

Generation of Electricity by Hybrid Mode of Vertical Axis Wind Turbine with Solar Panel

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Abstract:

The growing demand for sustainable and uninterrupted energy has accelerated interest in hybrid renewable energy systems. This research presents the design, fabrication, and performance analysis of a small-scale hybrid power generation system that combines a Vertical Axis Wind Turbine (VAWT) with a photovoltaic (PV) solar panel. The proposed system is designed to overcome the intermittency of individual renewable sources by ensuring electricity generation under varying environmental conditions. A four-bladed vertical axis wind turbine fabricated using half-cut PVC pipes is coupled with a synchronous motor acting as a generator, while a 10 W solar panel is integrated at the top of the structure. Both energy sources are regulated through a charge controller to charge a 6 V rechargeable battery, which powers low-power DC loads such as LEDs. Experimental observations demonstrate that the hybrid configuration provides improved reliability and energy availability compared to standalone systems. The study highlights the feasibility of low-cost hybrid renewable systems for rural, off-grid, and educational applications.

Keywords — Hybrid energy system, Vertical Axis Wind Turbine, Solar panel, Renewable energy

I. INTRODUCTION

The global energy sector is undergoing a transition from fossil fuel-based generation to renewable energy sources due to concerns over climate change, depletion of natural resources, and rising energy demand. Among renewable options, solar and wind energy are the most widely adopted due to their abundance and environmental benefits. However, both sources suffer from intermittency: solar energy is unavailable at night and during cloudy conditions, while wind energy is highly dependent on wind speed and location.

Hybrid renewable energy systems (HRES) integrate two or more energy sources to improve system reliability, efficiency, and energy continuity. Combining wind and solar energy is particularly attractive because their availability patterns are often complementary. Vertical Axis Wind Turbines (VAWTs) offer additional

advantages over Horizontal Axis Wind Turbines (HAWTs), such as omni-directional wind acceptance, simple construction, lower noise, and ease of maintenance.

This paper presents the development of a hybrid VAWT-solar power generation system intended for small-scale applications. The system emphasizes low cost, simplicity, and suitability for rural and off-grid environments while serving as an effective educational and experimental model.

II. PROBLEM STATEMENT

Standalone renewable energy systems are often unreliable due to their dependence on environmental conditions. Solar-only systems fail during nighttime or low-irradiance conditions, while wind-only systems cannot guarantee power generation during calm periods. In many rural and remote areas, grid access is limited or unreliable,

creating a need for compact, affordable, and continuous power generation solutions.

The challenge addressed in this research is the development of a cost-effective hybrid system that integrates wind and solar energy in a single unit to ensure continuous electricity generation for low-power applications.

3. Objectives

The main objectives of this research are:

- To design and fabricate a compact hybrid renewable energy system combining wind and solar power.
- To develop a low-cost vertical axis wind turbine using easily available PVC materials.
- To integrate a photovoltaic solar panel with the wind turbine for hybrid energy generation.
- To convert mechanical energy from wind into electrical energy using a synchronous generator.
- To store the generated electrical energy in a rechargeable battery.
- To evaluate the feasibility of the system for small-scale and off-grid applications.

4. System Description and Methodology

4.1 System Architecture

- The hybrid system consists of the following major components:
- Vertical Axis Wind Turbine (VAWT)
- Synchronous motor used as a generator
- Photovoltaic solar panel (10 W)
- Charge controller
- Rechargeable battery (6 V)
- DC load (LED lighting)

4.2 Vertical Axis Wind Turbine Design

The VAWT is constructed using four half-cut PVC pipes of 4-inch diameter, mounted vertically around a central shaft. The vertical axis

configuration allows wind capture from all directions without the need for yaw mechanisms. The lightweight PVC blades reduce inertia and cost while maintaining sufficient aerodynamic drag and lift for rotation at low wind speeds.

4.3 Solar Photovoltaic Integration

A 10 W photovoltaic solar panel is mounted at the top of the turbine structure. The panel converts solar irradiance directly into DC electrical power. The integration of the solar panel ensures energy generation during daytime conditions, complementing wind energy availability.

4.4 Power Conditioning and Storage

The electrical output from the wind generator and solar panel is fed into a charge controller, which regulates voltage and current to safely charge a 6 V rechargeable battery. The stored energy is used to power DC loads, ensuring stable output despite fluctuations in wind speed and solar radiation.

5. Working Principle

When wind flows across the PVC blades, aerodynamic forces cause the vertical shaft to rotate. The shaft is mechanically coupled to a synchronous motor acting as a generator, converting mechanical energy into electrical energy. The generated AC output is rectified to DC before being supplied to the charge controller. Simultaneously, the solar panel generates DC electricity when exposed to sunlight. The charge controller combines and regulates power from both sources to charge the battery and supply the connected load. This hybrid operation enables power generation during both daytime and nighttime conditions, depending on resource availability.

6. Experimental Observations and Performance Analysis

The fabricated prototype was tested under varying environmental conditions. Observations indicate that:

The VAWT begins rotating at relatively low wind speeds due to its vertical axis design.

The solar panel contributes significantly to battery charging during peak sunlight hours.

The hybrid system provides more consistent charging compared to standalone wind or solar setups.

Although the overall power output is limited due to the small size of the system, the results validate the effectiveness of hybridization for improving energy reliability.

7. Advantages and Applications

7.1 Advantages

- Continuous energy generation using two renewable sources
- Simple, compact, and low-cost design
- Omni-directional wind acceptance
- Environmentally friendly with zero emissions
- Suitable for educational and experimental purposes

7.2 Applications

- Rural and off-grid lighting systems
- Power supply for small electronic devices and sensors
- Educational demonstrations of renewable energy systems
- Micro hybrid power generation units

8. Limitations

- Low power output due to small-scale design
- Performance depends on wind speed and solar irradiance
- Generator efficiency is reduced at low rotational speeds
- Not suitable for large-scale or high-power applications

9. CONCLUSIONS

This research successfully demonstrates the design and implementation of a hybrid vertical axis wind turbine integrated with a solar photovoltaic system for small-scale electricity generation. The system effectively combines wind and solar energy to overcome the limitations of standalone renewable sources. Experimental results confirm improved reliability and continuous energy availability for low-power applications. The proposed model is suitable for rural electrification, educational purposes, and as a foundation for further research in hybrid renewable energy systems.

10. Future Scope

Future enhancements may include aerodynamic blade optimization, use of advanced lightweight composite materials, higher-efficiency generators, and maximum power point tracking (MPPT) charge controllers. Scaling the system to higher voltage levels and integrating IoT-based monitoring can further improve performance and applicability.

11. REFERENCES

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