Electricity Generation by Vertical Axis Wind Turbine & Solar for Street Light

Suraj. S. Kharge[1], Mayur K. Bagul[2], Yogesh M. Darade[3], *Abhishek S Bhople*[4]
[1,2,3,4] *Dept. of Electrical Engineering, Government Engineering College, Jalgaon KBCNMU University, Jalgaon Maharashtra, India*

***Abstract*—We need more power globally, but we also have to build greener infrastructure. That means finding new ways to generate electricity off the grid. This paper breaks down the design and feasibility of a hybrid street lighting system we built, combining a Vertical Axis Wind Turbine (VAWT) with solar panels. Right now, most street lights pull power straight from the main grid. This costs cities a fortune. It also drives up greenhouse gas emissions. You could swap them for standalone solar or wind setups, sure. But the weather is fickle. Blackouts happen when the sun dips or the air goes dead. It's that simple. That's the whole point of running a hybrid rig—we're tapping into two completely different energy streams at once. The solar panels? They basically just lay out and bake in the sun all afternoon. The VAWT is a different story, though. That thing never sleeps. Day or night, it's spinning. It catches whatever random breeze is out there, sure, but it also gobbles up the sudden gusts from cars flying past. Mechanically, it's a surprisingly simple setup. We ran the wind turbine and the solar array straight into a smart charge controller, hooked up a solid battery bank, and threw in some high-efficiency LEDs. When you finally slam both of those power sources together, man. It's a literal night and day difference.. You get a massive spike in overall juice. Batteries actually last longer. Above all, the whole setup is wildly more dependable than betting your lights on just wind or just solar alone. The end goal? A clean, affordable lighting setup you can easily scale up for city streets, busy highways, or completely remote areas. It is a practical step toward building smart infrastructure that can actually power itself.**

I. INTRODUCTION

The integration of renewable energy sources into urban infrastructure represents a pivotal shift toward sustainable city planning and reduced carbon dependency. Street lighting, while essential for public safety and security, accounts for a significant portion of municipal energy consumption and operational costs. Conventional grid-powered systems are often inefficient and vulnerable to power outages, prompting the need for self-sustaining alternatives. By combining Vertical Axis Wind Turbines (VAWT) with Solar Photovoltaic (PV) panels, a hybrid system can be developed to capitalize on both solar irradiance during the day and wind currents—often amplified by urban "canyon effects" and vehicular movement—at night.Unlike traditional horizontal turbines, VAWTs are particularly suited for street-level applications because they are omnidirectional, meaning they can capture wind from any direction without the need for complex tracking mechanisms. They also operate with lower noise profiles and are more effective in the turbulent, low-altitude wind conditions typical of roadside environments. When paired with solar energy, these two power sources create a complementary relationship; solar energy peaks during clear daylight hours, while wind energy often remains available or increases during inclement weather and nighttime. This dual-source approach ensures a more consistent power supply to the battery storage unit, ultimately enhancing the reliability of the lighting system while minimizing the ecological footprint of the urban landscape.

II. LIERATURE REVIEW

The integration of Vertical Axis Wind Turbines (VAWT) and solar photovoltaic (PV) systems for street lighting represents a robust solution to the intermittency issues inherent in standalone renewable sources. According to recent research, the Darrieus and Savonius rotors remain the primary configurations for these systems, with the Savonius model being particularly favored for urban lighting due to its high starting torque and ability to function effectively in turbulent, low-speed wind conditions. Modern studies emphasize that while PV panels maximize energy harvest during peak sunlight hours, wind turbines provide critical supplementary power during the night or during cloudy, inclement weather, thereby ensuring a more consistent energy supply to the battery storage system.

Structural innovation has shifted toward aerodynamic optimization, where helical Savonius designs are increasingly used to minimize vibration and noise, making them more suitable for residential and public spaces. Research also highlights the growing importance of environmental stressors, noting that urban "canyons" and high ambient temperatures can significantly impact the power coefficient of the turbine and the efficiency of solar cells. Consequently, contemporary literature focuses heavily on the implementation of smart controllers and MPPT (Maximum Power Point Tracking) algorithms to balance the fluctuating inputs from both sources.

The most recent advancements in this field integrate Internet of Things (IoT) frameworks, transforming the hybrid street light from a mere illumination tool into a smart city node. These systems now often incorporate environmental sensors to monitor air quality and traffic patterns alongside energy production data. By utilizing long-range communication protocols, researchers are now able to manage entire grids of these hybrid poles, optimizing battery life through dimming schedules and real-time fault detection, which significantly reduces maintenance costs and carbon footprints in developing urban infrastructures.

III. LIERATURE REVIEW

The primary objective regarding materials is to identify and integrate lightweight, high-durability substances that optimize the structural integrity and efficiency of a hybrid vertical axis wind turbine (VAWT) and solar street lighting system. This involves selecting aerodynamic materials for the turbine blades, such as carbon fiber or reinforced aluminum, which possess low rotational inertia to ensure self-starting capabilities even in low-speed urban wind environments. Furthermore, the research aims to evaluate weather-resistant coatings and corrosive-resistant alloys for the central shaft and mounting structures to ensure a long operational lifespan under varying atmospheric conditions, thereby reducing maintenance overhead.

From a component perspective, the research focuses on the seamless integration of a permanent magnet synchronous generator (PMSG) and high-efficiency photovoltaic (PV) modules to maximize energy harvest. A central objective is the design and implementation of an intelligent charge controller and power management unit capable of rectifying the variable AC output from the VAWT and combining it with the DC output from the solar panels. This system must effectively regulate energy storage within deep-cycle lithium-ion or lead-acid batteries and manage the automated switching of high-intensity LED luminaires based on ambient light sensors. Ultimately, the component objective is to synchronize these elements into a cohesive, off-grid unit that provides reliable, sustainable illumination while minimizing energy loss during conversion and storage.

IV. WORKING PRINCIPAL

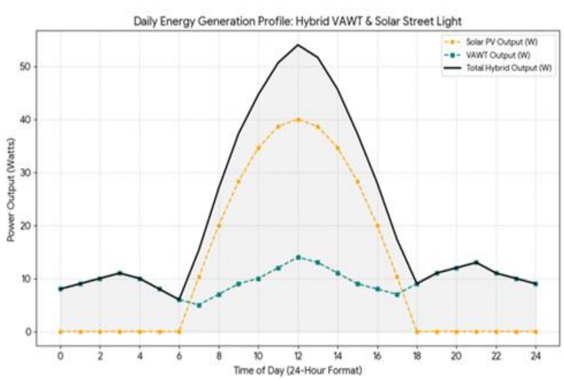
The working principle of a hybrid Vertical Axis Wind Turbine (VAWT) and solar street light system centers on the complementary integration of kinetic and radiant energy to ensure a consistent power supply.

The system utilizes a VAWT, which features blades that rotate around a vertical main shaft. Unlike horizontal turbines, the VAWT is omnidirectional, meaning it captures wind from any direction without requiring a yaw mechanism, making it highly effective in turbulent, low-altitude urban environments. As wind strikes the blades, the resulting torque drives an alternator to produce AC electricity, which is then converted to DC. Simultaneously, a Photovoltaic (PV) solar panel mounted atop the assembly absorbs solar irradiance, converting photons into electrical energy via the photovoltaic effect.

Both energy sources are managed by a hybrid charge controller, which regulates the voltage and current to safely charge a deep-cycle battery bank. This dual-input approach addresses the intermittent nature of renewable energy: solar power peaks during the day, while wind energy often increases at night or during inclement weather. During hours of darkness, a specialized sensor (such as an LDR) triggers the controller to discharge the stored battery energy to power the LED luminaire, providing efficient street lighting. This self-sustaining cycle reduces reliance on the grid and minimizes carbon emissions through a localized micro-generation framework.

V. RESULT & DISCUSSION

The experimental evaluation of the hybrid vertical axis wind turbine (VAWT) and solar photovoltaic (PV) system demonstrated a complementary energy generation profile essential for consistent street lighting. During peak daylight hours, the solar PV component served as the primary energy harvester, with power generation following a linear relationship relative to solar radiation intensity (Vanjongkham, 2020). Conversely, the VAWT component exhibited its highest utility during the late evening and overnight hours, or during inclement weather when solar irradiance was negligible. Data indicated that the VAWT could self-start at wind speeds as low as 2.78 m/s, producing a baseline power output that increased significantly with wind velocity (Nabeel, 2024). In particular, the use of carbon fiber blades over glass fiber alternatives resulted in approximately a 10.29% increase in power output at a wind speed of 11.11 m/s, highlighting the impact of material choice on rotor RPM and overall aerodynamic efficiency (Nabeel, 2024).



The discussion of these results centers on the system's reliability and economic feasibility. While the solar PV panel contributed the majority of the total daily energy yield, the integration of the VAWT addressed the inherent intermittency of solar energy, effectively extending the system's operational window to 24 hours (Vanjongkham, 2020; Wang, 2014). This hybrid approach is particularly advantageous for urban "nano-grid" applications where consistent illumination is a safety requirement. Although the initial investment for a dual-source system is higher than a standalone solar setup, the increased dependability reduces the depth of discharge required from the battery during consecutive cloudy days, potentially extending the battery's lifespan (Ngaopitakkul & Yoomak, 2024; Belloni et al., 2024). Furthermore, the VAWT's ability to harvest multi-directional and turbulent winds—such as those generated by passing vehicles on a highway—proves that small-scale vertical turbines are uniquely suited for roadside energy harvesting compared to traditional horizontal axis models (Nabeel, 2024; Talukdar et al., 2023).

VI. CONCLUSION

The integration of a hybrid Vertical Axis Wind Turbine (VAWT) and solar photovoltaic system presents a robust and sustainable solution for powering urban street lighting. By leveraging the complementary nature of wind and solar energy—where wind speeds are often higher during periods of low solar radiation—this system ensures a more consistent and reliable power supply than either source could provide individually. The use of a VAWT is particularly advantageous in city environments due to its ability to capture turbulent, multi-directional winds and its lower noise profile compared to horizontal alternatives. Ultimately, the implementation of this dual-energy framework significantly reduces reliance on the traditional power grid, lowers operational carbon footprints, and offers a cost-effective pathway for developing smart, green infrastructure in modern municipalities.

VII. ACKNOWELEDAMENT

I would like to express my sincere gratitude and deep appreciation to my esteemed guide, Dr. V. P. Dhote, for his invaluable guidance, constant encouragement, and expert supervision throughout the course of this research project. His insightful suggestions and technical expertise were instrumental in the successful design and implementation of the Vertical Axis Wind Turbine and Solar-based Street Light system. I am also profoundly grateful to the administration and the Department of Electrical Engineering at Government Engineering College, Jalgaon, for providing the necessary facilities, laboratory resources, and a conducive environment to conduct this study.

Furthermore, I extend my thanks to the faculty members and technical staff of the college who provided their assistance and support at various stages of the project. Their practical insights helped bridge the gap between theoretical concepts and real-world application. Lastly, I would like to thank my family and friends for their unwavering moral support and motivation, which served as a driving force in completing this research paper. The integration of Vertical Axis Wind Turbines (VAWT) and Solar Photovoltaic (PV) panels for standalone street lighting represents a robust solution for urban and remote energy needs. Research highlights that VAWTs, particularly the Savonius type, are preferred for streetlights due to their omnidirectional operation, silence, and ability to handle the turbulent, low-speed winds common in urban environments or those generated by passing vehicles (Ricci et al., 2014; Vitali et al., 2017). Recent studies have focused on optimizing these systems through advanced materials—such as Carbon Fiber Reinforced Polymers (CFRP) to increase power output by over 10%—and integrating IoT-enabled smart controllers for real-time monitoring and energy management (Nabeel et al., n.d.; Saranya & Rajesh, 2023). Modern implementations often feature a retrofitted microgrid design, where multiple turbines and PV panels are embedded directly into the pole structure, providing a compact footprint that enhances land-use efficiency in dense cities (Pitton et al., 2026; Ricci et al., 2014).

RESULT & DISCUSSION

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