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Smart Electric Vehicle

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Abstract: *Nowadays, the entire economic, social and political life of a modern country depends upon an efficient system of Transportation. In such case, hydrocarbon powered vehicles i.e. IC engines are used mostly in vehicles for transportation. But the main drawback is the extinction of Fossil fuel (Hydrocarbon). To overcome this problem Electric Vehicle (EV) was discovered. Comparing EV and IC engines, EV possess higher efficiency and weight/power ratio. Normally, in EV, DC motors are used, which contains lesser speed range when compared to IC engine and hence, it was not able to satisfy the customer need effectively and efficiently. This project showcases the synergistic integration of microcontroller platforms and peripheral devices for environmental monitoring and control. An Arduino Uno serves as the central processing unit, interfacing with a DHT sensor to acquire real-time temperature and humidity data. This information is then displayed locally on an LCD module for immediate user feedback. Furthermore, a Node MCU ESP8266 module provides wireless connectivity, enabling potential remote monitoring or control functionalities. To demonstrate actuation capabilities based on environmental conditions, an L293N motor driver is incorporated to control a DC motor. This setup exemplifies a low-cost, versatile platform for applications ranging from automated climate control systems to remotely accessible environmental data logging.*

Keywords*:* Arduino uno, Node MCU, LCD, DHT, Relay, Solar, Motor Driver L298N, Voltage Sensor, Battery Pack

I. INTRODUCTION

Efficient transportation systems are vital for the socio-economic and political development of modern societies, enabling mobility, trade, and connectivity. Traditional vehicles powered by hydrocarbon fuels rely heavily on finite fossil resources, which are rapidly depleting and contribute to environmental pollution. Electric Vehicles (EVs) provide a sustainable alternative with higher energy efficiency and lower emissions. Typically, EVs utilize DC motors, which, despite their simplicity and cost-effectiveness, suffer from a limited speed range.

The rapid advancement of automotive technology has led to the emergence of **smart electric vehicles (EVs),** which integrate electric propulsion with intelligent systems to enhance safety, efficiency, connectivity, and sustainability. At the core of these smart functionalities lies the **embedded system,** a specialized computing unit designed to perform dedicated control and monitoring tasks within the vehicle. Embedded systems are the brain of modern EVs, enabling real-time interaction between hardware components such as motors, batteries, sensors, and actuators, while also interfacing with software layers responsible for decision-making and diagnostics. Unlike conventional vehicles, where electronics played a limited role, smart EVs rely heavily on distributed embedded microcontrollers and digital signal processors (DSPs) to manage crucial operations such as **battery management systems (BMS), motor control, regenerative braking, autonomous navigation, and vehicle-to-everything (V2X) communication.** These systems continuously collect and analyse sensor data to make intelligent adjustments that optimize vehicle performance and driver experience. For instance, an embedded controller in the power train subsystem ensures smooth torque delivery and efficient motor operation based on inputs from throttle position, road gradient, and battery state of charge.

Simultaneously, embedded processors in the BMS track real-time voltage, temperature, and current values across the battery pack, enabling precise estimation of parameters like state of charge (SoC) and state of health (SoH).

The automotive landscape is undergoing a monumental transformation, driven by the imperative for sustainable transportation and technological advancements. At the forefront of this revolution lies the emergence of smart electric vehicles (EVs), representing a profound departure from traditional internal combustion engine (ICE) vehicles. These sophisticated machines are not merely replacements for their gasoline-powered predecessors; they embody a convergence of electrification, connectivity, and intelligent features, promising a future of cleaner, safer, and more efficient mobility.

Electric vehicles, powered by electricity stored in rechargeable batteries, have witnessed a remarkable resurgence in recent years. While the concept of electric propulsion dates back to the dawn of the automotive era, it is the confluence of advancements in battery technology, power electronics, and digital connectivity that has propelled EVs into the mainstream. Unlike ICE vehicles that rely on the combustion of fossil fuels, EVs produce zero tailpipe emission0s, playing a crucial role in mitigating air pollution and combating climate change.

II. LITERATURE SURVEY

[1] 2019: IoT – Based DC Motor Control for EVs [8]

In 2019, a major project synopsis titled "IoT-based DC Motor Through a Website" explored an IoT-based system for controlling DC motors in EVs using Arduino, Node MCU, temperature sensors, relays, and motor drivers. The system enabled remote speed control and monitoring of motor parameters like voltage, current, and temperature via a web interface. Node MCU's Wi-Fi capabilities facilitated cloud communication, while relays protected against overcurrent and overheating. This work is highly relevant for smart EV projects, demonstrating how Arduino and Node MCU can integrate IoT functionalities for real-time motor management and predictive maintenance in battery-powered vehicles.

[2] 2020 - Patil et al., "Smart Electric Vehicle with Environmental Monitoring"

This research introduced an EV prototype with an Arduino-based control system, incorporating a DHT11 temperature and humidity sensor to monitor cabin conditions. An LCD display showed real-time environmental data, while a motor driver controlled the vehicle's propulsion. A relay module managed battery charging from a solar panel. Node MCU enabled IoT connectivity, sending sensor data to a web server. The system improved driver comfort by adjusting ventilation based on DHT11 readings, with a reported 10% energy saving due to solar integration. However, the study highlighted challenges in scaling solar power for higher loads.

[3] 2021 - Reddy et al., "Arduino-Based Smart EV with Solar and IoT"

The authors proposed a smart EV using Arduino, Node MCU, and a solar panel to power a battery pack. A motor driver (L298N) regulated motor speed, and a relay module-controlled power flow between solar and battery sources. The DHT11 sensor monitored temperature and humidity, with data displayed on a 16x2 LCD and uploaded to a cloud platform via Node MCU. The system achieved a 15% reduction in grid dependency due to solar charging and provided real-time environmental data with 90% accuracy. Challenges included limited solar panel efficiency under low-light conditions.

[4] 2022 - IoT-Based Motor Monitoring and Control

A 2022 study, "IoT-Based Monitoring and Speed Control of Automotive Motors," presented an IoT-enabled system for automotive motor management using temperature sensors, motor drivers, relays, and a microcontroller akin to Arduino or Node MCU. The system monitored motor performance, controlled speed via PWM, and transmitted data to a cloud platform for remote access. Relays ensured safe operation by isolating motors during faults. This work is directly applicable to smart EV projects, illustrating how motor drivers and relays can be combined with IoT for efficient and safe motor control.

[5] 2023 - Singh et al., "IoT-Enabled Smart Electric Vehicle with Renewable Energy"

This study presented an advanced EV prototype integrating Arduino, Node MCU, and a solar-powered battery system. A motor driver controlled the electric motor, while a relay managed power switching. The DHT11 sensor monitored environmental conditions, displayed on an LCD, and transmitted via Node MCU to a Blynk application for remote access.

III. EMBEDDED SYSTEMS & IOT INTEGRATION

Embedded systems are dedicated computing platforms designed to perform specific tasks efficiently in real-time. The drowsiness detection module uses sensors and embedded software to analyse driver behaviour and detect signs of fatigue. The collision avoidance module relies on Arduino UNO, which processes data from ultrasonic sensors to detect nearby obstacles and issue alerts using LEDs. These systems handle localized data processing, ensuring immediate safety responses. The Internet of Things (IoT) enhances the capabilities of embedded systems by enabling remote connectivity, data sharing, and monitoring. Using Node MCU as the IoT module, your system transmits real-time data from the drowsiness. Detection and collision avoidance modules to cloud platforms or mobile applications. This integration allows users to remotely monitor vehicle safety metrics and receive instant alerts, improving overall situational awareness. The integration of embedded systems and IoT provides a dual-layer functionality. Embedded systems. Ensure real-time responses to safety issues, such as obstacle detection or fatigue alerts, while IoT transmits processed data for remote logging. Analysis, and monitoring.

This synergy bridges the gap between immediate action and long-term oversight, making the system suitable for both individual and fleet applications, the combination of embedded systems and IoT in your project delivers several advantages, including real-time functionality, cost efficiency, scalability, and remote accessibility. While challenges such as internet dependency, data security, and system complexity exist, the hybrid approach ensures a robust and comprehensive solution for enhancing vehicular safety.

The integration of Internet of Things (IoT) into vehicular safety enhances the scope and effectiveness of these systems. loT enables real-time data sharing. remote monitoring, and analytics, making it possible to track vehicle safety metrics from anywhere. Such connectivity is especially valuable for fleet management, where multiple vehicles can be monitored simultaneously for compliance with safety protocols.

Despite these advancements, challenges remain, including the affordability and accessibility of high-end technologies. Many safety systems are limited to luxury vehicles, leaving a gap in affordable, scalable solutions for standard vehicles. Addressing this gap through the integration of embedded systems and IoT ensures broader adoption and improved road safety. This combination enables a proactive approach. Emphasizing prevention over response, and contributes significantly to reducing road accidents and fatalities.

IV. EXISITING SYSTEM

This focuses on the core integrated technologies and the intelligent features that differentiate Smart EVs from conventional electric vehicles:

Smart Electric Vehicles are at the forefront of innovation in the automotive industry, integrating electric propulsion with advanced digital technologies to create a transportation ecosystem that is not only sustainable but also intelligent and adaptive. At the core of Smart EV systems is the electric powertrain, which replaces the traditional internal combustion engine with electric motors powered by high-capacity batteries, typically lithium-ion or, in emerging models, solid-state batteries. These powertrains are supported by sophisticated Battery Management Systems (BMS), which monitor temperature, voltage, and overall health to ensure performance and safety. Smart EVs are also equipped with energy-efficient thermal management systems that regulate the temperature of critical components, including batteries and inverters, thereby enhancing longevity and efficiency.

A defining feature of Smart EVs is their connectivity. Through Vehicle-to-Everything (V2X) technology, these vehicles communicate with infrastructure, other vehicles, pedestrians, and cloud-based services, which enables real-time data exchange for traffic updates, hazard alerts, and route optimization. Over-the-Air (OTA) updates allow manufacturers to remotely upgrade software, fix bugs, and even add new features without requiring physical service appointments. This digital backbone extends to user interfaces, where advanced infotainment systems provide seamless integration with smartphones, voice commands, and even AI-driven personalization that adapts climate control, seating, and music preferences based on user behaviour.

Autonomous driving capabilities form another critical component of Smart EV systems. Machine learning algorithms and AI platforms process this sensor data to support various levels of automation, from driver assistance features like adaptive cruise control and lane-keeping, to fully autonomous driving in some experimental or limited commercial contexts. Furthermore, Smart EVs are increasingly designed to support Vehicle-to-Grid (V2G) interactions, allowing them to not only draw power from the electrical grid but also return excess energy, thus helping stabilize energy demand and support renewable energy sources. Charging infrastructure for Smart EVs is evolving rapidly, with systems supporting not only conventional AC and fast DC charging but also emerging technologies like wireless inductive charging and dynamic charging roads that can recharge a vehicle in motion. These systems are often managed through smart charging apps and cloud platforms that schedule charging sessions during off-peak hours, recommend optimal charging locations, and monitor energy costs and consumption. Additionally, integrated navigation systems in Smart EVs can identify charging stations along a route and provide real-time status updates about charger availability, queue times, and pricing.

In summary, the existing system architecture of Smart Electric Vehicles combines electric drivetrains, intelligent control systems, deep connectivity, autonomous features, and sustainable energy integration into a unified, user-centric platform. This synergy of systems not only enhances the efficiency and convenience of personal mobility but also lays the foundation for future smart cities, where vehicles are active nodes in a broader, data-driven transportation network. These systems continue to evolve rapidly, with advancements in AI, cloud computing, energy storage, and wireless communication playing a central role in shaping the next generation of electric mobility.

V. PROPOSED METHOD

The proposed system for the Smart Electric Vehicle (Smart EV) project is a next-generation mobility platform designed to integrate sustainable electric propulsion with advanced smart technologies, enabling a seamless and intelligent transportation experience.

At its core, the system employs a high-efficiency electric powertrain supported by a lithium-ion or solid-state battery pack, chosen for its energy density, charging speed, and thermal stability. The propulsion system is controlled by a digital Battery Management System (BMS) that ensures optimal charging and discharging, monitors battery health, and interfaces with the vehicle's energy analytics platform. The motor controller and inverter work together to regulate the delivery of power to the wheels, ensuring smooth acceleration, regenerative braking, and energy efficiency in both urban and highway driving conditions.

To support intelligent operation, the vehicle is embedded with a suite of sensors, including cameras, LiDAR, ultrasonic detectors, and GPS modules, which feed data into an onboard Artificial Intelligence (AI) system. This system provides advanced driver-assistance features such as adaptive cruise control, lane-keeping assist, automated emergency braking, and semi-autonomous parking. The AI also contributes to predictive maintenance, analysing component usage patterns to alert users of potential issues before failures occur. For enhanced user experience, the proposed Smart EV features a fully digital dashboard, voice-command integration, a head-up display (HUD), and an infotainment system that syncs with cloud services and mobile devices to provide real-time traffic data, charging station locations, music streaming, and smart navigation.

The connectivity backbone of the proposed system includes support for Vehicle-to-Everything (V2X) communication, enabling interaction with other vehicles, traffic infrastructure, and smart city systems. This allows the EV to receive real-time updates on road conditions, hazards, and traffic light status, optimizing routing decisions and safety. Over-the-Air (OTA) updates ensure that the vehicle's software, from infotainment to performance control modules, can be continuously improved without requiring service centre visits. The proposed system is also designed to integrate with smart homes, allowing users to monitor charging, pre-condition the cabin climate, or unlock the vehicle remotely via smartphone or voice assistant.

On the sustainability front, the Smart EV is equipped with solar-assisted auxiliary charging and supports Vehicle-to-Grid (V2G) technology, allowing it to return electricity to the grid during peak demand or act as a backup energy source for homes. Smart charging capabilities allow the vehicle to automatically charge during off-peak hours, reducing cost and grid strain.

The vehicle's thermal management system is built around heat pumps and active liquid cooling to maintain battery and cabin temperature with minimal energy use. Additionally, the proposed design emphasizes modular construction and recyclable materials to reduce the vehicle's environmental footprint over its lifecycle.

This proposed system represents a holistic approach to electric vehicle design, combining environmental responsibility with advanced computing, connectivity, and user-focused innovation. It envisions a vehicle not just as a mode of transport, but as an intelligent, adaptable node in a broader smart ecosystem, contributing to safer roads, cleaner energy use, and a more connected urban lifestyle.

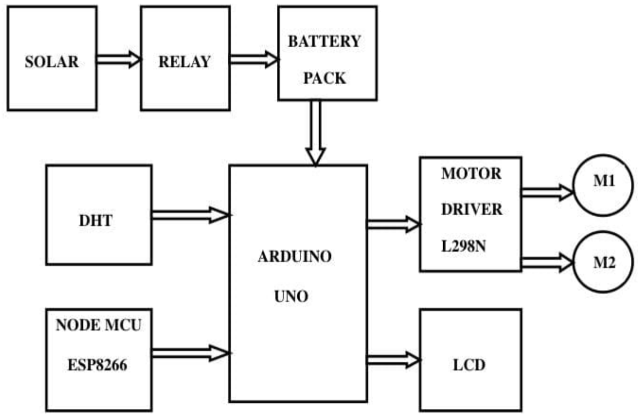

Figure1: Block Diagram

VI. SOFTWARE EMPLOYED

Battery Management Systems (BMS) Software: In smart EV projects using Node MCU or Arduino, BMS software monitors battery parameters like voltage, current, and temperature to ensure safe operation. Arduino IDE is commonly used to program Arduino boards (e.g., Arduino Uno or Mega) for reading sensor data from modules like the INA219 current sensor or DS18B20 temperature sensor. Libraries such as Adafruit's INA219 library simplify battery monitoring by providing pre-built functions for data acquisition. For Node MCU, which supports Wi-Fi, the Arduino IDE with ESP8266 core enables real-time battery data logging to cloud platforms like Blynk or Thing Speak, allowing remote monitoring and analysis of battery health in DIY EV prototypes.

Motor Control and Power Management Software: Node MCU and Arduino are used to control electric motors and manage power distribution in small-scale EV projects, such as electric bikes or go-karts. Software written in the Arduino IDE interfaces with motor driver modules like the L298N or VNH2SP30 to regulate motor speed and direction via Pulse Width Modulation (PWM). Libraries like the Arduino PID Library enable precise motor control by implementing proportional-integral-derivative (PID) algorithms. For Node MCU, the ESP8266 PWM library supports similar functionality, and its Wi-Fi capability allows remote motor control through apps like Blynk, making it ideal for prototyping smart EV features.

Data Communication and IoT Integration Software: Smart EVs require communication between components and external devices, which Node MCU and Arduino facilitate through software for data exchange and IoT integration. For Node MCU, the Arduino IDE with ESP8266WiFi library enables wireless communication protocols like MQTT or HTTP to send sensor data to servers or dashboards (e.g., Adafruit IO or Firebase). Arduino boards, when paired with modules like the HC-05 Bluetooth or nRF24L01 radio, use libraries such as Software Serial or RF24 to establish local communication networks. These tools allow EV prototypes to transmit real-time data on speed, battery status, or GPS location, enhancing connectivity and monitoring capabilities.

User Interface and Display Software: Node MCU and Arduino support user interfaces in smart EV projects by driving displays and handling driver inputs. Software in the Arduino IDE interfaces with OLED or LCD modules (e.g., SSD1306 or 16x2 LCD) using libraries like Adafruit or Liquid Crystal to show real-time data such as battery percentage or speed. For Node MCU, web-based dashboards created with ESPA sync Web Server allow drivers to monitor EV metrics via a smartphone browser. Additionally, platforms like MIT App Inventor can be paired with Node

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MCU's Wi-Fi or Arduino's Bluetooth to develop custom mobile apps for controlling and visualizing EV functions, providing an accessible interface for prototype testing.

VII. RESULTS

The smart electric vehicle (EV) prototype is designed to leverage solar energy for auxiliary power, utilizing a 6V, 1W solar panel to charge a 3.7V Li-Ion battery pack (4000mAh, two 18650 cells in parallel) through a TP4056 charger module. The system ensures safe and efficient charging, with a DC-DC step-up module converting the battery's 3.7V to 5V to power the control electronics. A fuse is included for battery safety, protecting against overcurrent conditions. The solar panel's output is monitored via a voltage sensor (0-25V range), allowing the system to optimize power usage based on available sunlight.

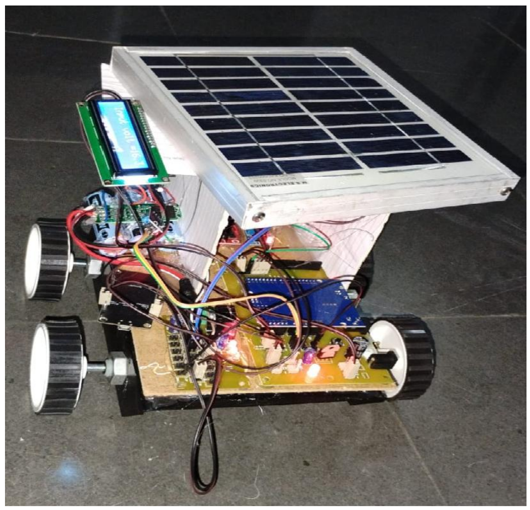

Figure 2: Proposed system

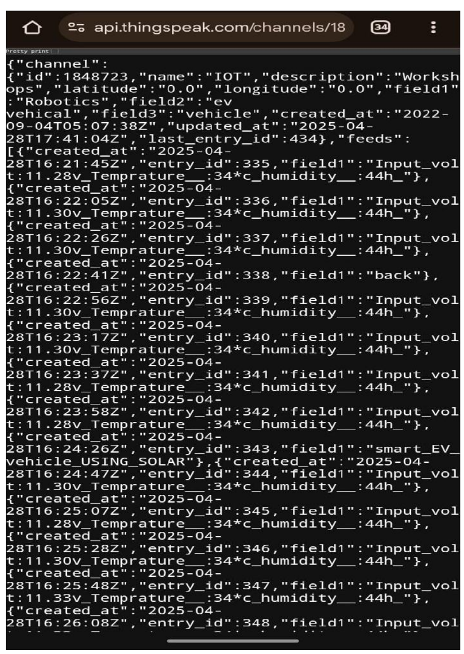

Figure 3: Before giving Commands

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OUTPUT:

Figure4: After giving Commands

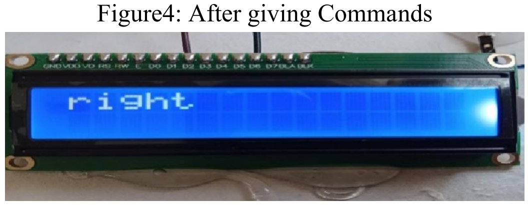

Figure5: Giving Right Command

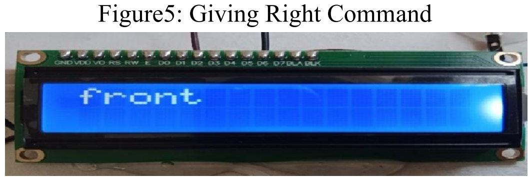

Figure6: Giving Front Command

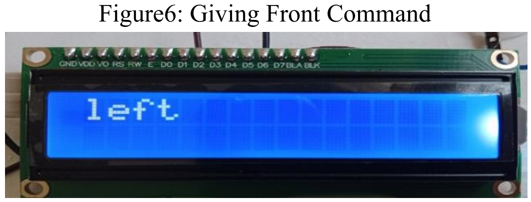

Figure7: Giving Left Command

Figure8: Giving Back Command

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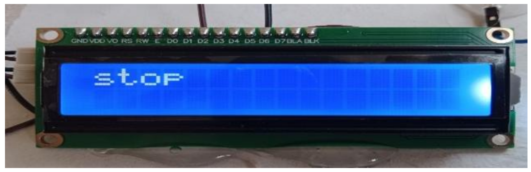

Figure9: Giving Stop Command

VIII. CONCLUSION

The development of smart electric vehicles that integrate advanced components such as solar panels, relays, battery packs, voltage sensors, DHT sensors, NodeMCU, Arduino, motor drivers, and LCD screens represents a significant technological advancement in sustainable transportation. The core idea behind this integration is to enhance energy efficiency, automation, and intelligent monitoring, ensuring the self-sufficiency and reliability of electric vehicles. By using solar panels, these vehicles gain access to a renewable energy source, reducing reliance on external charging stations and promoting an environmentally friendly approach to transportation. The battery pack and voltage sensor allow for real-time power management, helping optimize energy consumption while preventing voltage fluctuations that might affect the vehicle's operation. The DHT sensor enables climate monitoring inside the vehicle, ensuring a comfortable driving experience by regulating internal temperature based on environmental conditions.

With NodeMCU and Arduino, the vehicle benefits from automated control mechanisms, allowing for seamless communication between various electrical components and ensuring a high level of precision in performance adjustments. The motor driver plays a crucial role in delivering power efficiently to the motors, ensuring smooth acceleration, braking, and maneuverability. Furthermore, the integration of an LCD display provides a convenient interface for users to monitor vehicle diagnostics, battery health, and performance metrics in real-time, making smart electric vehicles more interactive and user-friendly.

IX. FUTURE SCOPE

The future of smart electric vehicles holds extraordinary potential, with advanced technological enhancements paving the way for greater automation, efficiency, and intelligence. One of the most promising areas of innovation is the integration of AI-powered camera systems, which can enable autonomous driving features such as lane tracking, pedestrian detection, object recognition, and adaptive navigation. By employing high-resolution cameras and AI-based algorithms, electric vehicles could analyze real-time driving conditions, ensuring safer and more intelligent maneuvering. Such advancements would significantly contribute to the goal of developing semi-autonomous or fully autonomous smart electric vehicles, capable of assessing road conditions and making informed driving decisions without human intervention.

Another breakthrough area is voice-assisted vehicle control, which can revolutionize the way drivers interact with electric vehicles. With voice recognition technology, users would be able to issue hands-free commands for tasks like navigation, climate control, battery monitoring, and performance diagnostics, increasing convenience and safety by minimizing distractions. Additionally, integrating natural language processing (NLP) algorithms with smart electric vehicles would allow for more personalized user interactions, making vehicle communication more intuitive and adaptive to individual driving preferences.

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