



Self-Charging Hybrid Electric Vehicle

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Abstract: The global adoption of electric vehicles (EVs) is steadily rising because they offer an environmentally sustainable alternative with minimal carbon emissions. However, challenges related to energy storage and efficient charging remain major obstacles to wider EV adoption. This paper provides solutions to charging systems with hybrid sources, plug-in hybrid electric vehicles (PHEVs), and all-electric vehicles (EVs). This project explores how Artificial Intelligence (AI) and the Internet of Things (IoT) can enhance EV performance monitoring and support autonomous vehicle operation through sensor integration. A self-charging system can be implemented and the exchange of information between the vehicle and its surroundings. Artificial Intelligence (AI) refers to the human mind that can perform tasks and decision-making like human intelligence through different logic and programs. AI technologies play a crucial role in advancing electric vehicles toward full automation. In the future, AI and IoT enabled autonomous vehicles could help minimize charging delays, improve parking management, and support the development of smart city infrastructure.

Keywords: Electric vehicles (EVs), Internet of things (IoT), Artificial Intelligence (AI), Plug-in Hybrid Electric Vehicles (PHEVs), Wireless Charging, Battery Monitoring System.

I. INTRODUCTION

Automakers are increasingly adopting AI and IoT technologies to enhance vehicle efficiency and transition toward smart, connected mobility solutions. Electric Vehicles (EVs) emit fewer greenhouse gases and air pollutants over their life than conventional vehicles. We know that due to the limited stock of fuel on earth we must move to another option electricity is the best option and electric vehicles are an example of it.

Hybrid electric vehicles (HEVs) provide a balanced alternative, reducing the harmful emissions associated with conventional combustion engines. In Hybrid electric vehicles, different charging techniques are used, for charging the electric vehicles, nowadays method is plug-in charging, which needs a plug connected to the vehicle for charging it, in a wireless charging system there is no plugin, it can be done by the inductive charging system.

Cognitive tasks that typically require human intelligence, such as decision-making and pattern recognition. Artificial Intelligence (AI) is a computer-based system that uses sensors, actuators, and software to complete functions like the human brain by producing data containing information such as navigation, voice recognition, vehicle speed, time, motion detection, image recognition, driver monitoring, battery charge monitoring, and virtual assistance. In IoT-based Autonomous Hybrid Electric Vehicles, IoT is mainly considered as a methodology for managing connected devices and their data. So, with the help of IoT, it is easy to monitor vehicle parking, traffic, weather condition as well as battery charging through different sensors used in it. In addition, these electric vehicles (EVs) will also be much helpful during heavy traffic conditions because a sensing device is installed in it which will be able to monitor all traffic situations. The Internet of Things (IoT) allows everyday devices to connect and communicate through the internet, enabling users to monitor and control systems remotely. In this work, we have analysed the Self-charging system by utilizing different charging techniques.

II. PROPOSED METHODOLOGY

The methodology for designing and developing an AI and IoT-based Autonomous Hybrid Electric Vehicle with Self-Charging Infrastructure involves a structured integration of hardware, software, and intelligent control systems. The main objective is to create a vehicle capable of generating and managing its own power through renewable sources solar and regenerative dynamo systems while using AI and IoT for autonomous operation and smart energy management. The proposed vehicle employs two power sources: a solar panel and a regenerative dynamo unit. The dynamo converts mechanical energy from the moving wheels into electrical energy, which is rectified, stabilized using a DC-DC converter, and stored in a lithium-ion battery.

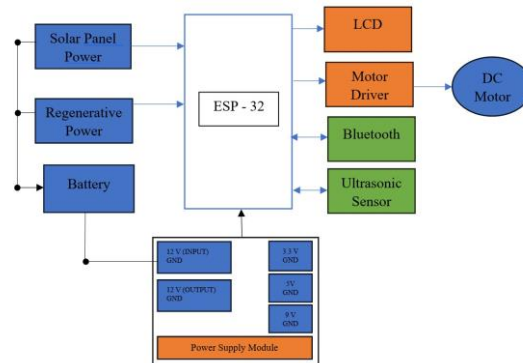
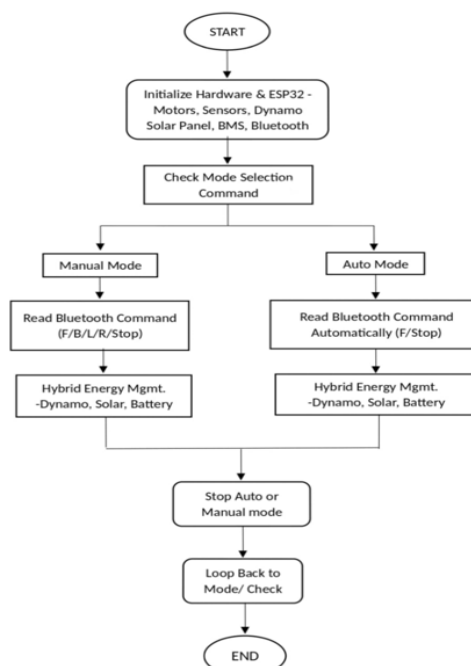


Fig. 2.1 Block Diagram of Self Charging Hybrid Electric Vehicle

Solar panels mounted on the roof generate DC power, regulated by a solar charge controller to prevent overcharging. Both sources feed the battery pack, managed by a Battery Management System (BMS) to ensure safe charging and A microcontroller (ESP32/Arduino) acts as the vehicle's control unit, collecting real-time sensor data and transmitting it to the cloud via IoT platforms such as ThingSpeak or Blynk using protocols like MQTT. Parameters such as battery voltage, current, temperature, and location are monitored remotely, enabling predictive maintenance and smart diagnostics. The Hybrid Energy Management System (HEMS) manages the energy flow from different sources. It prioritizes dynamo power during motion, solar power during sunlight, and external charging when needed. It also employs Maximum Power Point Tracking (MPPT) to optimize solar efficiency and uses AI algorithms to predict energy requirements and automatically switch power sources for maximum performance. A working prototype was built using a BLDC motor, 12V lithium-ion battery, 12V/20W solar panel, and dynamo generator. The software was developed using Arduino IDE in Embedded C, and data analysis was carried out using MATLAB and Python. Tests were conducted to evaluate power generation, battery charging efficiency, and IoT data monitoring. The vehicle supports Manual Mode (Bluetooth-based smartphone control) and Auto Mode (AI-based autonomous operation). In Manual Mode, user commands are transmitted via Bluetooth to the controller. In Auto Mode, sensors and AI algorithms enable obstacle detection and path following. A mode selector allows seamless switching between modes for flexibility and safety. This methodology integrates renewable power generation, AI-based decision-making, and IoT-based monitoring to develop a self-charging and intelligent hybrid electric vehicle. The system minimizes dependence on external charging and demonstrates a sustainable, smart mobility solution suitable for future urban transport.

III. IMPLEMENTATION





The flowchart begins with the System Initialization block, which activates when the vehicle is powered on through the main battery or ESP32 microcontroller switch. During this stage, the ESP32 loads its firmware, sets up its internal environment, and prepares all peripherals for operation. Initialization is essential because the ESP32 functions as the central controller, managing sensors, motors, energy modules, and communication interfaces. Once the microcontroller boots, it proceeds to configure hardware components including GPIO pins, PWM channels for motor speed control, communication protocols like UART, I2C, SPI, and ADC pins for reading analog inputs. The primary hardware initialized includes the drive motors, sensors such as ultrasonic or IR modules, the dynamo generator monitoring circuit, solar panel voltage sensing, the Battery Management System (BMS), and Bluetooth connectivity. This ensures that all components are fully functional and safe before the vehicle begins operation.

After initialization, the system moves to the Mode Selection stage. Here, the ESP32 waits for the user to choose either Manual Mode or Auto Mode through the Bluetooth app. The microcontroller continuously checks incoming Bluetooth packets, and once a valid selection is received, the flow branches accordingly. This prevents unintended movement and ensures user-directed operation.

In Manual Mode Operation, the ESP32 reads user commands such as Forward (F), Backward (B), Left (L), Right (R), and Stop. These commands are decoded and translated into motor driver signals to control direction and speed. Manual Mode is useful for testing, demonstrations, and navigating complex areas where autonomous sensors may face limitations. While the user controls movement, the hybrid energy system continues functioning in the background—solar panels collect energy, and the dynamo generates power when the wheels rotate. The vehicle stays in Manual Mode until the user switches modes or issues a stop command.

In Auto Mode Operation, the system performs movement autonomously with minimal user input. Typically, Auto Mode includes automatic forward movement and obstacle-based stopping using ultrasonic sensors. The ESP32 continuously checks for obstacles and halts the motors if any object is detected within a predefined distance. Auto Mode is ideal for autonomous demonstration and reduces the need for continuous human supervision.

Next, the flow enters the Hybrid Energy Management System, which handles energy from the dynamo, solar panel, and battery. Dynamo energy is produced from wheel rotation and helps charge the battery through kinetic recovery. Solar energy provides renewable power under sunlight, reducing battery usage. The battery, regulated by the BMS, supplies stable power while preventing overcharging, overheating, or excessive discharge. This energy combination ensures continuous and efficient vehicle operation.

Both operating modes eventually lead to Stop Mode Handling, where the motors are safely halted and protected from abrupt transitions. Afterwards, the system enters the Looping Logic, allowing the user to select modes again without restarting the system. Finally, if the user ends the session, the program reaches the End block, where the ESP32 disables active modules and minimizes battery drain.

IV. RESULTS AND DISCUSSION

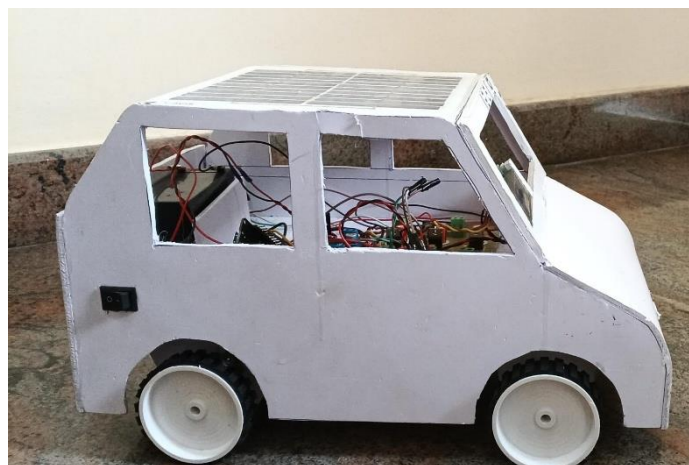


Fig. 4.1 Hybrid Electric Vehicle Model



The designed prototype represents the Hybrid Electric Vehicle model integrating solar panels, a regenerative dynamo, and a lithium-ion battery for self-charging operation. The system combines renewable energy sources with intelligent control for efficient power management. This model demonstrates the complete working prototype of IoT-based self-charging hybrid electric vehicle. The overall results validate the system's ability to generate, manage, and utilize renewable energy efficiently while ensuring autonomous operation.



Fig. 4.2 Dynamo voltage when vehicle is at halt.



Fig. 4.3 Dynamo voltage when vehicle is in motion.

Initially, the dynamo voltage is 0V because the engine is not running and no mechanical rotation is available to induce voltage. Once the vehicle starts and the dynamo begins to rotate, electromagnetic induction takes place and the output voltage gradually rises. After reaching normal operating speed, the dynamo generates approximately 6.7V, which is sufficient to power the electrical system and charge the battery.



Fig. 4.4 Battery charging due to solar energy.

When there is no sunlight, the solar panel output is 0V because insufficient light energy is available to generate electrical power. When sunlight is present, the solar panel begins converting light into electricity, producing an output voltage of approximately 2-4V, which contributes to powering the system or charging the battery depending on the vehicle's design.



Fig. 4.5 Obstacle Avoidance

In autonomous mode, the vehicle continuously monitors the path using ultrasonic sensor. When an obstacle is detected within a predefined safety distance, the controller immediately stops sending drive signals to the motor. At the same time, a stop command is activated to prevent collision. This ensures safe operation by halting the vehicle until the obstacle is removed or the path becomes clear.

CONCLUSIONS

The Self-Charging Hybrid Electric Vehicle successfully demonstrates an efficient combination of solar energy, dynamo-based kinetic recovery, and battery power to achieve extended runtime and reduced dependence on external charging. The integration of ESP32-based control, autonomous navigation, and smart energy management highlights the system's reliability and innovation. This project proves that hybrid self-charging mechanisms can significantly improve the sustainability and practicality of electric vehicles. Overall, the design serves as a cost-effective prototype with strong potential for future enhancement and real-world applications in eco-friendly transportation.

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