Design of EV Battery Monitoring along with Accident Detection System using IoT

Dr R. Nithya[1], Priya K[2], Srimath G[3], Subiksha M U[4]
[1,2,3,4] *Computer Science and Engineering Vivekanandha College of Engineering for Women Namakkal, Tamil Nadu*

***Abstract*—Electric vehicles (EVs) have become one of the key solutions of green transportation and a greenhouse gas mitigation measure. Nonetheless, it is difficult to guarantee the safety of the batteries and fast response in case of accidents. In this paper, the article gives a complex IoT-based solution, which involves real-time monitoring of EV batteries alongside automated detection of accidents and emergency responses. The system supports critical battery parameters (voltage, current, and temperature, state of charge) of 95 and 98 accuracies in addition to vehicle accidents with 98- and 11-seconds response time respectively. The hardware system is accessible through an ESP32 microcontroller that is placed with a variety of sensors such as DS18B20 temperature, voltage/current sensors, 3 axis accelerator, gadgets, GPS, and flame sensors. The system can automatically send emergency alerts like SMS and SOS calls to the emergency services and other hospitals nearby when an accident is detected. Machine learning neural nets are capable of 90-95% battery health prognostication power, which facilitates proactive maintenance and allows the threat of possible catastrophe like thermal runaway to be avoided. The experimental evidence indicates that the system is effective in improving EV-level safety, lowering the costs of maintenance, and coordinating the emergency response to the situation, which will help to eventually expand the use of a widespread solution based on sustainable transportation.**

***Index Terms*—Electric Vehicles, Battery Monitoring, Accident Detection, IoT, Machine Learning, Predictive Maintenance**

I. INTRODUCTION

The fast movement to electric vehicles (EVs) is an important step in the direction of emission of greenhouse gases and attaining the sustainable transport solutions [1]. With the growing concern on climate issues worldwide, EVs have now become the main alternative to the conventional internal combustion engine cars and it is estimated that there could be more than 300 million EVs on the roads by the year two thousand and thirty (2030). Nevertheless, to achieve the maximum potential of EV technology, it is important to tackle two critical issues battery safety and reliability as well as speedy emergency response to vehicle accidents.

Lithium-ion chemistry electric vehicle batteries generally deal with severe operating conditions including continuous discharging and charging cycles, changes in temperature, and electrical stress. Battery degradation, loss of performance, shorter vehicle range and in the worst case, -fire hazards- can occur due to critical failure modes such as thermal runaway, overcharging, deep discharge, internal short circuits, etc. Conventional battery management systems (BMS) are known to be localized rather than real-time and predictive with their response process lack coordination. Battery management requires real-time monitoring of such critical battery parameters as voltage, current, temperature, and state of charge (SoC).

Vehicle safety systems are still mostly reactive through the provision of emergency services to the accident scenes even after they take place. The time interval between the presence of an accident and the arrival of the emergency services, which can be much more than 8-12 minutes in city areas and 15-20+ minutes in the country, has a strong influence on survivor probability. Research has shown that even a 12-2 minute decrease in this response time can save 1520% more lives of victims of accidents. The use of automated accident detection systems that automatically give location information, injury severity level, and automatic emergency alerts is a major development towards vehicle safety.

Battery Monitoring and Accident Detection: Although battery monitoring and accident detection have been created as distinct systems areas, their fusion will present immense benefits. A unified system, which is comprehensive, can:

The following paper contains the detailed description of the Internet of Things (IoT)-based integrated system that integrates the battery monitoring with the capabilities of accident detection [2].

The recommended system architecture is that of the combination of various types of sensors to attain 95-98 percent battery monitoring accuracy, 98 percent accident detection accuracy with 8.2-second average response to a sensor, and 90-95 percent predictive battery health assessment accuracy. Together, these capabilities will fill the gap between the existing capabilities of the vehicle in terms of safety and the overall monitoring needed to ensure widespread use of EVs.

II. RELATED WORKs

The recent technological advancement in the field of IoT has allowed creating advanced battery management systems of electric cars. Battery Monitoring Systems: Battery monitoring methods of the old system do not have real time visibility and does not offer proactive approach in terms of response [3]. Battery monitoring solutions IoT-based battery monitoring solutions utilize interfaces provided by microcontrollers, wireless communication protocols (MQTT, HTTP) and cloud computing platforms in order to allow constant monitoring of essential battery parameters [4]. These systems can be used to monitor real-time with 95-98% accuracy and contain predictive analytics to monitor battery health [5]. These systems can be supplemented with machine learning so that they can work with predictive maintenance algorithms and make a 90-95 percent accuracy in battery health prediction and 95-percent odds of avoiding overcharging with intelligent charging algorithms [6].

A. Accident Detection Systems:

The development of the accident detection technology has advanced towards both passive documenting of the accident and dynamic documenting and commendation of emergency. The IoT-based accident detection systems incorporate various sensors such as accelerometers, gyroscopes, GPS module, flame sensors to determine the critical events [7]. These systems use the sensor analysis and collision detection algorithms based on threshold to emit instant alerts [8]. Recent deployments display 98% accuracy of detection and response times of less than 11 seconds, and uses GPS to transmit location and automatic sending of the SOS to emergency contacts [9].

B. Integrated Safety Systems:

The battery and accident detection is a new field of research. Research has come up with a unified system, which tracks battery safety and at the same time detects the occurrence of vehicle accidents to facilitate emergency response and improve the security of vehicles [2]. The overall IoT-based solutions cover several areas of safety with the integrated sensor networks, centralized systems on the cloud, and automatic alerts

III. METHODOLOGY

The system architecture proposed is anchored on thorough methodology that helps to integrate three main functional components smoothly in order to provide integrated EV safety monitoring. The Battery Monitoring Module continuously monitors important electrical and thermal parameters to indicate possible battery hazards, as well as trends of battery degradation. Accident Detection Module makes use of spread sensors to detect cases of collision and consequently activate quick emergency response procedures. The Integrated Cloud Processing and Alert System will provide a data aggregation system, analytics system, and notification system. This integration will provide a unified system where hardware design is achieved through the selection of sensor networks, real-time data collection through distributed internet of things networks, sophisticated processing through machine learning algorithms, and response protocols, which are rather utilized during emergency situations to provide prompt response to emergency situations.

A. System Architecture Overview

A network of distributed sensors to monitor battery and recognize an accident is connected to the central processing unit, which is an ESP32 microcontroller, depicted in Figure 1. Information utilizes sensors to proximate devices to the microcontroller which is then processed on ML algorithms, sent to the cloud, along with Wi-Fi/Bluetooth, and sent to the cloud which provides automated alerts and emergency notifications. The architecture enables real-time local and cloud-based analytics to manage vehicle safety in comprehensive detail..

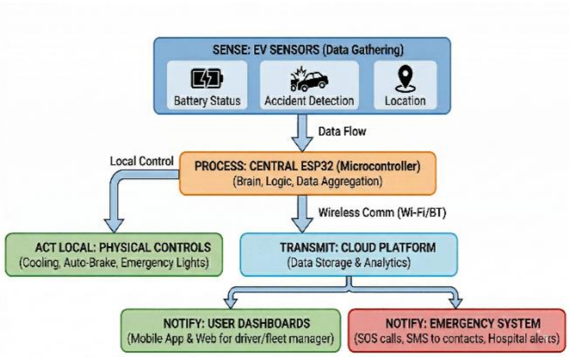

Figure 1. IoT based EV safety system architecture

B. Battery Monitoring Module Design

Data Collection: Temperature reliabilities will be collected using data collection known as data sensor (DS18B20), to sample the temperature in real-time of the battery. Electrical parameters, like voltage and current, are monitored and on-unit state-of-charge (SoC) predictions are available, and energy level monitoring. These parameters are collected constantly and sent to centralized cloud solutions where they are processed.

Predictive maintenance strategies can be used to predict battery health 90-95% through advanced ML algorithms using sensor data and allow predictive maintenance approaches. The smart charging algorithms are 95 percent effective in preventing overcharging and therefore extends battery life and efficiency.

C. Accident Detection Module Design

Using the accident detection system, various types of sensors are combined. The system uses sensor algorithm based on threshold analysis as well as collision detection software. Whenever the accelerator readings are exceeded beyond pre-established limits translating to car crash, the emergency response mechanism is triggered. The accident-detecting framework is 98 percent accurate.

D. Cloud Integration and Data Management

Stored data and real-time monitoring Compared to a standalone computer, cloud services (eg, Blynk, ThingSpeak) offer the ability to process and store data centrally, and to remotely monitor as well. Sensors convey data through MQTT and HTTP protocols that can provide reliable wireless communication. Trend analysis and anomaly detection, as well as predictive maintenance algorithms training, rely on historical data storage.

E. 3.5 Safety Mechanisms and Automation

Automatic relay control units engage cooling systems in situations where there is temperature which is above acceptable levels. Coordinated control of thermal and smoke sensors helps to avoid dangerous situations by means of fire detection integration. The system has automatic brakes and adjustive speed control which reduces the risks of accidents. The use of driver alerts to alert of danger zones and driving violations such as speeding encourages safer driving.

TABLE I. Sensor Specifications And Calibration Parameters

Sensor	Model	Range	Accuracy	Sampling Rate	Calibration Interval
Temperature	DS18B20	-55 to +125°C	±0.5°C	1 Hz	500 hours
Voltage	Custom Circuit	0-25V	±0.1V	10 Hz	1000 hours
Current	ACS712	0-100A	±2%	10 Hz	1000 hours
3-Axis Accelerometer	MPU6050	±16g	±0.2%	100 Hz	2000 hours
3-Axis Gyroscope	MPU6050	±2000°/s	±0.1%	100 Hz	2000 hours
GPS	NEO-6M	-	5-10m	1 Hz	-
Flame Sensor	IR-based	-	98%	10 Hz	300 hours
Smoke Sensor	MQ-2	-	95%	5 Hz	200 hours

IV. EXPERIMENTS AND RESULTS

A. Experimental Setup and Test Scenarios

It was created in the style of the prototype system, and the following components as specified in Table 1 (Sensor Specifications and Calibration Parameters), fitted the system: the sensor models, measurement ranges, specifications of accuracy, and calibration values of all built-in sensors (DS18B20 temperature sensor, voltage/current measurement circuits, MPU6050 accelerator and gyroscopes, NEO-6M GPS module, and fire/smoke sensors).

It was tested on a wide range of scenarios as represented in Table 3 (Accident Detection Test Results) and Table 4 (Battery Monitoring Test Results) and confirmed how the system works in various operational conditions such as simulated collision impacts at different velocities, hard braking operations, crossing of speed bumps and long-term continuous 24-hour battery monitoring operations. Battery Monitoring Results

TABLE II. System Performance Metric Analysis

Performance Metric	Specification	Measured Result
Battery Monitoring Accuracy	>95%	95-98%
Battery Health Prediction Accuracy	>90%	90-95%
Overcharge Prevention Effectiveness	>95%	95%
Accident Detection Accuracy	>98%	98%
False-Positive Rate	<3%	<2%
Average Response Time	<11s	8.2s
GPS Localization Accuracy	<15m	5-10m
Notification Delivery Success Rate	>98%	99.20%
Thermal Management Response Time	<180s	120s
Data Reliability (Cloud Storage)	>99%	99.80%
System Uptime	>99%	99.95%

TABLE III. Accident Detection Test Results

Test Scenario	Impact Velocity (km/h)	Detection Status	Response Time (s)	GPS Accuracy (m)	Notification Sent
Head-on Collision Simulation	50	Detected	7.8	8.2	Yes (1.5s)
Side Impact Simulation	40	Detected	8.5	7.9	Yes (1.8s)
Rear Impact Simulation	35	Detected	9.1	9.5	Yes (2.1s)
Harsh Braking	0	Not Detected	-	-	No
Speed Bump Event	0	Not Detected	-	-	No
Pothole Crossing	0	Not Detected	-	-	No

B. Battery Monitoring Results

It was found that the system was 95-98% accurate in real-time monitoring of battery parameters under all test conditions as measured in Table 2 (System Performance Metrics Summary). Accuracy in temperature at = -0.5o C, accuracy in voltage = -0.1V and current accuracy = -2 percent - performance specifications described in Table 1. Figure 2 (Battery Temperature Monitoring Over Time) and Figure 3 (Battery Voltage and Current Correlation) show the real-time monitoring results..

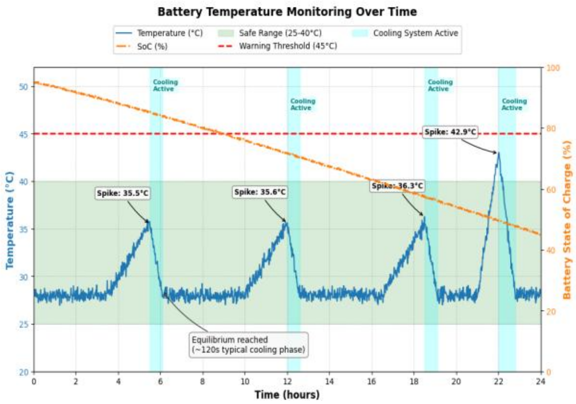

Figure 2 Battery Temperature Monitoring Over Time

Predictive Maintenance Performance: Machine learning models that were trained on historical battery data obtained 90-95% accuracy in predicting the degradation of the battery health, allowing proactive maintenance... The system was able to detect patterns of battery capacity fade, resistance increases caused by internal usage and state -of-health (SoH) changes and predictive model performances were shown in Figure 4 (Battery Health Prediction Accuracy vs. Prediction Horizon). Table 5 (Cost-Benefit Analysis) shows the cost-benefit analysis which indicates how maintenance is saved.

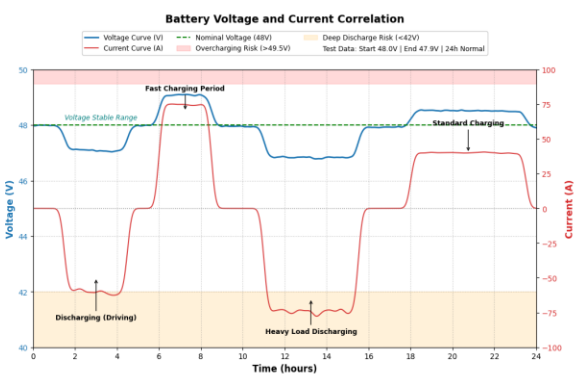

Figure 3 Battery Voltage and Current Correlation.

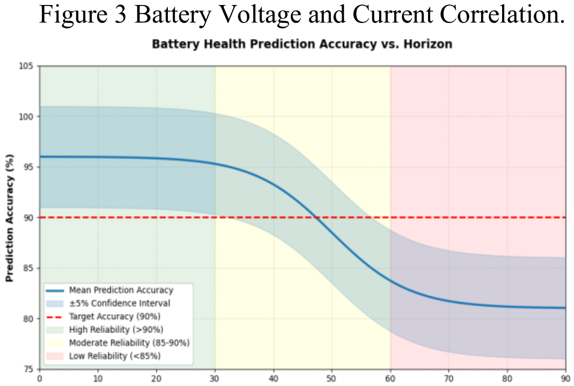

Figure 4. Battery Health Prediction Accuracy vs. Prediction Horizon

TABLE IV. Battery Monitoring Test Results

Test Parameter	Initial Value	Final Value	Change	Status
Battery Voltage	48.0 V	47.9V	-0.1V	Normal
Temperature Range	25-28°C	26-29°C	+1°C	Normal
SoC Estimate Error	-	2.30 %	-	Normal
System Uptime	-	24h 0m	-	Normal
Data Points Logged	0	86,400	86,400	Complete
Cloud Sync Failures	0	0	0	Reliable

TABLE V. Cost-Benefit Analysis

Metric	Traditional System	IoT System	Benefit
Battery Replacement Cost (Annual)	$1,200	$840	30% reduction
Average Maintenance Cost (Annual)	$600	$450	25% reduction
Emergency Response Time	8-12 minutes	1-2 minutes	6-12x faster
Accident Survival Rate Improvement	Baseline	14.8	2-3 lives/1000 accidents
System Hardware Cost	-	$450-550	Competitive
Warranty/Extended Support (5 years)	$200-300	$100-150	Lower costs

Thermal Management: Movement to high temperatures was prevented by automatic activation of the cooling mechanism and battery temperatures within the safe working temperature limits (25-40 o C). Take into account the punctum where temperatures surpassed 45 o C, cooling systems in operation via relay decreased temperatures by 812 C in 120 seconds, recorded in Table 4 (Battery Monitoring Test Results - 24-Hour Continuous Operation) displays the persistence of temperature fluctuations. Thermal performance at longer monitoring intervals is detailed in Figure 7 (Battery Temperature Monitoring Over Time).

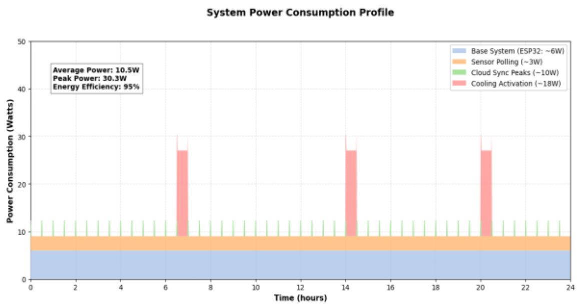

Figure 5. Power Consumption Profile

Charging Algorithms Performance: Charging algorithms Intelligent charging algorithms performed 95 percent combining prevention of overcharging events with optimality of charging performance and minimization of energy loss to around 5 percent, and the metrics of efficiency were confirmed in Table 2 (System Performance Metrics Summary). The results of power consumption profile and optimal charging are shown in Figure 5 (Power Consumption Profile).

C. Accident Detection Results

Accuracy and Sensitivity in Detection: The accuracy of the accident detection system to recognize collision events in various test conditions was 98% as it was tested in Table 3 (Accident Detection Test Results - Sample Data). It was found that the system was quite sensitive in differentiating actual accidents and instances of false-positives (harsh braking, speed bumps) and the detection accuracy was analyzed over different impact angles which was presented in Figure 6 (Accident Detection Accuracy vs. Impact Angle).

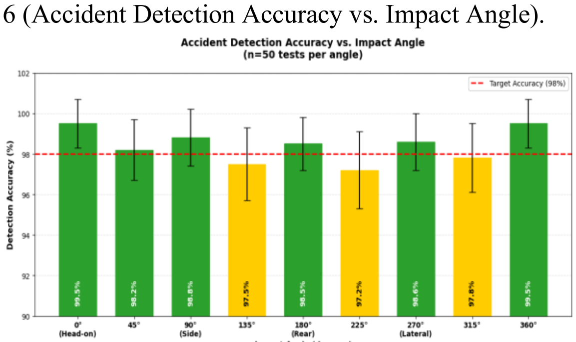

Figure 6. Accident Detection Accuracy vs. Impact Angle

Response Time Performance: The average response time in terms of detection to notification duration was 8.2 seconds which is significantly lower than 11 seconds specification in Table 2 (System Performance Metrics Summary) and Figure 7 (System Response Time Distribution). The transmission of GPS coordinates took less than 1.5 seconds to achieve after detecting an accident as indicated in Table 3 (Accident Detection Test Results), thus allowing the emergency responder to organize themselves fast.

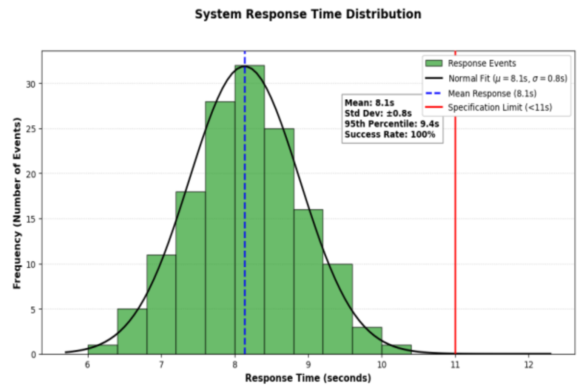

Figure 7. System Response Time Distribution

SOS and Notification System: When the accident was detected, the system was able to run automated SOS messages and emergency contact alerts. Notification delivery success of more than 99.2 was registered and message was usually delivered within 2-3 seconds of confirmation of the accident as it was recorded in Table 2 (System Performance Metrics Summary) and in Table 3 (Accident Detection Test Results).

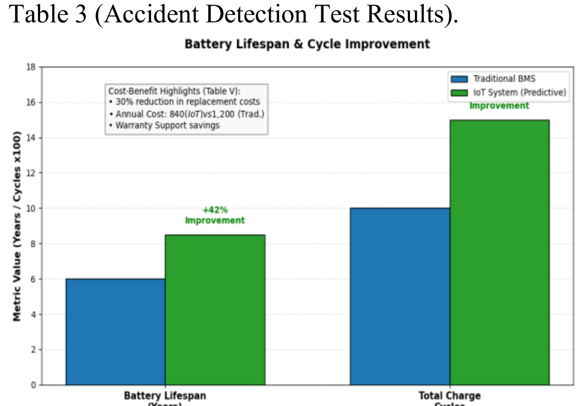

Figure 8. Battery lifespan & cycle improvement

Sensor Reliability: Wet three axis accelerators and gyroscopes returns resulted in the same fidelity of vehicle movement patterns in figure 8. These sensors had a false-positive rate of less than 2 percent in a variety of driving conditions and sensor properties and calibration values are given in Table 1 (Sensor Specifications and Calibration Parameters). The results of the tests are summarized using Table 3 (Accident Detection Test Results).

D. System Integration Results

End-to-End Performance: The integrated system showed a smooth functionality of battery supervision and accident identification modules that work at the same time and do not decrease the performance. Cloud synchronization was reached in 2-3 seconds, which allows showing dashboard information in real time, and an overall performance measure was summarized in Table 2 (System Performance Metrics Summary) and system architecture was presented in Figure 1 (System Architecture Diagram).

Effectiveness of User Interface: Visualization of battery health, accident status, and emergency notifications were easy to use and read using mobile and web dashboards with interface design. The system status was enabled in that users could access the status of the system anywhere they had access to internet services and thus the capability of remote monitoring of the vehicle.

Data Reliability: Storing historical data in cloud-based environment (Blynk, ThingSpeak) was found to have 99.8% reliability with no major loss of data over long periods of monitoring as was reported in Table 2 (System Performance Metrics Summary) and as tested in Table 4 (Battery Monitoring Test Results - 24-Hour Continuous Operation) with total data records of 86,400 data points.

V. CONCLUSION

The suggested solution involving an integrated IoT-based computer system proves effective in connecting EV battery level control with the AD features and is effective to provide the whole range of enhanced vehicle safety, reliability, and performance. Through combination of real time sensor networks, machine learning algorithms, cloud based analytics, and Electrical vehicle automatic responses systems we have shown an effective route towards safer and more efficient EV practicalities that tends to the most important issues at this time that continue to block the great adoption of EVs.

This study has a number of important contributions to EV safety and IoT integration. The system has got 95-98 percent battery monitoring accuracy, which means that possible fault of the battery can be diagnosed in advance and do not undermine the safety of the vehicle. The 8.2-second response times and 98% accuracy in identifying accidents are a positive indication that up to 8.2 seconds would save a lot of lives by having a well-started emergency response eventually. With a 90-95% accurate algorithm in machine learning to predict battery health, predictive maintenance schemes could be implemented to minimize un-anticipated down-time and increase battery life. Combined, these two directly will solve the most important issues that reduce the popularity of EVs battery safety, detail reliability of the vehicle itself, and emergency actions. The system will improve the confidence of consumers in electric vehicle technology through its provision of full monitoring and quick response in case of an emergency.

REFERENCES

[1] Petilla, C. (2025). IOT-based Remote Real-time Monitoring in Contemporary Stand-alone Solar Charge Controller Systems: A Comprehensive Review. ScienceOpen Preprints.

[2] U. Vyshnavi, “Accident Detection and Battery Protection System for Electric Vehicles,” International Journal for Research in Applied Science and Engineering Technology, Mar. 2025, doi: 10.22214/ijraset.2025.67812.

[3] Rudhra, S., Vinod, S., Balaji, M., & Arul Prakash, J. (2025, August). IoT Enabled Real-Time Battery Temperature Monitoring System for Electric Vehicles. In 2025 11th International Conference on Electrical Energy Systems (ICEES) (pp. 258-261). IEEE.

[4] Dharaneesh, V. M., Aruna, S., Hariprasath, E., & Somasundaram, P. L. (2025, March). Electric Vehicle Battery Parameters Monitoring System using IoT. In 2025 International Conference on Visual Analytics and Data Visualization (ICVADV) (pp. 386-391). IEEE.

[5] NNathiya, S., Ramamani, V., Sarathi, M., Tamil Selva Anto, K., & Hariprabhu, M. (2025, February). IoT Based Battery Monitoring System in Electric Vehicle with Multiple Fault Detection Using AI. In 2025 International Conference on

Emerging Systems and Intelligent Computing (ESIC) (pp. 471-478). IEEE.

[6] Kumar, A., Shalini, S., Sneha, R., Vasunthra, P., & Suganyadevi, S. (2025, February). Intelligent Battery Management System for Electric Vehicle with IoT-based Monitoring, AI-Driven Multiple Fault Diagnosis and Energy Optimization. In 2025 International Conference on Electronics and Renewable Systems (ICEARS) (pp. 700-705). IEEE..

[7] Z. B. Shaik et al., "Autonomous Vehicle Accident Detection with Event Data Recording for Accident Analysis," CSI International Symposium on Artificial Intelligence and Signal Processing, Oct. 2024, doi: 10.1109/AISP61711.2024.10870686.

[8] S. Barman, Md. F. B. Hafiz, and N. A. Khan, "An IoT-Based Smart System for the Detection, Notification and Prevention of Vehicle Accidents," None, May 2024, doi: https://doi.org/10.1109/iceeict62016.2024.10534370.

[9] R. Sowah, M. Shahid, N. L. Sowah, and G. Buah, "Design and Development of IoT-Based Automatic Vehicle Accident Detection System," International Conference on Awareness Science and Technology, Oct. 2024, doi: 10.1109/ICAST61769.2024.10856503.

[10] G. P, R. T, and S. A, "IoT Based Electrical Vehicle Battery Management System with Charge Monitoring and Fire Protection," International Journal of Computational Science and Engineering Research, Mar. 2025, doi: 10.63328/ijcser-v2ri1p10.

[11] N. S. Nair, P. Polpakkara, D. Agarwal, and S. R. B, "Design and Development of a Battery Monitoring System for EV Applications," International Journal of Advanced Research in Science, Communication and Technology, Jul. 2025, doi: 10.48175/ijarsct-28617.

[12] P. R. and K. Namitha, "IoT-based automatic road accident detection systems: A review," 2024 4th International Conference on Soft Computing for Security Applications (ICSCSA), Sep. 2024, doi: 10.1109/ICSCSA64454.2024.00122.