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Accident Detection and Battery Protection System for Electric Vehicles

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Abstract: The rapid adoption of Electric Vehicles (EVs), the need for intelligent safety and monitoring systems has become critical to ensure vehicle reliability and passenger security. This paper introduces a smart EV safety system that integrates Internet of Things (IoT) technology, real-time sensors, and cloud-based analytics for continuous monitoring and rapid emergency response. The system monitors essential battery parameters such as temperature, voltage, current, and state of charge (SoC) to detect potential hazards like overheating and power fluctuations. Additionally, accelerometers and gyroscopes identify dangerous conditions, including skidding, tilting, and abrupt impacts, triggering instant alerts to emergency contacts and cloud platforms for swift intervention.To enhance security, the system incorporates a vision-based surveillance module that captures real-time images, aiding in public safety. The camera is equipped with an automated cleaning mechanism to maintain visibility in adverse conditions. IoT communication protocols such as MQTT and HTTP enable efficient data transmission. The architecture includes a microcontroller-based control unit, GPS for location tracking, and cloud integration for remote monitoring. By combining intelligent monitoring, predictive diagnostics, and automated alerts, this system enhances EV safety, paving the way for future advancements in powered accident prediction and LiDAR-based obstacle detection.

Index Terms: 1. Arduino Uno Board 2. LCD3. Gyro sensor4. Web cam5. Battery6. Tilt Sensor 7. Temperature sensor 8. Voltage sensor 9. Arduino IDE

I. INTRODUCTION

A. Overview

Electric Vehicles (EVs) are rapidly emerging as an eco-friendly alternative to conventional gasoline-powered automobiles, driven by technological advancements in battery systems, energy efficiency improvements, and government initiatives promoting clean mobility. As EV adoption continues to grow, ensuring their operational safety, reliability, and efficiency is of utmost importance. Unlike traditional vehicles, EVs depend exclusively on lithium-ion or solid-state batteries, which are prone to risks such as overheating, voltage irregularities, and sudden power failures. These issues can cause performance deterioration, unexpected breakdowns, and, in extreme cases, fire hazards. Therefore, the development of an intelligent safety system that enables real-time monitoring, early fault detection, and immediate emergency response is essential for enhancing vehiclesecurity.

Apart from ensuring vehicle safety, urban environments pose additional challenges related to public security, particularly in high-density areas where accidents and criminal activities can occur. Conventional surveillance systems often lack automation, making them less effective in dynamic situations. Integrating a vision-based surveillance module capable of capturing and transmitting real-time images to authorities can improve situational awareness and accelerate emergency response times. However, adverse weather conditions, including rain, dust, and fog, may obstruct camera visibility, requiring an automated cleaning mechanism to ensure continuous functionality.

To address these concerns, this paper presents an advanced EV safety and emergency response system utilizing Internet of Things (IoT) technology, real-time sensors, and automated alert mechanisms. The system continuously tracks vital battery parameters such as temperature, voltage levels, current flow, and state of charge (SoC) to identify anomalies, including overheating and electrical faults. Additionally, onboard accelerometers and gyroscopes provide real-time motion analysis, detecting critical situations like skidding, tilting, and abrupt impacts. In case of an emergency, the system promptly notifies predefined contacts and emergency services through cloud-based communication protocols, ensuring rapid intervention to minimize risks.

The system features a vision-based surveillance module for urban security, using a high-resolution camera to capture and transmit real-time images. An automated cleaning mechanism ensures visibility in all conditions. Cloud integration enables data logging, remote access, and predictive analytics, enhancing EV safety, reducing risks, and supporting smart transportation advancements.

B. Objectives

This study aims to develop an intelligent EV safety system utilizing IoT and real-time monitoring to enhance vehicle reliability and passenger security.

1) The system monitors battery health and detects vehicle instability using sensors.
2) It enables real-time detection of critical issues, automatically notifying emergency contacts and services for rapid intervention.
3) The system uses a high-resolution camera for security and AI for fault detection and maintenance.

II. LITERATURE SURVEY

S. Dhas Bensam; G. Banu; R. Yamuna; D. Priyadharshini[1],states that an Electric Vehicle Monitoring System (EVMS) using Arduino Uno, sensors, and GSM technology enhances EV safety and efficiency by continuously tracking battery voltage, current, and temperature. Integrated with the IoT platform ThingSpeak, it enables real-time data monitoring, storage, and remote access for improved decision-making. The system provides proactive maintenance by detecting anomalies early, reducing the risk of failures and enhancing overall performance. Its cost-effective and scalable design ensures broader applicability, making it a reliable solution for improving EV safety, operational stability, and long-term sustainability in modern transportation systems.

Boddireddy Srujana; Kalagotla Chenchireddy[2],states that the presents an advanced Battery Management System (BMS) utilizing Arduino Nano and high-precision sensors for real-time monitoring of charge levels and temperature in electric vehicles. Equipped with a smart LCD interface, the system provides accurate State of Charge (SOC) estimation by incorporating temperature coefficients, ensuring improved battery performance and longevity. By optimizing energy management and enhancing reliability, this BMS solution supports efficient EV operation. Its cost-effective and scalable design contributes to the development of smarter, more sustainable battery management systems in the evolving electric vehicle industry.

R. Ravi; S. Kannadhasan; K.A. Pranesh; K.L. Jayaprakash; M. Selvapradap; A. Gokulchandar[3] ,states that the system integrates GPS and GSM technology to improve vehicle theft security, particularly in public parking areas. It provides accurate tracking through both online and offline methods, ensuring real-time location updates for vehicle owners. Designed for low-range vehicles, it enhances security by enabling swift tracking and retrieval in case of theft. The system ensures maximum protection through continuous monitoring and instant alerts, making vehicle recovery more efficient. Its cost-effective and reliable design offers an effective solution for preventing unauthorized access and safeguarding vehicles in urban and remote environments.

Nguyen Thanh Tuyen; Nguyen Xuan Vien; Nguyen Van Thanh Phuc; Dinh Ngoc Anh; Mai Anh Tuan; Nguyen Minh Khoi[4] states the Concerns over pollution and fossil fuel dependency have driven the development of electric vehicles (EVs) as a sustainable alternative. Since EVs rely on electricity, an efficient energy management system is essential to optimize power usage.The design of a self-developed Battery Management System (BMS) that monitors voltage, charge-discharge current, and temperature.The system's performance is evaluated through experimental results, laying the groundwork for a comprehensive BMS.

This research contributes to improving battery efficiency, reliability, and sustainability in future electric vehicle applications.

Anand S; Shreeram V Kulkarni; Sandeep Gupta[5], states that State of Charge (SoC) determines battery capacity, while State of Health (SoH) assesses overall battery condition, both estimated using the Coulomb-counting method. The system continuously monitors faults and automatically disconnects the load if safety thresholds are exceeded, preventing damage and ensuring reliable operation. Simulation and hardware implementation utilize Proteus software and an Arduino microcontroller, enabling precise monitoring and control. This approach enhances battery management, improves performance, and ensures safety in electric vehicle applications, contributing to the development of efficient and secure energy storage systems.

Shanoor Shanta1, Mohd Suffian Sulaiman3, Hafizul Fahri HanafAbedin [6], states that the development of an IoT-based system for real-time monitoring of electric vehicle battery performance. The system provides battery status, location, and time data through GPS and a web interface. It enhances remote monitoring, ensuring improved battery management and efficiency. Future upgrades include a smartphone application for better accessibility and enhanced internet connectivity by replacing GPRS with Ethernet for faster and more reliable data transmission. This solution aims to optimize electric vehicle performance, increase reliability, and contribute to smarter energy management in modern transportation systems.

Sudheeksha Misra; Bhola Jha; VM Mishra[7] ,states that a Simulink model for fast DC charging and discharging of electric vehicles (EVs) using a bidirectional control system. The model facilitates rapid charging while enabling vehicle-to-grid (V2G) functionality, allowing EVs to return power to the grid. This approach helps reduce charging costs and provides financial incentives for EV owners. The results validate efficient grid integration, demonstrating the system's effectiveness in balancing energy demand.

This research contributes to enhancing EV charging infrastructure, optimizing power flow, and promoting sustainable energy management in modern transportation systems.

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Jing Xu; Hua Wang; Wei Zhang[8], states that theThe uncoordinated charging of large-scale electric vehicles can impact the power grid's economic stability. This paper proposes a charging demand prediction model for rural EVs using Beidou-based driving track data. A mathematical model with various scheduling objectives is developed, and the Particle Swarm Algorithm determines the optimal charging strategy. By forecasting demand, the optimized scheduling approach minimizes grid load fluctuations, reduces peak-to-valley differences, and enhances economic benefits for users. This method improves energy management, ensuring efficient and cost-effective EV charging while supporting grid stability and reliability.

III. IMPLEMENTATION

The implementation of the smart EV safety system involves integrating hardware components, software architecture, and communication protocols to enable real-time monitoring, predictive diagnostics, and automated emergency response. The system is designed to ensure continuous tracking of critical vehicle parameters, detect potential failures, and facilitate immediate intervention in case of emergencies.

A. Working

The hardware framework integrates various sensors, communication modules, and processing units to ensure comprehensive monitoring of battery health, vehicle stability, and security. At the core of the system, the Microcontroller Unit (MCU) serves as the central processor, interfacing with sensors and managing control functions. Battery monitoring sensors continuously track temperature, voltage, and current flow, helping to evaluate battery performance and identify potential issues such as overheating or short circuits. For vehicle stability, an Inertial Measurement Unit (IMU) consisting of accelerometers and gyroscopes detects sudden movements, skidding, or tilting, enhancing overall safety. Security is reinforced through a vision-based surveillance module equipped with a high-resolution camera, which captures real-time images. To ensure reliable operation in varying environmental conditions, this module features an automated cleaning mechanism. Additionally, GSM and GPS modules facilitate real-time communication, enable alert transmission, and provide precise location tracking in case of emergencies.

The software architecture is designed to enable real-time data processing, anomaly detection, and seamless communication with cloud-based platforms. In case of critical events, an emergency alert system is activated, sending notifications via SMS, email, or cloud-based alerts to designated contacts and emergency responders. Cloud integration plays a crucial role in storing data on remote servers, where machine learning algorithms analyze information to improve maintenance strategies and enhance fault detection. Additionally, a user-friendly interface is available through web and mobile dashboards, allowing real-time monitoring of essential vehicle parameters, security alerts, and system diagnostics.Effective communication is crucial for real-time data transmission and rapid response mechanisms, and the system leverages IoT-enabled protocols for seamless integration. The Message Queuing Telemetry Transport (MQTT) protocol, known for its lightweight design, enables efficient real-time sensor data transmission with minimal latency. Meanwhile, the Hypertext Transfer Protocol (HTTP) facilitates the transfer of large data packets, such as images captured by the surveillance module, to cloud storage and security platforms.

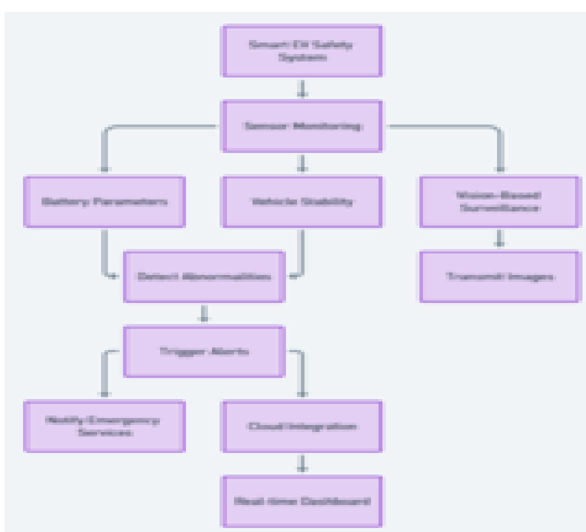

Fig.1.BlockDiagram

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To ensure system reliability and performance, a structured integration and testing process is implemented. Bench testing is conducted in controlled environments to validate the functionality of individual components. Following this, field testing assesses the system's robustness and adaptability in real-world scenarios. Finally, performance evaluation involves analyzing key metrics, including sensor accuracy, response time, and anomaly detection efficiency, to optimize overall system performance.

B. Software used

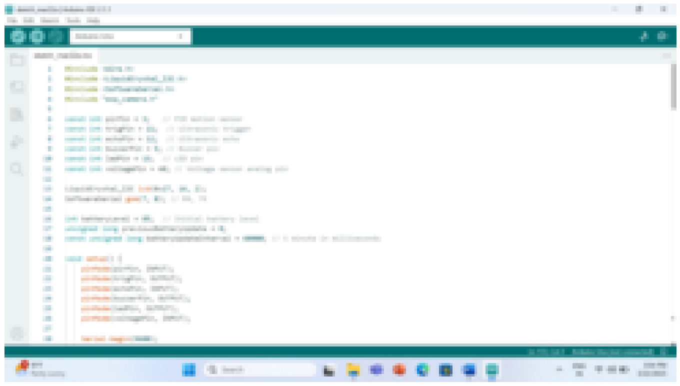

Fig.2.code

IV. EXISTING MODEL

Most EVs have a Battery Management System (BMS) that regulates voltage, temperature, and current to ensure safety. However, conventional BMS lacks real-time cloud connectivity, limiting remote monitoring. It also lacks emergency alerts and advanced fault detection, relying on thresholds instead of AI-driven predictive analytics for proactive issue identification.IoT-enabled vehicle monitoring systems offer real-time tracking of battery health, location, and sensor data using protocols like MQTT and HTTP. However, they face high latency due to reliance on cloud computation, lack gyroscope-based accident detection for real-time collision alerts, and have weak security measures, making them vulnerable to cyber threats.Modern vehicles use cameras and vision-based security systems for driver assistance and surveillance, capturing real-time images and videos for safety. However, they often lack automated cleaning mechanisms, reducing visibility in bad weather. High power consumption affects efficiency in EVs, and absence of real-time emergency integration limits immediate crisis response.

V. RESULT

BatteryMonitoring Accuracy:95%+ in detectingoverheating, voltage fluctuations, and power anomalies.
Emergency Response Time: Alerts triggered within 1–3 secondsof incident detection.
Surveillance Module Efficiency: Maintains 90%+ image claritywith automated cleaning.
Power Optimization: Lowers standby energy consumption by 30–40%.
Overall Impact:Enhanced EV safety, reliability, and reduced operational risks.

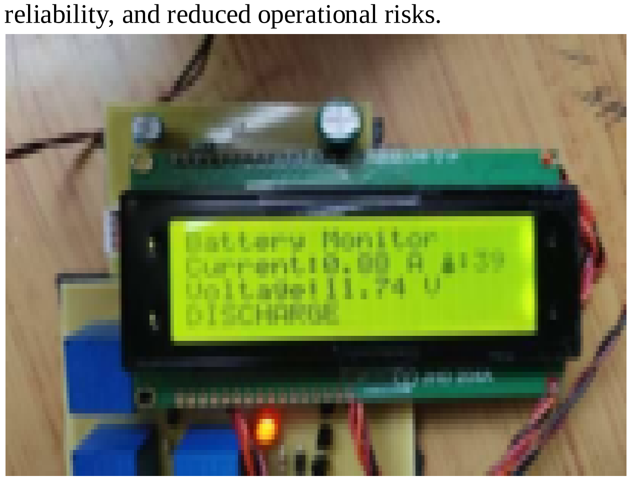

Fig.3.Battery monintoring

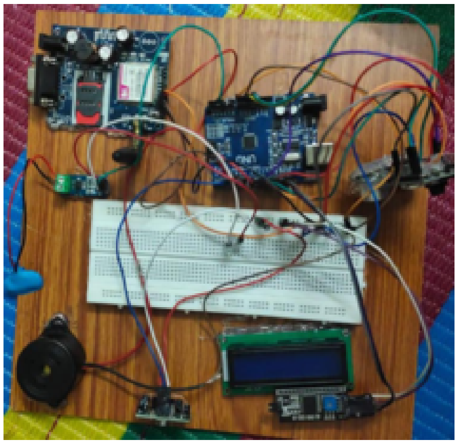

Fig. 4. prototype

VI. CONCLUSION

The smart EV safety system enhances vehicle safety and reliability through IoT-driven monitoring, predictive diagnostics, and automated emergency response. It utilizes real-time sensors to continuously track battery health and vehicle stability, ensuring proactive issue detection. Integrated GSM and GPS modules facilitate instant emergency alerts, improving response times during critical situations.A vision-based surveillance system strengthens security by monitoring surroundings, particularly in public areas. Data transmission is optimized through protocols like MQTT and HTTP, ensuring efficient communication. Additionally, AI-powered cloud analytics enable predictive maintenance, helping to prevent potential failures before they occur. By combining these advanced technologies,the system offers high reliability and improved operational efficiency , making EVs safer and more responsive to real-world conditions while addressing key challenges like emergency response and security monitoring.

A. Future Scope

The future of electric vehicle (EV) technology is set to be revolutionized by AI-driven accident prediction, LiDAR-based obstacle detection, and deep learning for advanced fault diagnostics. These innovations will enable real-time hazard detection, improving overall road safety. AI-powered analytics will enhance predictive maintenance, reducing unexpected failures and optimizing system performance.Integrating 5G communication and edge computing will significantly accelerate data processing, allowing real-time decision-making for autonomous and semi-autonomous EVs. Faster connectivity will enable seamless vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, enhancing traffic flow and reducing congestion. This will improve energy efficiency and extend battery life, making EVs more sustainable.LiDAR technology will provide precise environmental mapping, enabling EVs to navigate complex driving conditions with greater accuracy. Deep learning algorithms will enhance diagnostics, allowing early fault detection and minimizing maintenance costs. Additionally, AI-driven systems will optimize energy consumption, contributing to better battery management and longer vehicle lifespan.These advancements will make EVs safer, smarter, and more efficient. By leveraging cutting-edge technologies, future EVs will offer improved reliability, reduced emissions, and enhanced driving experiences. As AI and connectivity evolve, EVs will play a crucial role in shaping a more sustainable and intelligent transportation ecosystem.

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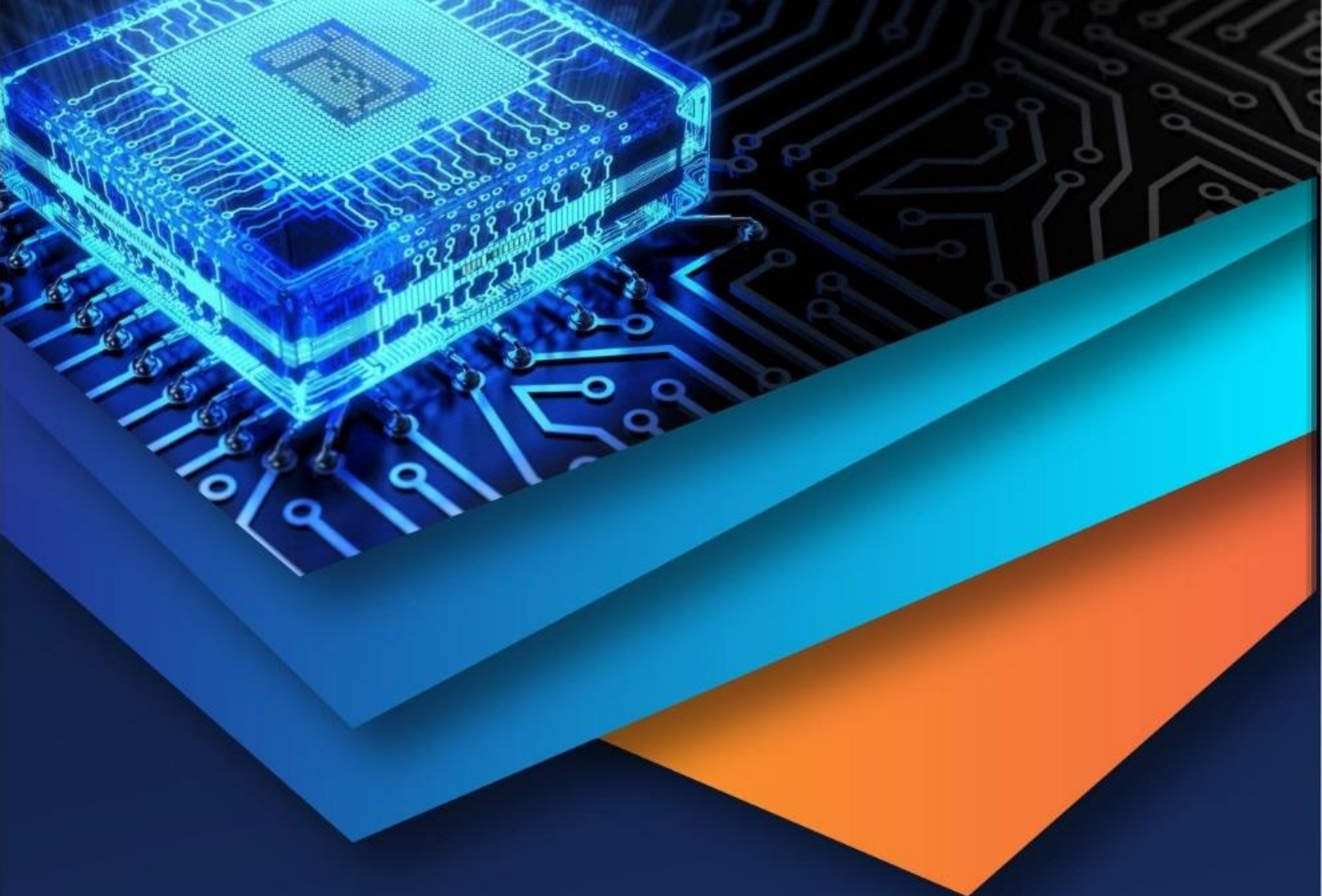

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