SECURE AND SUSTAINABLE VERTICAL AXIS WIND ENERGY SYSTEM FOR GREEN HIGHWAYS WITH REAL-TIME MONITORING AND WIRELESS CHARGING PATHS FOR EVS

FIELD OF THE INVENTION

This invention relates to renewable energy generation, specifically to a system that utilizes vertical axis wind turbines (VAWTs) installed along road dividers to harness wind energy generated by moving vehicles. The invention also integrates features such as IoT-based monitoring, tamper detection, and the use of stored energy for electric vehicle (EV) wireless charging and roadside utilities.

BACKGROUND OF THE INVENTION

Traditional wind energy systems are primarily installed in remote or elevated locations, relying on natural wind patterns. These systems are often large, expensive, and not feasible for urban or highway deployment. Simultaneously, the potential of utilizing the consistent airflow caused by fast-moving vehicles on highways remains largely untapped. Additionally, most energy generation systems lack integrated monitoring, security, and multi-functional energy utilization capabilities such as EV charging.

There is a need for a compact, secure, and smart energy generation system that can be deployed along highways to leverage vehicle-induced wind for power generation, ensure real-time monitoring and security, and support modern utility applications like EV charging.

SUMMARY OF THE INVENTION

The present invention proposes a smart Vertical Axis Wind Turbine (VAWT) system designed for installation along road dividers. The system harnesses the wind generated by moving vehicles in both directions. Each turbine is enclosed in a protective cover and integrated with touch sensors and an alert mechanism to detect unauthorized tampering.

The system features an IoT-based web interface that monitors the real-time status of each turbine, including parameters such as temperature, humidity, and fault detection. Each turbine is assigned a unique ID that is displayed on the interface when a fault or security breach occurs.

The electricity generated is stored in on-site batteries and used to power street lights and other roadside utilities. Additionally, the system includes an electromagnetic road segment that delivers continuous wireless charging to electric vehicles passing over it.

DETAILED DESCRIPTION OF THE INVENTION

1. **Turbine Design and Placement**: Vertical axis wind turbines are mounted on highway dividers, oriented to capture wind from vehicles traveling in both directions.

2. **Protective Enclosure and Security**: Each turbine is enclosed in a tamper-proof casing equipped with touch sensors. On detecting unauthorized access, a buzzer and visual alert are triggered, and an alert is sent to the central monitoring system.

3. **IoT Monitoring System**: A microcontroller unit within each turbine captures environmental data (temperature, humidity) and turbine performance (rotation speed, power output). Data is transmitted to a web-based dashboard for remote access.

4. **Battery Storage**: Generated electricity is stored in high-capacity rechargeable batteries positioned nearby, ensuring efficient power usage and backup during low wind activity.

5. **Power Distribution**: The stored energy is utilized to power street lighting, signage, and surveillance systems along the road. It is also routed to an embedded electromagnetic coil installed in the road surface.

6. **EV Wireless Charging Segment**: The electromagnetic road segment provides continuous wireless charging to EVs as they drive over it. This segment operates using the stored energy and is activated based on vehicle detection.

7. **Maintenance and Fault Detection**: In the event of performance anomalies or tampering, the web interface flags the specific turbine ID, aiding rapid maintenance and ensuring uptime.

8. **Interactive 3d visualization of vertical axis wind turbine (vawt)**

   Explore a real-time interactive 3D model of a Vertical Axis Wind Turbine (VAWT) in action. This animation helps in understanding:

   - How the turbine blades rotate when wind flows from any direction
   - The core mechanical structure of VAWT systems
   - The vertical shaft and rotor dynamics
   - Applications in urban wind energy generation, including roadside and divider-based installations

   Click this link to visualize and explain VAWT-based energy harvesting during presentations, demos, or project showcases.

   Visit: VAWT-ANIMATION

ADVANTAGES OF THE INVENTION

- Utilizes underused energy source (vehicle wind)
- Modular and scalable design
- Real-time IoT monitoring and security
- Dual-purpose power use: public utilities and EVs
- Enhances highway infrastructure sustainability

Numbered Claims for Patent

1. A vertical axis wind energy generation system for roadside deployment, comprising:
   • A vertical axis wind turbine (VAWT) mounted on a road divider;
   • A rotor and generator assembly configured to convert vehicle-induced wind into electrical energy.

2. The system of claim 1, wherein the turbine is enclosed in a tamper-resistant casing.

3. The system of claim 2, further comprising at least one touch sensor affixed to the casing for detecting unauthorized physical contact or tampering.

4. The system of claim 3, wherein tampering triggers an alert system comprising a buzzer and a red LED indicator.

5. The system of any preceding claim, further comprising a microcontroller configured to monitor turbine status and environmental parameters including temperature and humidity.

6. The system of claim 5, wherein the microcontroller transmits real-time data to a remote server via a web-based IoT dashboard.

7. The system of any preceding claim, further comprising a rechargeable battery bank connected to the turbine for storing generated electricity.

8. The system of claim 7, wherein stored electricity is used to power public utilities including street lights, surveillance cameras, and emergency roadside devices.

9. The system of claim 7, wherein the stored energy is routed to an electromagnetic coil embedded in the road surface to enable wireless charging of electric vehicles.

10. The system of claim 9, wherein the electromagnetic coil produces an oscillating magnetic field to induce a current in receiver coils located in electric vehicles driving over the coil segment.

11. The system of any preceding claim, wherein each turbine is assigned a unique identification code for individual monitoring, maintenance, and fault tracking.

12. The system of claim 11, wherein the dashboard displays alerts corresponding to turbine ID, timestamp, and nature of the fault or tampering event.

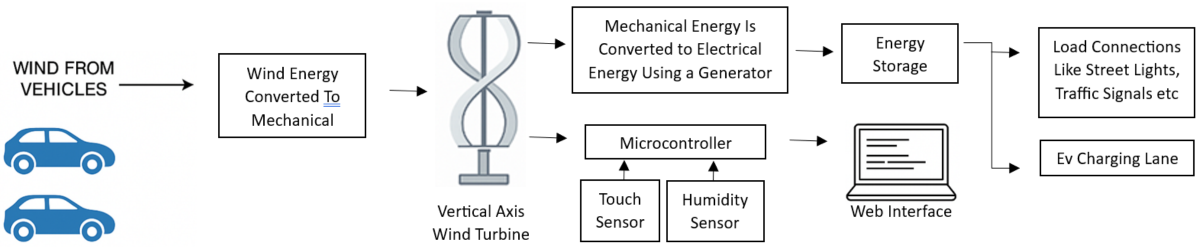
13. The system of any preceding claim, further comprising a 3D interactive visualization interface configured to demonstrate turbine operation and airflow dynamics for monitoring or educational purposes.

14. A method for real-time monitoring of vertical axis wind turbines on highways, comprising the steps of:

- detecting wind flow from vehicle movement;
- rotating the turbine blades;
- generating electrical power;
- storing the power in batteries;
- monitoring system status via sensors;
- transmitting sensor data to a remote dashboard.

15. The method of claim 14, further comprising activating a wireless EV charging system when a vehicle is detected above the embedded coil segment.

DRAWINGS / ILLUSTRATIONS



ABSTRACT

This project aims to design a **compact**, **smart**, and **sustainable wind energy system** for highway environments by harnessing vehicle-induced wind using **Vertical Axis Wind Turbines (VAWTs)**. The invention proposes an intelligent energy generation system installed along road dividers to capture wind generated by fast-moving vehicles. It incorporates **tamper-detection sensors**, a **buzzer alert mechanism**, and an **IoT-based real-time monitoring dashboard** for enhanced security and operational efficiency.

The electricity produced is stored in high-capacity batteries and utilized to power **streetlights** and **roadside utilities**. Additionally, the system supports **dynamic wireless charging** of electric vehicles through an **embedded electromagnetic road segment**, activated when vehicles pass over it. The invention contributes to **highway sustainability** by combining **renewable energy harvesting**, **security features**, and **smart grid integration** in a unified solution.

ABOUT

Our project introduces an innovative smart energy generation and electric vehicle (EV) charging system utilizing Vertical Axis Wind Turbines (VAWTs) installed along road dividers. This setup is designed to harness aerodynamic wind energy produced by moving vehicles, convert it into usable electricity, and simultaneously provide dynamic wireless charging for EVs—all while ensuring security and remote monitoring through an integrated web dashboard.

1. VAWT-BASED WIND ENERGY GENERATION

We have deployed a series of Vertical Axis Wind Turbines on road medians/dividers, where fast-moving vehicles on both sides generate natural wind turbulence. This airflow rotates the vertical blades of the VAWT system, which then drives an alternator or generator to produce clean, renewable electricity.

Electricity Usage:

- Powering public utilities, such as:

    - Street lights
    - Traffic lights
    - CCTV surveillance cameras
    - Roadside emergency systems
- Storing excess energy in batteries for use in EV charging paths.

2. ELECTROMAGNETIC INDUCTION-BASED EV CHARGING

Integrated into the road surface are electromagnetic coils that create a dynamic inductive charging pathway. As electric vehicles pass over these sections, their in-built receiver coils harvest the magnetic flux and charge the vehicle battery wirelessly while moving. This process, known as dynamic wireless charging, eliminates the need for EVs to stop for charging, increasing convenience and travel efficiency.

Key Features:

- No plug-in required – charging happens seamlessly during vehicle motion
- Compatible with EVs having inductive charging receivers
- Reduces charging downtime and dependency on charging stations

3. ANTI-TAMPERING & THEFT DETECTION SYSTEM

To safeguard the infrastructure, we have implemented a tamper-detection and theft-prevention mechanism:

- Touch sensors and motion detectors are attached to each VAWT and induction unit
- If any unauthorized physical interference is detected (e.g., shaking, dismantling), an instant alert is triggered
- The system logs the GPS location and sends a real-time notification to the central monitoring server

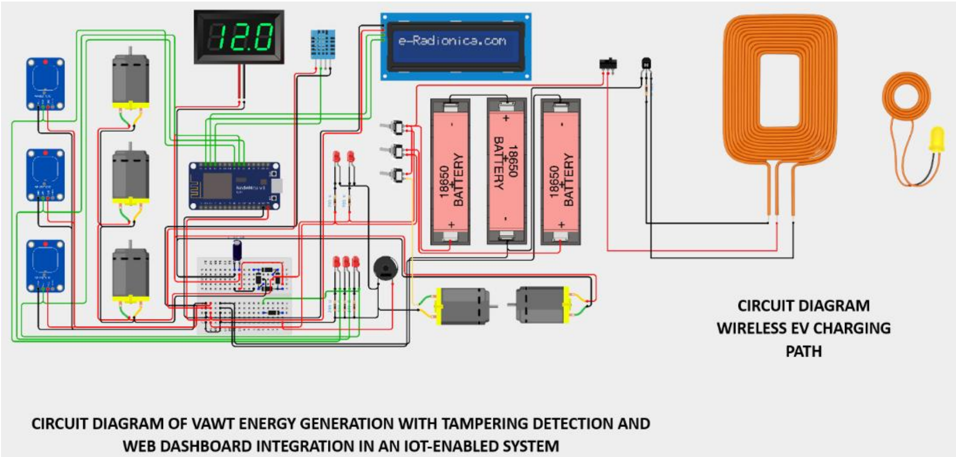
4. SMART WEB DASHBOARD

A custom-built IoT-enabled web dashboard allows for real-time monitoring, analytics, and control of the entire system. The dashboard is accessible through both desktop and mobile devices.

Dashboard Features:

- Tampering alerts with location, time, and sensor data, Turbine Number
- Environmental data – wind speed, traffic volume, and temperature (if sensors are integrated)

CIRCUIT DIAGRAM



COMPONENTS USED

POWER GENERATION & STORAGE

- Generators (DC)
- Lithium-ion Rechargeable Batteries
- Copper Wire
- Capacitors
- Diodes
- Switches

CONTROL & PROCESSING

- NodeMCU (ESP8266)
- NPN Transistor

DISPLAY & OUTPUT

- LCD 16x2 Display (with or without I2C module)
- Digital Voltmeter
- Buzzer
- Red LEDs

SENSORS

- Touch Sensors
- DHT11 Sensor (Humidity and Temperature)

WIRELESS CHARGING MODULE

- NPN Transistor (e.g., 2N2222, BC547)
- Transmitter Coil (30 turns enameled copper wire with center tap at 15th turn)
- Resistor (1kΩ for base current limiting)

- Power Source (3.7V–5V battery)
- Receiver Coil (30 turns)
- LED (Indicator of wireless power reception)

CONNECTION DESCRIPTION

COMPONENT	CONNECTION / PIN DETAILS
DC GENERATOR	Output → Bridge Rectifier → Capacitor → Battery
LITHIUM-ION BATTERY	Positive → VIN (NodeMCU), Voltmeter, Sensors
	Negative → GND (Common Ground)
TOUCH SENSOR	OUT Pin → D2 (GPIO 4) on NodeMCU
	VCC → 3.3V, GND → GND
DHT11 SENSOR	DATA Pin → D5 (GPIO 14) on NodeMCU
	VCC → 3.3V, GND → GND
LCD 16X2 (I2C)	SDA → D2 (GPIO 4), SCL → D1 (GPIO 5)
	VCC → 3.3V (or 5V if supported), GND → GND
DIGITAL VOLTMETER	V+ → Battery +ve, V– → Battery –ve
RED LED (FOR TAMPER)	Anode → D6 (GPIO 12) via 220Ω resistor, Cathode → GND
BUZZER	+ve Terminal → D7 (GPIO 13), –ve Terminal → GND
NPN TRANSISTOR	Base → D8 (GPIO 15) via 1kΩ resistor, Collector → Load, Emitter → GND
SWITCH	One end → GND, Other end → D3 (GPIO 0) with pull-up enabled
COIL WIRE	**CONNECTED TO**
1st Turn (Start wire)	→ Resistor (1kΩ) → **Base of NPN Transistor**
15th Turn (Center tap)	→ **+ve of Battery**
30th Turn (End wire)	→ **Collector of NPN Transistor**
Emitter of Transistor	→ **-ve of Battery**
RECEIVER COIL END	**CONNECTED TO**
One End of Coil	→ **Cathode of LED**
Other End of Coil	→ **Anode of LED** (via optional diode if needed)

1. NODEMCU (ESP8266 WI-FI MODULE)

- Main Controller that reads sensor data, controls output devices (LED, buzzer), interfaces with the LCD, and hosts a web dashboard.

- Operates at 3.3V logic, powered using a battery or power supply.

2. DHT11 SENSOR (TEMPERATURE & HUMIDITY SENSOR)

- **PIN CONNECTIONS:**

  - VCC → 3.3V (or 5V)
  - GND → GND

- OUT (Data) → D5 (GPIO14) of NodeMCU

- **CODE BEHAVIOR:**
    - The code uses the DHT library to read temperature and humidity values from the DHT11 sensor using the readTemperature() and readHumidity() functions.
    - These values are displayed on the LCD screen and sent to the web interface.

3. CAPACITIVE TOUCH SENSOR (TAMPERING DETECTION)

- **PIN CONNECTIONS:**
    - VCC → 3.3V
    - GND → GND
    - OUT → D2 (GPIO4) of NodeMCU
- **CODE BEHAVIOR:**
    - The code reads the state of the touch sensor using digitalRead(D2).
    - If a human touches the sensor (tampering), the output goes HIGH, triggering an alert system.

4. BUZZER (TAMPER ALERT SOUND)

- **PIN CONNECTIONS:**
    - Positive Terminal → D7 (GPIO13) through a current-limiting resistor
    - Negative Terminal → GND
- **CODE BEHAVIOR:**
    - When tampering is detected, digitalWrite(D7, HIGH) activates the buzzer, giving an audible warning.

5. RED LED (TAMPER ALERT INDICATOR)

- **PIN CONNECTIONS:**
    - Anode (long leg) → D6 (GPIO12) through a 220Ω resistor
    - Cathode (short leg) → GND
- **CODE BEHAVIOR:**
    - When tampering is detected, digitalWrite(D6, HIGH) turns on the LED as a visual alert.

6. LCD DISPLAY (16X2 I2C)

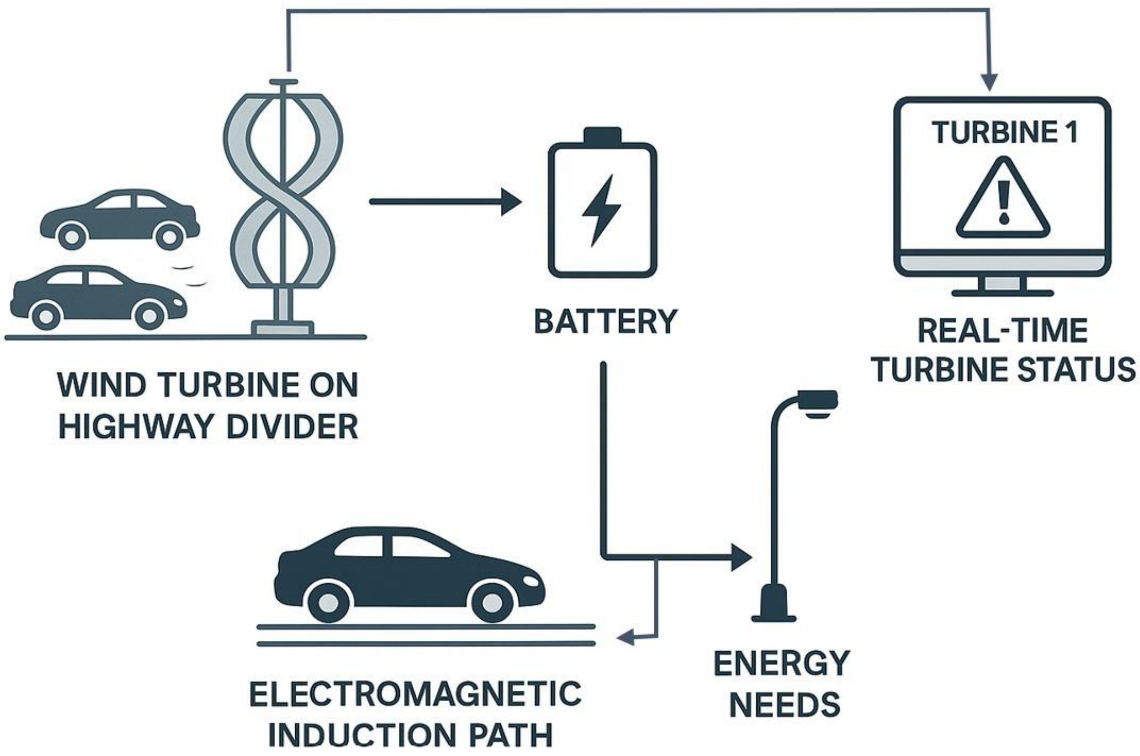
- **PIN CONNECTIONS:**
    - SDA (Serial Data) → D2 (GPIO4)
    - SCL (Serial Clock) → D1 (GPIO5)
    - VCC → 5V
    - GND → GND
- **CODE BEHAVIOR:**

- The LiquidCrystal_I2C library is used to control the display.
- It shows:
    - First Line: Tampering status (System Secure or Tampering Alert!)
    - Second Line: Temperature & Humidity values

7. WIRELESS CHARGING SYSTEM

- The transmitter coil is powered by the VAWT (Vertical Axis Wind Turbine) installed in road dividers, which generates power as vehicles pass.
- This energy is converted into a high-frequency AC using an NPN transistor-based oscillator circuit.
- The transmitter coil (30 turns copper wire, center-tapped at the 15th turn) produces an oscillating magnetic field.
- As the EV moves above the coil, the receiver coil (placed under the EV) comes into proximity with the magnetic field.
- This induces an AC voltage in the receiver coil using the principle of Faraday's Law of Electromagnetic Induction.

BLOCK DIAGRAM



PROTOTYPE IMAGES

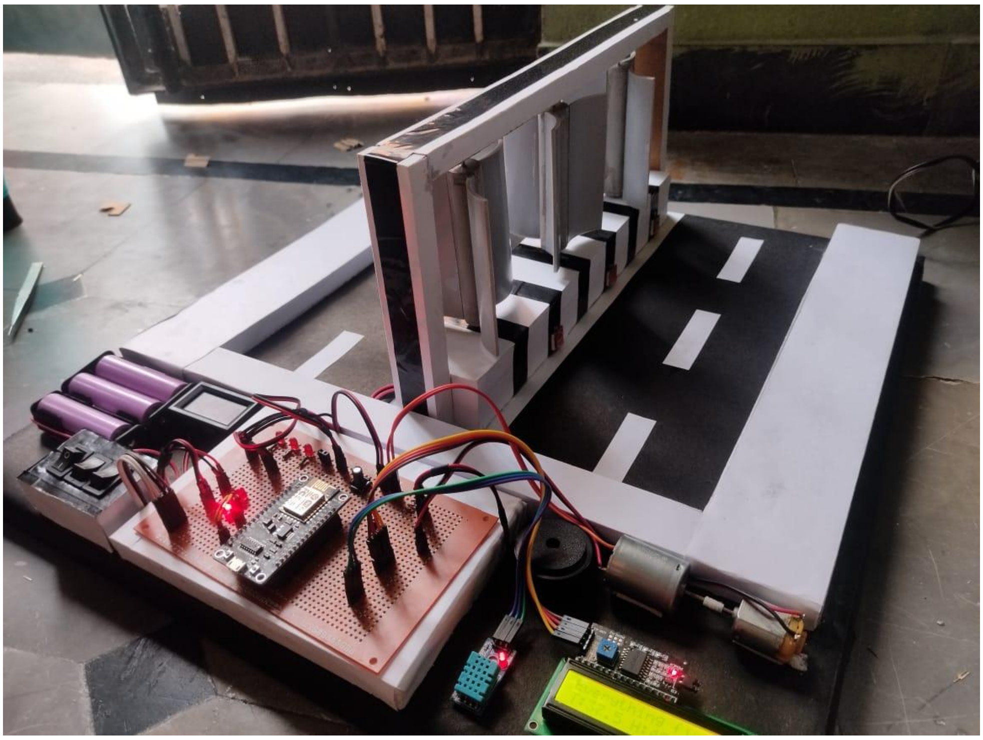


FIGURE 1: PROTOTYPE IMAGE OF THE VAWT-BASED ENERGY GENERATION

FIGURE 2: PROTOTYPE IMAGE OF THE VAWT-BASED ENERGY GENERATION SYSTEM WITH TAMPER DETECTION USING TOUCH SENSORS

FIGURE 3: WEB DASHBOARD