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SELF SUSTAINING WIND-POWERED STREETLIGHT

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ABSTRACT

This project focuses on harnessing wind energy to generate electricity for street lighting. It integrates an ESP32 microcontroller to monitor key parameter such as voltage, current, speed, and light. An infrared (IR) sensor is used to track the rotational speed of the wind turbine, while a current sensor module measures the electrical output from the generator or DC motor. Light detection is handled by a light-dependent resistor (LDR), ensuring the streetlights automatically activate in low-light conditions. Additionally, all monitored data and system controls are accessible via a mobile application (Blynk), which is programmed into the ESP32 for remote management and real-time monitoring. Its parameter also display in liquid crystal display (LCD).

1. Introduction

Wind energy is one of the most abundant and sustainable sources of renewable energy available today. It is harnessed through wind turbines, which convert the kinetic energy of the wind into mechanical power and subsequently into electrical energy. The growing demand for clean and environmentally friendly energy sources has led to increased research and development in wind energy technologies (Burton et al 2011).

As part of the broader category of renewable energy, wind power plays a crucial role in reducing dependency on fossil fuels and minimizing greenhouse gas emissions. Unlike conventional energy sources such as coal and oil, wind energy **is** inexhaustible and does not produce harmful pollutants. Governments and organizations worldwide are promoting wind energy as a key solution for achieving sustainable energy goals (Sadorsky P. 2021).

Wind energy can be integrated into urban infrastructure, such as wind turbine-powered streetlights**,** to provide efficient and cost-effective lighting solutions. By utilizing wind-generated electricity, such systems contribute to energy conservation and environmental sustainability while reducing reliance on conventional power grids (S. R and B. Asaithambi , 2024) .

Small-scale wind turbines can be installed along highways where vehicles create artificial wind flow, optimizing energy harvesting (A.A. Al-Aqel et al,2016). In recent years,

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microcontroller-based monitoring systems have improved the efficiency of renewable energy projects. The ESP32 microcontroller is commonly used due to its low power consumption, built-in Wi-Fi, and compatibility with various sensors (P. R. **Babu** et al, 2023)**.**

This project integrates an infrared (IR) sensor to measure wind turbine speed**, a** current **sensor** to monitor power output, and **a** light-dependent resistor (LDR) **to** detect ambient light levels. The ESP32 microcontroller processes this data and controls the operation of the streetlights. Additionally, a mobile application using **Blynk** is implemented to provide real-time monitoring and remote access to system parameters. This smart, wind-powered streetlight system aims to reduce reliance on conventional electricity while promoting energy-efficient urban lighting.

2. Materials and Methods

The wind turbine converts the kinetic energy of the wind into electrical energy through a generator mechanism. The generated electrical current is channeled into a storage battery before being used to power the streetlight (Renato Ricci et al, 2015) . The ESP32 is chosen as the main controller because it supports Wi-Fi for remote data communication and has the capability to read input from various sensors.

In this project the hardware components are wind turbine , ESP32 microcontroller , IR sensor , current sensor module, LDR , rechargeable battery, LCD and LED streetlight . For sensor integration and monitoring , IR sensor detects the turbine's rotation speed by counting interruptions in the infrared beam and current sensor measures the electrical output from the wind turbine. While LDR sensor monitors ambient light levels and triggers the LED streetlight when it gets dark. All sensor data is processed by the ESP32 microcontroller and transmitted to the Blynk mobile application for real-time monitoring (Figure 1).

The ESP32 communicates wirelessly with the Blynk app via Wi-Fi, allowing users to monitor parameters such as wind turbine speed (from IR sensor) , power output (from current sensor) and streetlight status (from LDR readings). During daytime, excess energy is stored in the battery. At night, the LDR sensor detects low ambient light, and the ESP32 activates the LED streetlight using stored energy. If wind speed drops significantly, alternative power management strategies can be implemented. The system's software is developed using Arduino IDE for data processing using ESP32 that get input from IR sensor , current sensor , and LDR sensor. It also integrate with Blynk apps which the data will displayed in real time on a mobile app . Beside it also can be display on the LCD.

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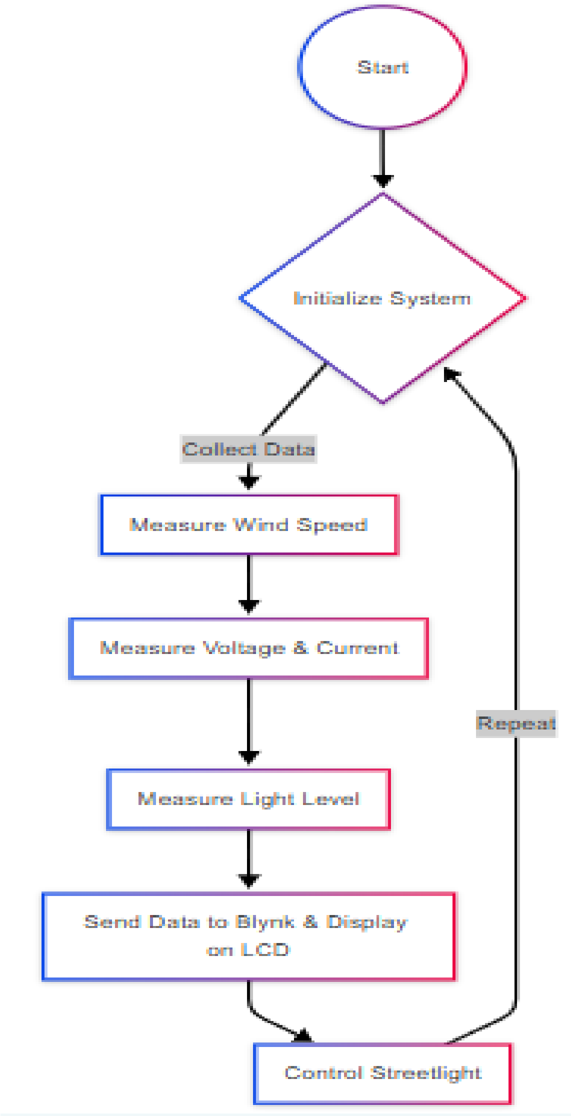

Figure 1 : Wind powered street light

3. Results

Figure 2 shows the prototype of the wind powered street light and its will activate when the ambient light is low and deactivated when sufficient light is detected . This process runs in a continuous loop, where data is collected every second and updated on both the LCD display (Figure 3) and the Blynk application via smart phone (Figure 4).

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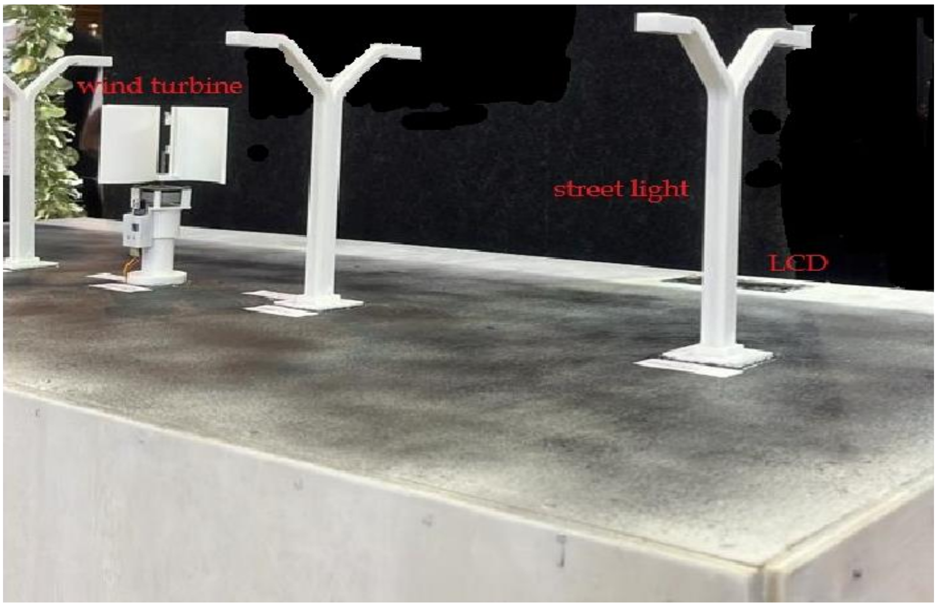

Figure 2 : Prototype of wind powered street light

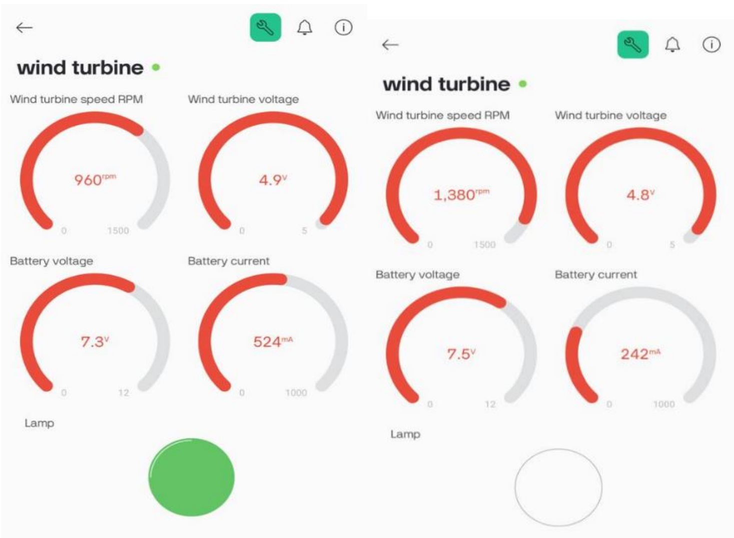

Figure 3 : Measurement display using Blynk apps

Figure 4 : Measurement display using LCD

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4. Discussion

Table 1 : Result of monitoring wind speed ,voltage and current and power in different condition .

	Power (W)	Voltage (V)	Current (mA)	Speed	Condition	LED
1	1622mW	7.53V	243mA	1680RPM	Dark	on
2	1780mW	7.44V	237mA	1440RPM	Bright	off
3	1828mW	7.53V	243mA	1560RPM	Dark	on
4	1626mW	7.25V	216mA	1320RPM	Bright	off
5	1826mW	7.52V	243mA	1380RPM	Dark	on

It can be observed that when the surrounding is dark , the LDR's resistance increases, leading to a rise in voltage. This triggers the controller to activate a relay or transistor, turning on the streetlight and vice verse . This automatic system helps conserve energy by ensuring the light operates only when necessary. Beside that its also display the parameters generated by the wind turbine-powered streetlight model fully adhere to the principles of wind turbine power. In other words, as wind speed increases, the voltage produced by the model also increases accordingly. These results consistently reflect a positive correlation between wind speed and voltage in the context of wind turbine power, reinforcing the model's reliability in predicting and optimizing wind power performance based on variations in wind speed.

5. Conclusion

This project successfully demonstrates the integration of a wind turbine-powered streetlight system with an LDR-based automatic lighting control. The system ensures energy efficiency by activating the streetlight only in low-light conditions, conserving power and optimizing performance. Additionally, the data collected confirms that the generated voltage follows the principles of wind turbine power, where an increase in wind speed results in a corresponding rise in voltage output. Overall, the project highlights the potential of renewable energy solutions for sustainable and efficient street lighting systems.

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6. Acknowledgements

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