



Smart Electric Vehicle

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KEYWORDS

Electric Vehicle, Solar Charging, Arduino, Smart Monitoring, Renewable Energy, Safety Sensors, GPS Module, Drowsiness Detection, Alcohol Detection.

ABSTRACT

Electric vehicles (EVs) play a vital role in modern transportation, offering sustainable and efficient mobility. However, conventional EV charging systems depend heavily on grid electricity, which contributes to higher energy consumption and limits eco-friendliness. This paper presents a smart electric vehicle charging system utilizing solar energy as its primary power source. The system integrates solar photovoltaic modules, Arduino-based control circuitry, sensors for alcohol detection and driver drowsiness monitoring, GPS-based navigation support, and a remote-controlled driving mechanism. The proposed design enhances driving safety through real-time monitoring, reduces grid dependency, promotes renewable energy usage, and provides user-friendly interface for improved EV operation. The experimental results demonstrate successful solar-based battery charging, accurate safety detection with automatic vehicle stoppage, and reliable system performance under various test conditions.

INTRODUCTION

The rapid adoption of electric vehicles has increased the demand for reliable, sustainable charging infrastructure. Existing EV charging systems rely mainly on grid electricity, often generated from non-renewable sources, defeating the environmental purpose of e-mobility. Solar-powered charging systems offer a solution by providing clean and renewable power.

A Smart Electric Vehicle Charging System using Solar Energy integrates photovoltaic modules with intelligent energy management and safety features. It incorporates

sensors for alcohol detection, drowsiness monitoring, battery status measurement, GPS navigation assistance, and wireless communication for efficient vehicle control. The proposed design enhances driving safety, reduces carbon footprints, supports energy independence, and aligns with modern trends in green mobility.

In recent years, the rapid growth of electric vehicles has created an increasing demand for efficient and sustainable charging infrastructure. Traditional EV charging stations rely heavily on grid power, which is often generated from non-renewable energy sources

such as coal or natural gas. This dependency not only adds pressure on the existing power grid but also contributes to carbon emissions, undermining the environmental benefits of electric vehicles [1].

The concept of Connected, Autonomous, Shared and Electric (CASE) mobility represents the future vision of transportation. Safety features for driving an Electric vehicle are also very important. This system integrates renewable solar power with smart charging technologies to provide a clean, reliable, and cost-effective energy source for EVs [2]. Moreover, the smart charging system can be designed to operate in hybrid mode, drawing power from both solar panels and the conventional grid when necessary, ensuring uninterrupted operation even during low sunlight conditions.

LITERATURE SURVEY

Several researchers have explored solar-powered EV charging systems and safety integration in recent years. A summarized literature review based on recent research is presented below.

In 2020, researchers designed and simulated a PV-powered electric vehicle charging station with grid support using MATLAB/Simulink, demonstrating effective solar power utilization and reduced grid load during daytime charging. However, this was a simulation-based study lacking real-time implementation results [3].

Studies in 2021 utilized IoT and microcontroller-based monitoring to control and record charging operations from solar panels, enabling real-time monitoring of charging status and optimized solar energy use. The limitation was limited scalability for multiple EVs and high-power applications [4].

In 2022, hybrid PV-grid systems with Maximum Power Point Tracking (MPPT) and battery storage were developed, improving charging reliability and energy efficiency. The main limitation was high initial cost due to PV panels and battery bank [5].

IoT-enabled smart EV chargers using renewable energy were implemented in 2023, providing remote control, data logging, and energy optimization capabilities. These systems were dependent on internet connectivity and cloud service reliability [6].

Recent work in 2024 focused on prototypes with solar panels, charge controllers, inverters, and lithium-ion battery storage, achieving consistent charging during varying sunlight with storage backup. The limitation was regular maintenance and battery replacement requirements over time [7].

AI-based energy management for smart solar EV charging has shown enhanced charging efficiency and reduced grid dependency. However, such systems are complex and require advanced computation with higher setup costs [8].

In 2021, real-time driver drowsiness detection system was developed using eye-blink monitoring and image-processing techniques. The system triggers an alert when prolonged eye closure is detected. However, its performance depends on lighting conditions and continuous camera monitoring [9].

In 2020, Arduino-based alcohol detection system using an MQ-3 sensor was designed to prevent drunk driving. If alcohol levels exceed a set threshold, the vehicle ignition is disabled and an alarm is activated. The system is cost-effective but requires proper calibration for accurate detection [10].

METHODOLOGY

The proposed system introduces an Arduino-based Smart Electric Vehicle Charging and Safety System powered by solar energy and equipped with multiple safety sensors. The methodology is organized into functional modules as described below

3.1 System Architecture

The system uses solar panels mounted on the vehicle to charge its onboard 12V battery, ensuring renewable and self-sufficient energy usage. A wired remote control enables vehicle

The Fig.1. circuit is designed around an Arduino (AT Mega series) microcontroller, which acts as the main control unit of the system. A regulated power supply provides the required DC voltage to all components. The alcohol sensor and eye blink sensor are connected to the input pins of the microcontroller to continuously monitor the driver's condition. A 16x2 LCD is interfaced with the Arduino to display system status and warning messages. The motor driver circuit is used to control the

DC motor, as the microcontroller cannot drive the motor directly. A buzzer is connected as an alert device and is activated whenever unsafe conditions such as alcohol detection or driver drowsiness are identified. Based on sensor inputs, the microcontroller either allows normal motor operation or disables the motor to stop the vehicle, thereby ensuring enhanced safety. movement in four directions—forward, backward, left, and right—through an L298 motor driver controlling DC geared motors.

The architecture consists of interconnected components including: Solar Panel, Power Supply Circuit, 12V Battery, Voltage Regulators and Capacitors, Arduino Controller, DC Motors and L298 Motor Driver, GPS Module, Drowsiness Sensor, Alcohol Sensor, LCD Display, Buzzer, Manual Switch for Control, and Voltage Monitoring Module.

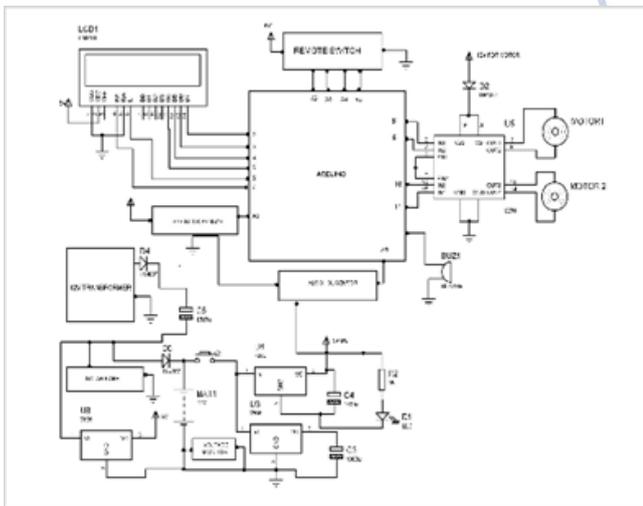


Fig. 1. Circuit Diagram of the Smart EV Charging System
Vehicle Movement Control

The vehicle moves forward, backward, left, and right using a wired remote connected to the L298 motor driver and DC geared motors. The L298 motor driver module successfully drives the DC geared motors, enabling controlled, stable, and jerk-free motion.

Solar Charging System

A solar panel mounted on the vehicle charges the 12V battery through voltage regulators ensuring stable DC output. The voltage regulator and filter capacitors provide a constant, ripple-free DC output, allowing uninterrupted control operation.

Safety Monitoring System

For driver safety, alcohol and drowsiness sensors are integrated to continuously monitor the driver's condition. The Alcohol Sensor (MQ-3) detects alcohol presence; if detected, the system immediately stops vehicle movement and activates a buzzer alarm. The Eye Blink Sensor detects drowsiness by monitoring eye closure patterns; when eyelids remain closed beyond a preset threshold duration, the vehicle is automatically stopped.

Battery and GPS Monitoring

A battery voltage monitoring module keeps track of the battery's charge status, ensuring efficient power management. A GPS module is interfaced to display the latitude and longitude of the nearest EV charging station on the LCD display, providing real-time location guidance

Software Implementation

Embedded C Programming language is used to write the logical part of the project. Arduino IDE Compiler is used to write the program code and compile it. Input of the sensors is connected to the Analog pin of Arduino and Output is connected to the Digital Pins of the Arduino board. The entire system operates on a 12V DC supply regulated through voltage regulators and filter capacitors for stable performance.

RESULTS:

The development and implementation of the Innovative Electric Vehicle Using Solar-Based Renewable Charging System with Safety Measures successfully demonstrates the feasibility, reliability, and enhanced safety of integrating renewable energy sources and intelligent monitoring technologies in modern electric mobility solutions.



Fig. 2. Side View of the Solar-Powered EV Prototype

Functional Performance

The EV prototype operates smoothly in all four directions—forward, backward, left, and right—using the wired remote-control interface. During multiple field tests, the EV demonstrated good torque and stable speed with the DC geared motor configuration, accurate directional control, quick response time between input command and vehicle movement, and zero signal loss as wired remote ensured uninterrupted communication.

Solar Charging Performance

The solar panel mounted on top of the EV vehicle provides continuous energy to charge the onboard 12V battery. Performance tests conducted under different lighting conditions showed: under normal sunlight (10 AM – 3 PM), the charging rate was stable and optimal; battery voltage levels improved consistently when the vehicle was stationed under sunlight; the system-maintained power even during extended operational hours due to the combination of solar charging and battery storage



Fig. 3. Top View of the EV Prototype Showing Solar Panel and Remote Control

Safety System Test Results

The Alcohol Sensor was evaluated by simulating conditions where the driver was normal (no alcohol presence), exposed to mild traces of alcohol, and exposed to strong alcohol vapors. In normal conditions, the system allowed normal vehicle operation. When alcohol vapors crossed the threshold limit, the system immediately restricted vehicle movement and the buzzer alarm functioned accurately.

The Eye Blink Sensor was tested under multiple conditions including normal eye blinking, slow blinking, complete eye closure for a predefined unsafe time

threshold, and long-duration closed eyes simulating momentary sleep. Normal eye blinking did not trigger any false alarms. When the eyes remained closed beyond the set threshold, the system detected drowsiness accurately and immediately brought the vehicle to a STOP condition.

GPS and Display Performance

The GPS module demonstrated fast initialization time under open-sky conditions, stable and accurate coordinate readings. GPS values were correctly processed and updated on the 16x2 LCD module. The LCD exhibited clear visibility, stable contrast, and noise-free display.

System Integration Results

The entire EV system programmed using Embedded C Language in Arduino IDE showed coordinated performance of all hardware modules. Key software results include: no program crashes or freezes during prolonged testing, sensor inputs at analog pins were sampled accurately without noise interference, digital outputs timed perfectly with motor control and buzzer activation, and the program successfully handled simultaneous tasks.

CONCLUSION

The Smart Electric Vehicle Charging System using Solar Energy provides a practical and eco-friendly approach to EV charging. By utilizing renewable solar power and integrating safety features such as alcohol and drowsiness detection, the system ensures both sustainability and enhanced driver security. The inclusion of GPS-based guidance and real-time monitoring further experience. improves the user The test outcomes and performance evaluations clearly indicate that the proposed system meets the design goals with high operational accuracy, safety assurance, energy sustainability, and functional reliability. The integrated system exhibited stable behavior across multiple test scenarios, confirming that it is a feasible solution for future smart electric vehicle technologies

The following key achievements were accomplished: a fully functional EV prototype driven by DC motors and Arduino control; renewable solar charging integrated seamlessly with the electrical system; driver safety ensured using Alcohol and Eye Blink Sensors; battery

monitoring delivered accurate voltage feedback; GPS module integrated to assist in locating charging stations; real-time LCD display improved user interaction; and efficient embedded software ensured synchronized performance.

Future enhancements include expanding solar capacity for longer driving range, integration with IoT for remote monitoring and control, fast-charging support using MPPT algorithms, AI-based predictive safety and energy management, multi-vehicle charging hubs using solar microgrids, and cloud-based data logging for performance analytics.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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