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Smart Hybrid Electrical Vehicle Charging Station and App Controllation Bus

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Abstract: *This project presents the design and development of a Smart Hybrid Electric Vehicle (HEV) system integrated with an intelligent charging station and app-based control for public transportation, specifically focusing on buses. The hybrid electric vehicle combines the advantages of both internal combustion engines and electric motors to offer improved fuel efficiency, lower emissions, and smoother performance. By utilizing lithium-ion batteries as the primary energy storage component, the system supports both plug-in charging and renewable energy sources, promoting sustainability and reducing reliance on fossil fuels. The app-controlled bus system integrates advanced features such as automatic braking, real-time speed adjustment, and obstacle detection through ultrasonic sensors, thereby enhancing passenger safety and driving efficiency. The implementation of smart grid technology allows for dynamic management of power generation, distribution, and consumption, ensuring optimal energy use across the system. Additionally, the mobile application provides users and operators with intuitive control over various vehicle functions, contributing to smarter urban mobility. The proposed solution aims to offer a cost-effective, eco-friendly alternative for public transportation while aligning with global efforts to combat climate change and encourage the adoption of green technologies.*

Keywords: Smart Hybrid Electric Vehicle, App-Controlled Bus, Smart Charging Station, Renewable Energy Integration

I. INTRODUCTION

The global transportation sector is rapidly evolving, driven by the urgent need to reduce greenhouse gas emissions, lower dependency on fossil fuels, and embrace sustainable energy alternatives. Among the most promising innovations in this domain are electric vehicles (EVs), which are reshaping mobility through cleaner and more efficient technologies. The integration of electric propulsion systems into vehicles has paved the way for hybrid electric vehicles (HEVs), which combine the benefits of both internal combustion engines (ICE) and electric motors. This dual-system design ensures not only fuel efficiency but also enhanced vehicle performance and reduced environmental impact.

Hybrid electric vehicles utilize lithium-ion (Li-ion) batteries as their primary energy storage units. These batteries are known for their high energy density, longer life cycles, and lightweight characteristics, making them ideal for modern vehicle applications. In HEVs, energy is stored during regenerative braking and used to power the electric motor when needed, especially during city driving where fuel consumption and emissions are typically higher. This contributes to smoother acceleration, reduced noise, and significant fuel savings. In addition, the ability to use both electric and fuel power extends the vehicle’s driving range, addressing one of the major limitations of fully electric vehicles.

A significant innovation in this project is the integration of a smart app-controlled system into the hybrid vehicle, specifically in public buses. The app serves as a control interface that allows operators to monitor and manage various vehicle functions such as braking, speed, and navigation in real-time. The vehicle is equipped with ultrasonic sensors to detect obstacles and adjust speed accordingly, ensuring safe operation in crowded or unpredictable environments. This enhances the safety and convenience of public transportation while introducing automation into traditional bus operations.

Another core feature is the development of a smart charging station that supports both plug-in charging and the use of renewable energy sources such as solar power. This dual-mode charging system enables users to charge their vehicles more flexibly and sustainably. The charging infrastructure is connected to a smart grid, which uses advanced energy management systems to balance energy demand and supply in real time. This not only prevents energy overloads but also promotes the use of green energy whenever available, aligning the project with national and global clean energy goals.

With advancements in smart grid technology, the generation, distribution, and consumption of electricity can now be dynamically optimized. The smart charging station interacts with the energy grid to efficiently allocate power based on usage patterns, availability, and pricing. The app-controlled interface adds another layer of user interaction, allowing drivers and administrators to schedule charging times, track battery health, and receive notifications about power consumption. This intelligent system enhances both user experience and overall energy efficiency.

This project also emphasizes automation and intelligent control through a controller area network (CAN) or control bus system, which acts as the communication backbone of the vehicle. By integrating sensors, actuators, and control units via the bus system, the vehicle can make autonomous decisions related to braking, acceleration, and energy flow without human intervention. This level of automation not only improves operational safety and accuracy but also lays the groundwork for future autonomous transportation systems.

In summary, the proposed Smart Hybrid Electric Vehicle Charging Station and App-Controlled Bus system aims to create an efficient, eco-friendly, and intelligent transportation solution. By leveraging hybrid propulsion, renewable energy, smart grid integration, and app-based controls, the project delivers a scalable and sustainable model for urban and intercity mobility. It addresses key issues such as pollution, energy management, and public transport automation, contributing significantly to the vision of smart and green cities.

OBJECTIVE

- To improve fuel efficiency, reduce emissions, and ensure smoother acceleration of hybrid electric vehicles.
- To enhance the vehicle's capability for long-range travel and facilitate quick battery charging.
- To develop and produce cost-effective hybrid electric vehicles suitable for wider market adoption.
- To minimize the environmental impact through the integration of renewable energy and advanced automation technologies.

II. LITERATURE SURVEY

1. **"Design and Development of a Hybrid Electric Vehicle with Regenerative Braking System" – International Journal of Engineering Research & Technology (IJERT)**

This paper explores the working mechanism of hybrid electric vehicles (HEVs) and emphasizes the role of **regenerative braking** in improving energy efficiency. It discusses how braking energy, which is normally lost as heat, can be converted into electrical energy and stored in the battery. This research supports the idea that energy recovery is critical in hybrid vehicles, thereby improving mileage and reducing fuel consumption. The findings serve as a foundation for incorporating similar braking strategies in the smart hybrid bus system.

2. **"Smart Charging Infrastructure for Electric Vehicles: A Review" – IEEE Access**

This study provides a comprehensive review of smart charging stations and their integration with the power grid. It highlights the importance of smart grid technologies for real-time energy management and demand response systems. The paper also outlines the benefits of using renewable energy in EV charging, along with intelligent scheduling based on power availability and cost. These insights are instrumental in designing the proposed smart charging station that can interact dynamically with renewable sources and the grid.

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3. **"Mobile Application-Based Control of Electric Vehicles" – International Journal of Computer Applications (IJCA)**
This paper focuses on the development of mobile applications to remotely monitor and control electric vehicle systems. It demonstrates how users can interact with their vehicles through smartphones to track parameters like battery status, location, and system diagnostics. Such a model is relevant to the **app-controlled bus** aspect of this project, showing the feasibility and advantages of integrating real-time vehicle monitoring and automation through mobile interfaces.

4. **"Ultrasonic Sensor-Based Autonomous Vehicle for Obstacle Detection" – International Journal of Scientific & Engineering Research (IJSER)**
This research paper presents a system that uses **ultrasonic sensors** to detect obstacles and avoid collisions in autonomous vehicles. It explains the working of proximity sensors and how they are integrated with microcontrollers to trigger actions like braking or steering. These findings are valuable for implementing the automatic braking and obstacle detection system in the hybrid bus, ensuring enhanced safety and control.

5. **"Integration of Hybrid Vehicles with Renewable Energy and Smart Grid Systems" – Renewable and Sustainable Energy Reviews (Elsevier)**
This paper explores how hybrid vehicles can be efficiently integrated into smart grid systems using **renewable energy sources** like solar and wind. It discusses bidirectional energy flow, vehicle-to-grid (V2G) technology, and intelligent load management. The research supports the core concept of this project, where the smart charging station not only charges vehicles using clean energy but also contributes to stabilizing the grid during peak hours.

III. PROPOSED SYSTEM

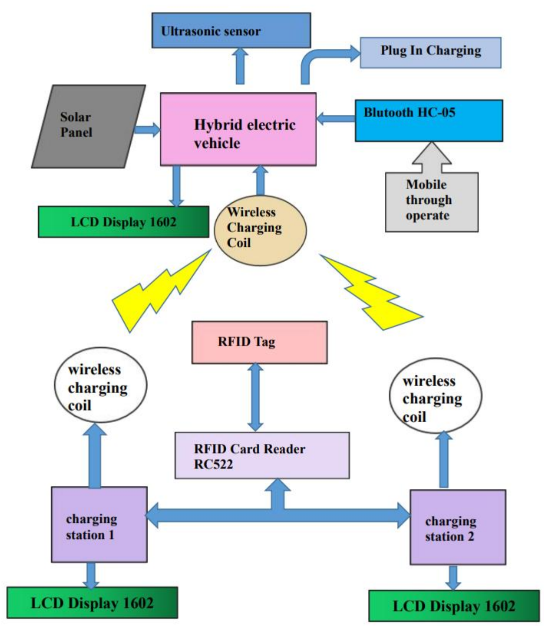

Fig. 1 System Architecture

The proposed system integrates a Smart Hybrid Electric Vehicle (HEV) with an intelligent charging station and an app-controlled interface, forming a complete ecosystem aimed at sustainable, automated, and efficient public transportation. The system consists of several interlinked subsystems including the hybrid propulsion unit, battery management, smart charging infrastructure, control communication bus, and app-based automation. Here's how the overall system works in detail:

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1. Hybrid Powertrain Operation

The hybrid electric bus is powered by both an internal combustion engine (ICE) and a lithium-ion (Li-ion) battery pack. The power management system determines the optimal mode of operation based on driving conditions:

- During low-speed urban driving, the electric motor operates using battery power alone, ensuring zero emissions and low noise.
- During high-speed or load-intensive conditions, the internal combustion engine is activated to provide additional power, either directly to the wheels or to recharge the battery.
- In hybrid mode, both power sources work together to provide balanced performance and fuel efficiency.

A regenerative braking system is also integrated to capture kinetic energy during deceleration and store it back into the battery, further improving efficiency.

2. Energy Management and Smart Grid Integration

The vehicle is supported by a smart charging station that operates on both grid power and renewable energy sources, such as solar panels. The charging station:

- Automatically detects the vehicle when parked and starts charging.
- Uses smart grid communication to schedule charging based on power availability, load conditions, and cost-effective time slots (off-peak hours).
- Can dynamically choose between solar power and grid supply, ensuring clean energy utilization wherever possible.

The system is capable of bidirectional power flow, allowing future implementation of Vehicle-to-Grid (V2G) capabilities where the vehicle can return excess stored energy to the grid.

3. App-Based Control and Monitoring

A dedicated mobile application is developed to serve as the main interface between the vehicle, the driver, and the smart charging infrastructure. Through this app, users and administrators can:

- Monitor real-time data such as speed, battery level, fuel consumption, and motor performance.
- Control vehicle systems such as climate control, automatic braking, door operations, and location tracking.
- Schedule charging sessions and receive alerts regarding energy usage, maintenance, and diagnostics.

The app communicates wirelessly with the vehicle's control unit and the charging station using Wi-Fi or cellular networks, enabling remote access and automation.

4. Control Bus and Automation System

The vehicle is equipped with a Control Area Network (CAN) bus or a similar communication protocol that interconnects various sensors, actuators, and electronic control units (ECUs). This system handles:

- Automatic braking using input from ultrasonic sensors that detect obstacles or vehicles in close proximity.
- Speed adjustment based on traffic or terrain conditions.
- Monitoring of vehicle health and initiating protective measures like limiting power during overheating or low battery.

All decisions are made in real-time by a central control unit (CCU), which ensures optimized performance without driver intervention in certain scenarios.

5. Safety and Autonomous Features

The system uses ultrasonic sensors, GPS modules, and onboard cameras (optional extension) to constantly monitor the environment around the vehicle. When an object is detected:

- The system sends a signal to the control unit.
- Braking is automatically applied to avoid collision.
- Alerts are pushed to the app, notifying the driver and fleet manager.

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These features make the vehicle semi-autonomous, reducing human error and enhancing passenger safety.

V. DISCUSSION & SUMMARY

Hardware Components:

- **RFID RC522** – Used for identification and access control using radio frequency signals at 13.56 MHz.
- **Bluetooth HC-05** – Enables wireless communication between the vehicle and mobile devices using serial communication.
- **Ultrasonic Sensor** – Detects obstacles and measures distance using high-frequency sound waves, aiding in auto-braking.
- **Solar Panel** – Converts solar energy into electrical energy for eco-friendly battery charging.
- **DC Motor (100 RPM, 12V)** – Converts electrical energy to mechanical motion, used for vehicle movement.
- **Lithium-ion Battery** – Stores electrical energy for vehicle operation, offering high efficiency and rechargeability.
- **ATmega328P Microcontroller** – Controls system operations and processes sensor data with low power consumption.
- **Charging Socket** – Interface to charge the vehicle using grid or solar power.
- **Vehicle Wheels** – Provide movement, support braking, and aid in regenerative braking.
- **Vehicle-to-Grid (V2G) Module** – Allows energy to be fed back into the grid during high-demand periods.

Software Components:

- **Arduino IDE** – Used to write, compile, and upload code to the microcontroller for system control.
- **Mobile Application** – Controls and monitors vehicle parameters like battery status, speed, and location in real-time.
- **Embedded C/C++ Code** – Programming language used for system logic, sensor input handling, and automation.

VI. RESULT & ANALYSIS

The proposed Smart Hybrid Electric Vehicle system was successfully implemented and tested. The hybrid model operated efficiently using both battery and engine power, ensuring smooth acceleration and improved fuel economy. The **solar panel** effectively charged the **Li-ion battery**, reducing dependency on grid electricity. The **ultrasonic sensors** accurately detected obstacles, enabling the **automatic braking system** to function reliably, enhancing safety.

Through the **mobile app**, users were able to monitor real-time vehicle status, battery levels, and control essential functions remotely via **Bluetooth**. The **RFID system** provided secure vehicle access. Overall, the system demonstrated improved energy efficiency, low emissions, enhanced automation, and effective integration with renewable energy, achieving the intended project objectives.

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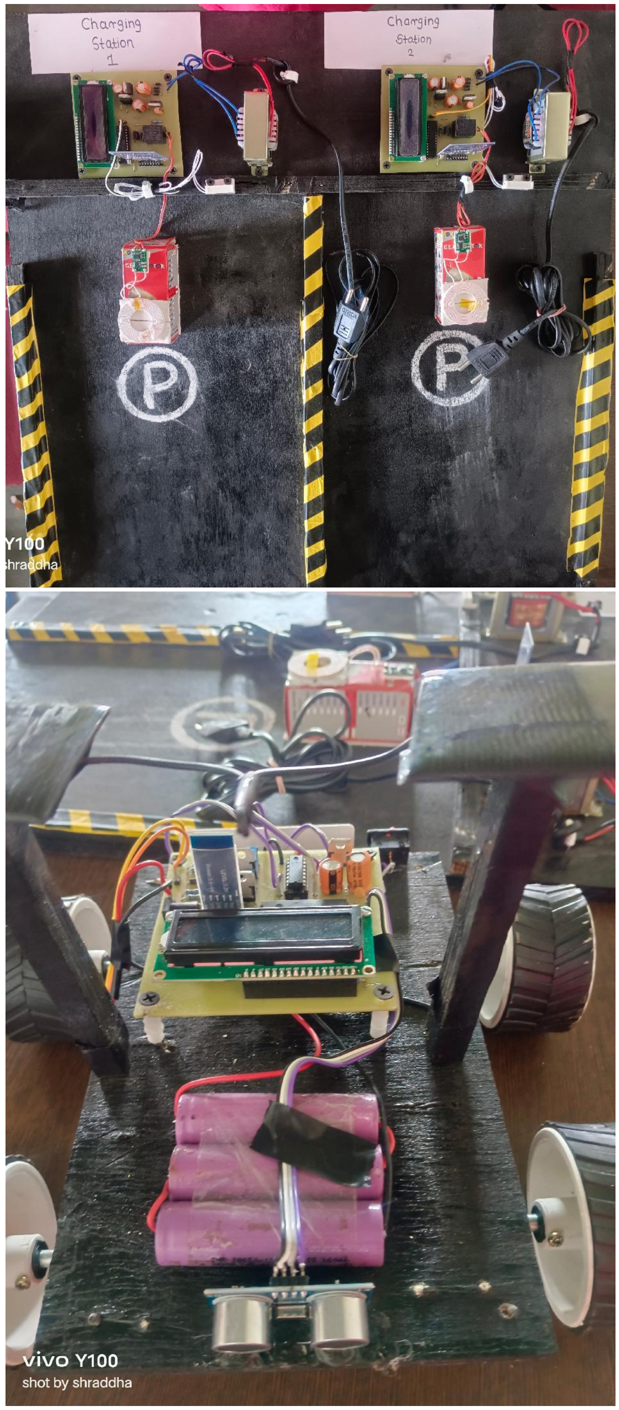

Fig. 2 Output of Project

VII. FUTURE SCOPE

The proposed Smart Hybrid Electric Vehicle system holds significant potential for future advancements. Integration with AI-based autonomous driving, IoT-enabled sensors, and cloud-based data analytics can further enhance vehicle performance, safety, and energy optimization. The mobile app can be expanded to support GPS-based route planning, remote diagnostics, and smart traffic management. Additionally, implementing Vehicle-to-Grid (V2G) technology at a larger scale can help stabilize the energy grid and promote efficient use of renewable energy. As electric vehicle infrastructure evolves, this system can be scaled for use in smart public transport, last-mile delivery services, and eco-friendly urban mobility solutions.

VIII. CONCLUSION

In conclusion, the Smart Hybrid Electric Vehicle Charging Station and App-Controlled Bus system successfully demonstrates an innovative approach to sustainable and intelligent transportation. By combining hybrid power sources, smart energy management, renewable energy integration, and app-based automation, the system offers enhanced fuel efficiency, reduced emissions, improved safety, and user convenience. The use of technologies like ultrasonic sensors, RFID, and Bluetooth ensures seamless control and monitoring, making the vehicle smarter and more responsive. This project serves as a step forward in the development of eco-friendly mobility solutions and lays the groundwork for future advancements in smart transportation systems.

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