as lightweight generator design, balloon stabilization, and environmental considerations is crucial. The goal is to develop and characterize this system for powering EV charging stations, exploring applications in coastal regions, workplaces, homes, and assessing cost-effectiveness.

Objectives

- Conduct performance analysis of a horizontal axis wind turbine using QBlade software.
- Design an airborne solar and wind hybrid power generation system, aiming to integrate renewable energy sources efficiently.
- Fabricate aerodynamically efficient structure to ensure stability and positioning for optimal energy capture, prioritizing weight optimization with lightweight materials for buoyancy and solar panels, turbine blades, and other equipment.
- Conduct static tests in a wind tunnel for various air speeds and environmental testing at different altitudes to collect performance data across different wind velocities.
- Assess the feasibility of the airborne solar and wind hybrid power generation system for various applications and environments, with scalability considerations to meet future energy demands effectively.

Methodology



The methodology for developing an airborne wind turbine system involves several critical steps to ensure efficiency, durability, and lightweight construction.

The process begins with the design of aerodynamic turbine blades. Computational fluid dynamics (CFD) simulations are used to optimize blade shape and size, maximizing energy capture while minimizing weight. Advanced composite materials are selected for their strength and lightweight properties. The designed blades undergo structural analysis using finite element analysis (FEA) to ensure they can withstand high-altitude winds and other environmental stresses. Performance evaluations and fatigue testing further validate the durability and efficiency of the blades under various conditions. Lightweight, high-efficiency photovoltaic cells are chosen to supplement wind energy. Thin-film solar panels are integrated into the system, providing additional power during daylight hours without adding significant weight.

The turbine and solar panels are integrated with a helium balloon, focusing on maintaining minimal weight and structural stability. High-strength, lightweight materials are used for the balloon, ensuring it can support the system’s weight and remain stable in varying wind conditions. Advanced lithium-ion batteries, known for their high energy density and lightweight properties, are used for energy storage. These batteries store energy generated by the turbine and solar panels, ensuring continuous power availability. To support the entire system, the helium balloon is reinforced with lightweight, durable materials. This enhances the balloon's durability and resistance to environmental stresses without significantly increasing its weight. The system is deployed by filling the balloon with helium and launching it to the desired altitude. Real-time monitoring systems track the performance of the turbine, solar panels, and energy storage, providing data on wind speed, power output, and system health. The collected data is used to optimize the system’s performance, ensuring efficient energy generation and addressing any operational issues promptly.

Results and Conclusions

The speed at which maximum performance can be from the turbine is known as Design speed. In Q-blade software analysis, for the present design, a wind speed of 12 m/s was found to be the design speed. But in actual scenario this might differ as the friction losses that occur at the bearings end are being neglected. Hence a controlled wind testing is required where the model will be placed in front of a wind source (Wind tunnel) and the rpm is measured Through meticulous performance analysis utilizing QBlade, conducted a comprehensive evaluation of a Horizontal Axis Wind Turbine. Successfully fabricated and tested a prototype of an Airborne Hybrid Power Generation System, capable of generating 52 watts from wind and 50 watts from solar.

Experimental Results

Wind Speed (m/s)	Experimental Power (watts)	Theoretical Power (Watts)
3.5	1.91	4.36
4.5	3.71	9.27
5.5	7.71	16.93
6	9.60	21.98
7	12.21	34.90
7.5	15.93	42.92
8	22.25	60.09
9	29.36	74.17
10	34.46	101.74
12	52.87	175.80

This project represents a culmination of research, meticulous design, and precise fabrication, demonstrating the viability of an airborne solar and wind hybrid power generation system. By synergizing the abundant and renewable resources of solar radiation and wind currents, this innovative system presents a sustainable alternative to conventional fossil fuel-based power generation methods. The successful execution of this endeavor highlights the significance of innovation in addressing global energy challenges while mitigating adverse environmental impact. The balloon structure has the capacity to accommodate up to 2400 liters of helium, enabling it to lift a maximum weight of 3.9 kg for the entire system. At a height of 15 meters from the ground, the turbine blade yields 55 watts of power when wind speeds reach 12 m/s. The solar cells integrated onto the surface of the system are capable of generating 50 watts of power at their peak efficiency

Applications:

- Remote Area Electrification: Providing off-grid electricity solutions in remote regions where conventional power infrastructure is lacking.
- Disaster Relief Operations: Offering emergency power supply in disaster-stricken areas to support essential services and relief efforts.
- Telecommunications: Powering remote communication towers to ensure uninterrupted connectivity in underserved areas.
- Agriculture: Supporting irrigation systems, livestock operations, and agricultural machinery in rural and off-grid farming communities.
- Environmental Monitoring: Powering sensors and data collection devices in

remote wilderness areas for research and conservation purposes.

Assembly of the prototype

Description of the innovation in the project

The "Lighter than Air" project represents a significant advancement in renewable energy technology by harnessing high-altitude wind currents, which are stronger and more consistent than those at ground level. This innovation involves the design and deployment of a lightweight turbine system, integrated with efficient solar panels, all suspended by a helium balloon. The system leverages cutting-edge materials and aerodynamic designs to maximize energy capture while maintaining minimal weight. Advanced energy storage solutions ensure efficient power retention and delivery. Real-time monitoring and optimization enhance performance, making this airborne system a groundbreaking solution for sustainable and reliable energy generation.

Future work scope

Future scope for airborne wind energy systems includes enhancing aerodynamic efficiency, developing lightweight yet durable materials, integrating advanced control systems for optimal power generation, and exploring new deployment strategies such as high-altitude platforms. Additionally, research into energy storage solutions and grid integration methods will be crucial for maximizing the potential of airborne wind energy as a sustainable power source. Studying panel positioning, orientation, and the integration of bifacial panels in airborne wind energy systems presents an avenue for maximizing energy capture. Research should focus on optimizing the angle and direction of panels to ensure maximum exposure to sunlight and wind. Additionally, exploring the use of bifacial panels, which can capture sunlight from both sides, offers potential efficiency gains. Advanced modeling and simulation techniques can aid in determining the ideal configurations for panel placement and orientation, taking into account factors such as altitude, wind patterns, and solar irradiance