

# Smart Road Divider with Wind Energy Harvesting and IoT Based Highway Monitoring System

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**Abstract:** *The increasing demand for sustainable infrastructure and renewable energy solutions has encouraged the development of intelligent highway systems that can utilize unused environmental resources efficiently. This paper presents a Smart Road Divider with Wind Energy Harvesting and IoT-Based Highway Monitoring System designed to generate electrical energy from the wind pressure created by moving vehicles on highways. In the proposed system, a rotating armature mechanism is installed inside the road divider to convert vehicle-induced airflow into electrical energy, which is then stored in a DC battery through a charging circuit. The stored energy is utilized to power automatic highway lighting using an LDR-based control mechanism for day and night operation. An ESP32 microcontroller is integrated to manage sensor inputs, monitor battery voltage, and control system operations efficiently.*

**Keywords:** Smart Road Divider, Wind Energy Harvesting, ESP32, IoT Monitoring, Highway Automation, Renewable Energy, Smart Street Lighting, Cloud Platform

## I. INTRODUCTION

The rapid growth of transportation infrastructure and increasing vehicle population have significantly raised the demand for electricity in highway systems, particularly for street lighting, monitoring devices, and traffic safety equipment [1]. Conventional highway lighting systems consume a considerable amount of electrical power and mostly depend on grid-based energy sources, leading to higher operational costs and increased carbon emissions [2]. With the expansion of smart city concepts and sustainable infrastructure development, there is a growing need to integrate renewable energy solutions into transportation systems to minimize environmental impact and improve efficiency [3]. Smart highways equipped with intelligent monitoring and automated systems are becoming essential for modern transportation networks, enabling better traffic management, energy conservation, and road safety improvements [4]. These advancements highlight the importance of adopting innovative and sustainable technologies in road infrastructure development.

In recent years, renewable energy harvesting technologies have gained major attention due to their capability to convert unused environmental energy into useful electrical power [5]. One of the most overlooked sources of renewable energy on highways is the airflow generated by moving vehicles, which creates significant wind pressure around road dividers and roadside structures [6]. Research has shown that vehicle-induced wind can be utilized through micro wind turbines or rotating armature systems to generate electrical energy for small-scale highway applications [7]. This method provides an effective way to harvest otherwise wasted kinetic energy and convert it into sustainable power, reducing dependency on traditional electricity sources [8]. The use of wind-based roadside energy harvesting systems presents a promising opportunity for developing self-powered highway infrastructure.

Along with renewable energy generation, automation in highway lighting systems has become increasingly important for reducing unnecessary power consumption and improving operational efficiency [9] [10]. Such automated control mechanisms significantly enhance energy efficiency while reducing manual intervention and maintenance requirements. Furthermore, intelligent lighting systems improve visibility and safety for drivers during nighttime travel



and adverse weather conditions [3]. This project proposes a Smart Road Divider with Wind Energy Harvesting and IoT-Based Highway Monitoring System that combines renewable energy generation, automatic lighting, and cloud-based monitoring into a single integrated platform. The proposed system aims to enhance road safety, reduce energy consumption, and promote sustainable smart highway development through intelligent automation and renewable technology integration [4].

## II. PROBLEM STATEMENT

Conventional highway road dividers serve only as passive safety barriers and do not contribute to energy generation or intelligent monitoring, while highway lighting systems consume a significant amount of electrical power from conventional grid sources, increasing operational costs and environmental impact. Therefore, there is a need to develop a smart road divider system capable of harvesting wind energy, powering highway lighting, and enabling IoT-based monitoring for sustainable and intelligent transportation infrastructure.

## III. OBJECTIVES

- To harvest wind energy using a rotating armature installed inside road dividers.
- To store the generated electrical energy in DC batteries for efficient utilization.
- To control street lighting automatically using an LDR-based ON/OFF system.
- To monitor and record environmental temperature and humidity using sensors.
- To display system data and operational status on a cloud dashboard for remote monitoring.

## IV. LITERATURE SURVEY

**Moreno-Pacheco et al. (2024)**, “Assessment of Wind Energy Potential Generated by Vehicles” studied the possibility of generating electricity from airflow created by moving vehicles on highways using vertical axis wind turbines. The authors analyzed the wind pressure generated by vehicles and concluded that sufficient airflow exists near highways to support small-scale energy harvesting systems. Their research highlighted that vehicle-generated wind can be effectively converted into electrical energy when turbines are properly positioned. This study provides a strong foundation for integrating wind-based energy harvesting systems into road infrastructure for sustainable power generation.

**Bakırcı et al. (2024)**, “Highway Wind Energy Conversion with a Savonius-Darrieus Vertical Axis Wind Turbine” proposed a hybrid vertical axis wind turbine specifically designed for highway applications. The researchers combined Savonius and Darrieus turbine models to improve efficiency in capturing wind generated by moving vehicles. Their findings demonstrated enhanced energy conversion efficiency and improved turbine performance under varying traffic conditions. The paper emphasized the practical implementation of compact turbine systems in highway environments for powering road-based applications.

**Khemakhem et al. (2024)**, “A Comprehensive Survey on an IoT-Based Smart Public Street Lighting Infrastructure” reviewed IoT-enabled smart street lighting systems designed for modern smart cities. The study discussed automated lighting control using sensors, wireless communication, and cloud-based monitoring systems to improve energy efficiency and reduce maintenance requirements. The authors concluded that IoT-integrated lighting systems significantly reduce energy consumption and enhance infrastructure intelligence. This research supports the use of smart lighting automation in highway monitoring applications.

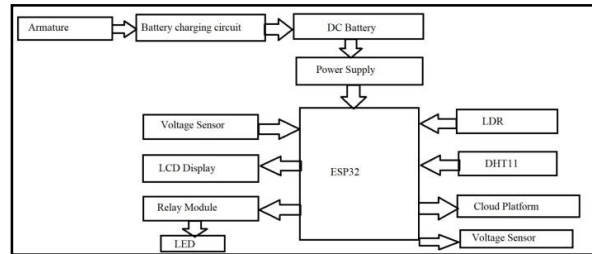
**Alagirisamy et al. (2025)**, “Energy Harvesting from Vehicle-Induced Wind for Sustainable Applications” explored methods of capturing vehicle-induced wind energy for sustainable electrical power generation. The study focused on optimizing turbine structures and placement to maximize harvested power output from vehicle movement. Results showed that properly designed wind harvesting systems can provide continuous supplementary energy for roadside electrical devices. The paper recommended integrating energy harvesting with intelligent control systems for improved infrastructure sustainability.



Sharma et al. (2024), “Harvesting Low-Grade Wind Energy from Highways Using Vertical Axis Wind Turbines” investigated advanced vertical axis turbine models for collecting low-speed wind energy produced on highways. The authors found that even low-grade airflow from traffic movement can generate measurable electrical power when efficient turbine blade structures are used. Their study suggested that combining wind harvesting systems with storage batteries and automation controllers can enhance practical deployment in real-world highway applications.

**V. PROPOSED RESEARCH**

**METHODOLOGY**



**Fig 1: Design of the system**

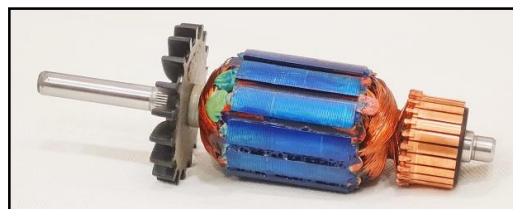
The proposed system begins by capturing wind energy generated from moving vehicles using a rotating armature installed inside the road divider. The generated electrical energy is regulated through a charging circuit and stored in a DC battery for powering the system components. An ESP32 microcontroller then manages automatic street lighting, environmental monitoring, and cloud-based data transmission for smart highway operation.

The proposed smart road divider system starts its operation by utilizing the wind pressure produced from fast-moving vehicles on highways. A rotating armature mechanism is installed inside the road divider, which spins whenever airflow from passing vehicles strikes its blades. This rotational motion converts the mechanical wind energy into electrical energy through electromagnetic induction, enabling the system to generate renewable power from otherwise wasted highway airflow.

The ESP32 microcontroller functions as the brain of the system by processing sensor inputs and controlling all connected devices. It receives data from the LDR sensor to automate street light switching based on day and night conditions, while the DHT11 sensor monitors temperature and humidity levels around the highway. All operational data, including battery voltage, environmental conditions, and lighting status, is displayed on the LCD screen and uploaded to the cloud dashboard for real-time remote monitoring through IoT technology.

**VI. SYSTEM DESIGN**

**1. Armature**

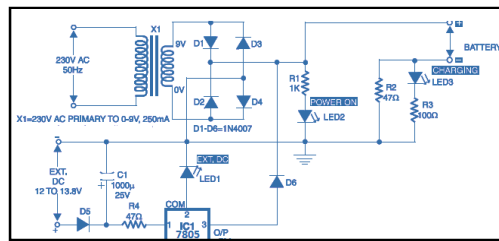


**Fig 2: Armature**

The armature is the primary energy harvesting component of the system, installed inside the road divider structure. It rotates when wind pressure generated by moving vehicles strikes its blades. This rotational movement converts mechanical energy into electrical energy through electromagnetic induction, enabling the generation of renewable power from highway traffic airflow.



## 2. Battery Charging Circuit

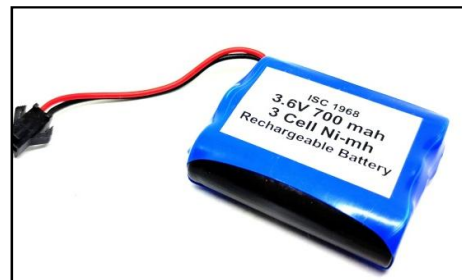


**Fig 3: Battery Charging Circuit**

The battery charging circuit regulates the electrical energy produced by the armature before supplying it to the battery. It ensures safe charging by controlling voltage and current levels, preventing overcharging and deep discharge of the battery. This circuit improves battery life and maintains stable energy storage performance.

## 3. DC Battery

The DC battery is used to store the electrical energy generated by the armature for later use. It acts as the main power source for operating the complete system, including sensors, controller, and street lighting. The battery provides continuous power supply even when wind generation is low or unavailable.



**Fig 4: DC battery**

## 4. Power Supply Unit

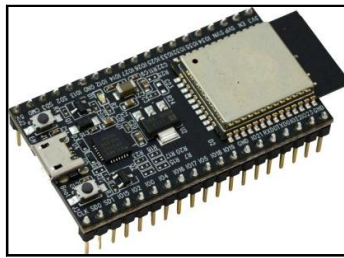


**Fig 5: Power supply unit**

The power supply unit converts and regulates the stored battery voltage into the required operating voltage for different electronic components. It ensures that the ESP32, sensors, LCD, and relay receive stable and appropriate power for reliable functioning of the system.



### 5. ESP32 Microcontroller

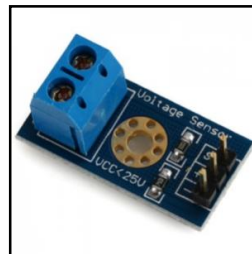


**Fig 6: ESP32 microcontroller**

The ESP32 microcontroller serves as the central processing unit of the project. It collects data from all connected sensors, processes input signals, controls output devices, and manages overall system operations. Additionally, it enables Wi-Fi communication for transmitting real-time data to the cloud dashboard for remote monitoring.

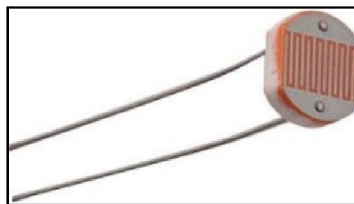
### 6. Voltage Sensor

The voltage sensor measures the battery voltage continuously and sends the readings to the ESP32. This helps in monitoring battery charge levels and system power availability. It also allows users to track generated energy efficiency and battery health.



**Fig 7: Voltage sensor**

### 7. LDR Sensor

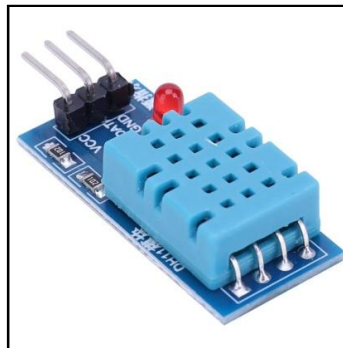


**Fig 8: Light Dependent Resistor (LDR)**

The Light Dependent Resistor (LDR) detects surrounding light intensity in the environment. During daytime, it senses high light levels and signals the controller to turn OFF the street lights. During nighttime or low-light conditions, it activates the street lighting automatically.



### 8. DHT11 Sensor



**Fig 9: DHT11 sensor**

The DHT11 sensor is used to measure environmental temperature and humidity. It provides real-time weather data that can be displayed locally and uploaded to the cloud dashboard for monitoring environmental conditions around the highway.

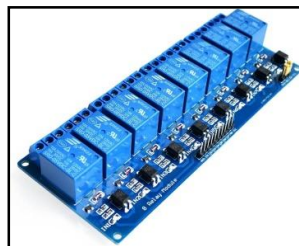
### 9. LCD Display



**Fig 10: LCD display**

The LCD display is used to present important system parameters such as battery voltage, temperature, humidity, and lighting status. It allows users and maintenance personnel to monitor system operation directly from the hardware setup.

### 10. Relay Module



**Fig 11: Relay module**

The relay module acts as an electrically controlled switch used to control the street light operation. It receives switching signals from the ESP32 and turns the LED ON or OFF based on LDR input and system conditions.



**11. LED Light**



**Fig 12: LED**

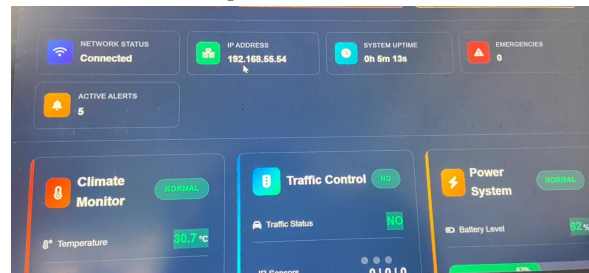
The LED represents the highway street light in the system. It automatically turns ON during low-light conditions and OFF during daylight, helping reduce energy wastage and improve highway illumination efficiency.

**Cloud Dashboard**

The cloud dashboard provides remote access to all system data through IoT connectivity. It displays battery voltage, environmental readings, and light status in real time, allowing users to monitor and analyze the performance of the system from any location.

**VIII. RESULTS**

The developed Smart Road Divider with Wind Energy Harvesting and IoT-Based Highway Monitoring System was successfully designed and tested under simulated highway conditions. The rotating armature mechanism effectively generated electrical energy from airflow produced by moving vehicles, demonstrating the feasibility of converting vehicle-induced wind pressure into usable electrical power.



**Fig 13: Interface 1**



**Fig 14: Interface 2**



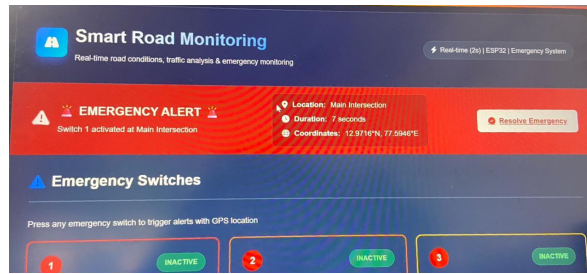


Fig 15: Interface 3

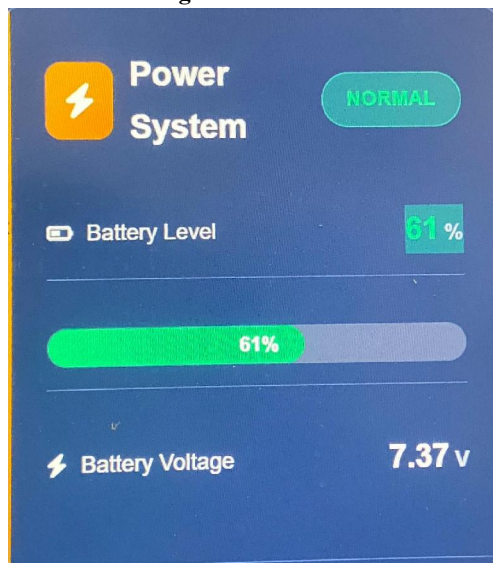


Fig 16: Interface 4

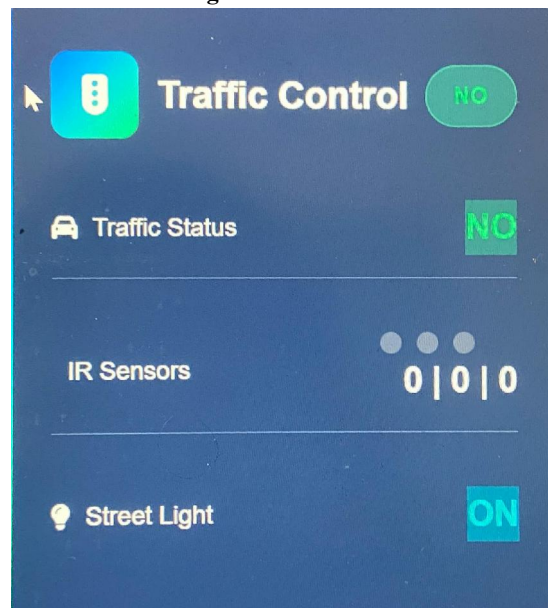
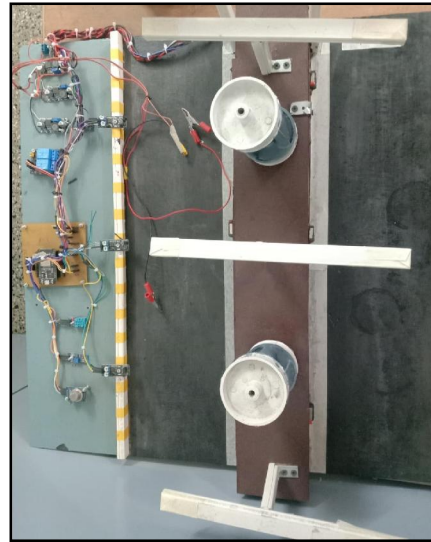


Fig 17: Interface 5





**Fig 18: Model prototype**

### IX. CONCLUSION

The Smart Road Divider with Wind Energy Harvesting and IoT-Based Highway Monitoring System presents an innovative and sustainable approach for improving highway infrastructure by integrating renewable energy generation, smart automation, and remote monitoring into a single platform. The system successfully utilizes wind pressure generated by moving vehicles to produce electrical energy, which is stored in a battery and used for powering automated street lighting and monitoring components. The implementation of LDR-based lighting control ensures energy-efficient operation by automatically switching lights based on environmental brightness, while the DHT11 sensor and cloud dashboard enable real-time environmental and system performance monitoring. Overall, the proposed system reduces dependency on conventional power sources, enhances highway safety, and supports the development of intelligent transportation infrastructure for future smart city applications.

### Future Scope

The proposed Smart Road Divider system can be further enhanced by integrating solar panels along with wind energy harvesting to develop a hybrid renewable power generation model for improved energy output and reliability. Advanced sensors such as air quality, noise, and vehicle counting sensors can be added to expand highway monitoring capabilities and support smart traffic management applications. Artificial intelligence and machine learning algorithms may also be incorporated for traffic prediction, energy optimization, and automated fault detection. Additionally, the system can be upgraded with accident detection and emergency alert mechanisms to improve highway safety and enable faster emergency response in future smart transportation networks.

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