International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

EV Battery Monitoring and Protection based on IOT and AI

[1] Prof. V.G.Umale , [2]Sachin Kewat , [3]Sajal Meshram , [4] Madhavi Dharpure , [5]Pranali Bhoyar , [6]Shreyash Patil

PROF., DEPARTMENT OF ELECTRICAL ENGINEERING , PRIYADARSHINI COLLEGE OF ENGINEERING NAGPUR, MAHARASHTRA, INDIA[1]

U.G. DEPARTMENT OF ELECTRICAL ENGINEERING , PRIYADARSHINI COLLEGE OF ENGINEERING NAGPUR, MAHARASHTRA, INDIA[2,3,4,5,6]

Abstract: Electric vehicle (EV) battery monitoring and protection systems are crucial for ensuring the safety, reliability, and longevity of battery packs. In this study, we propose an integrated approach that leverages Internet of Things (IoT) and Artificial Intelligence (AI) technologies to monitor and protect EV batteries in real-time. The proposed system continuously collects data from various sensors embedded within the battery pack, including voltage, current, temperature, and state of charge (SoC). This data is transmitted to a centralized IoT platform for analysis and processing. Using AI algorithms, such as machine learning and deep learning models, the system analyzes the collected data to detect anomalies, predict potential failures, and optimize battery performance. Additionally, the system incorporates intelligent protection mechanisms to prevent overcharging, over-discharging, and overheating of the battery pack, thereby ensuring safe and efficient operation. The integration of IoT and AI technologies enables proactive monitoring and management of EV batteries, leading to improved safety, reliability, and lifespan. This study presents a comprehensive framework for EV battery monitoring and protection, highlighting the potential benefits of IoT and AI in advancing sustainable transportation.

Keywords: **Electric vehicles, Battery monitoring, IoT, Artificial Intelligence, Machine learning, Deep learning, Battery protection.**

I. INTRODUCTION

With the rapid proliferation of electric vehicles (EVs) worldwide, ensuring the safety, reliability, and longevity of battery packs has become a paramount concern. Electric vehicle battery monitoring and protection systems play a pivotal role in safeguarding these critical components against potential failures and optimizing their performance. Traditional monitoring approaches often lack real-time visibility and proactive management capabilities, necessitating innovative solutions to address emerging challenges. In response to this need, this study proposes an integrated approach that harnesses the power of Internet of Things (IoT) and Artificial Intelligence (AI) technologies to revolutionize EV battery monitoring and protection. By leveraging IoT-enabled sensors embedded within the battery pack, coupled with AI-driven analytics and intelligent protection mechanisms, the proposed system offers unparalleled insights and proactive management capabilities. This introduction outlines the significance of EV battery monitoring and protection, discusses the limitations of existing approaches, and sets the stage for the exploration of the integrated IoT and AI solution. The subsequent sections will delve into the architecture, functionalities, and potential benefits of the proposed system, highlighting its role in advancing sustainable transportation and ensuring the widespread adoption of electric vehicles. Through this integrated approach, we aim to address the evolving needs of the electric vehicle industry, enhance safety and reliability, and accelerate the transition towards a cleaner and more sustainable transportation ecosystem.

II. LITERATURE SURVEY

"IoT-Based Battery Management System for Electric Vehicles" by Zhang et al. (2020)
This paper presents a comprehensive review of IoT-based battery management systems (BMS) for electric vehicles. It discusses various IoT technologies, sensor configurations, data analysis techniques, and communication protocols used in BMS applications. The study highlights the importance of real-time monitoring, predictive maintenance, and safety features in optimizing battery performance and extending lifespan.
"Lithium-Ion Battery Monitoring Techniques: A Review" by Li et al. (2019)
This review paper provides an overview of monitoring techniques for lithium-ion batteries, including both offline and online methods. It discusses the principles of battery monitoring, sensor technologies, data acquisition systems, and analysis approaches. The study emphasizes the importance of real-time monitoring in detecting early signs of degradation and preventing catastrophic failures.
"State of Charge Estimation Techniques for Lithium-Ion Batteries in Electric Vehicles: A Review" by Singh et al. (2018)
This review article focuses specifically on state of charge (SoC) estimation techniques for lithium-ion batteries in electric vehicles. It compares various SoC estimation methods, including model-based, data-driven, and hybrid approaches. The study evaluates the accuracy, complexity, and practicality of different techniques and discusses their implications for EV battery management systems.
"IoT-Based Battery Health Monitoring System for Electric Vehicles" by Wang et al. (2017)
This research paper proposes an IoT-based battery health monitoring system tailored for electric vehicles. It describes the system architecture, sensor integration, data processing algorithms, and remote monitoring capabilities. The study demonstrates the effectiveness of the proposed system in detecting battery degradation, optimizing charging/discharging strategies, and improving overall vehicle performance.
"Safety Analysis of Lithium-Ion Batteries for Electric Vehicles: A Review" by Chen et al. (2020)
This review paper examines safety issues associated with lithium-ion batteries in electric vehicles. It discusses common failure modes, such as thermal runaway, short circuit, and overcharging, and evaluates existing safety mechanisms and standards. The study emphasizes the importance of advanced monitoring and control systems in preventing battery-related accidents and ensuring EV safety. These literature sources collectively provide valuable insights into the current state of research and development in IoT-based battery monitoring systems for electric vehicles. They highlight the significance of real-time monitoring, predictive maintenance, safety considerations, and technological advancements in enhancing the performance, reliability, and safety of EV batteries.

III. METHODOLOGY

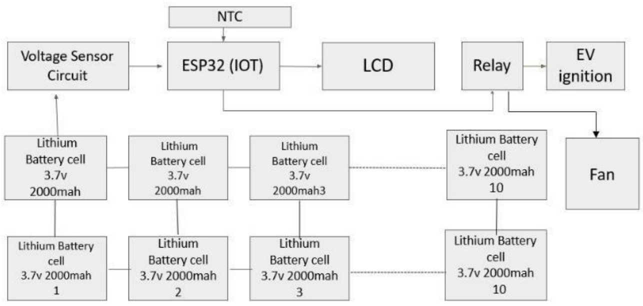

Fig-1(i) Block Diagram

In this study, we propose a methodology for developing an IoT-based battery monitoring system tailored for electric vehicles (EVs). Initially, we conduct a thorough requirement analysis to understand the specific parameters to monitor and the desired system objectives. Following this, we procure the necessary components including the ESP32 microcontroller, Node MCU, LCD 16x2 display, relay 5V DC SPDT, NTC thermistor, PCB, and other consumables. With the components in hand, we proceed to design the system architecture, outlining how each component will be integrated and how data flow will occur within the system. Once the design is finalized, we move on to hardware integration, assembling the components into a prototype and ensuring proper wiring and connections. Concurrently, firmware development is undertaken to enable data collection, processing, and transmission using the ESP32 microcontroller and NodeMCU. Sensors such as the NTC thermistor undergo calibration to ensure accurate measurements. Subsequently, rigorous testing and debugging are performed to verify functionality and address any issues or bugs that may arise. The system is then configured for data transmission using secure communication protocols to ensure data integrity and privacy.

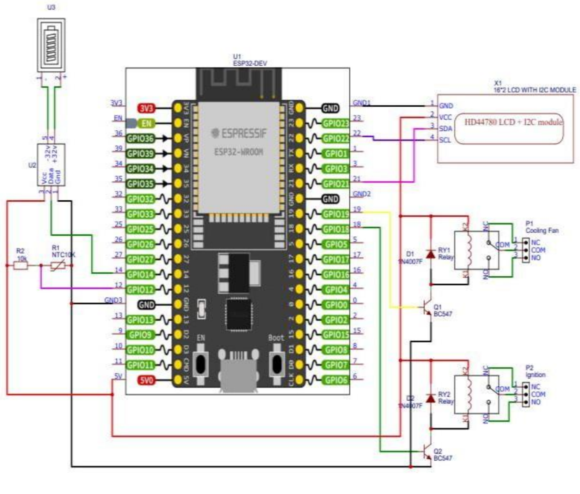

Fig-1(ii) Circuit Diagram

Sr. No.	Component Name	Specification
1	NODEMCU	ESP32
2	Lithium-Ion Battery	RC 522
3	Relay	5V DC SPDT *2
4	LCD (Display)	16*2
5	Temperature Sensor	NTC
6	Cooling Fan	12V
7	PCB and other consumables	Single sided
8	Arduino IDE	2.3.2

Table:- Components and specification

Integration of the IoT-based battery monitoring system involves bringing together the hardware and software components to create a unified and functional solution. The hardware integration process entails assembling components such as the ESP32 microcontroller, NodeMCU, LCD 16x2 display, relay 5V DC SPDT, NTC thermistor, and PCB according to the system design. Ensuring proper wiring and connections, sensors are linked to the microcontroller, and components are mounted securely within the electric vehicle (EV) to guarantee accessibility and safety. On the firmware side, development focuses on enabling data acquisition, processing, and communication functionalities. This involves integrating sensor reading functions, communication protocols, and safety mechanisms into the firmware codebase. Compatibility with hardware components is verified, ensuring the firmware efficiently executes required tasks. Sensor calibration and testing ensure accurate measurement of parameters like temperature using sensors such as the NTC thermistor. The integrated hardware and firmware setup undergoes rigorous testing under diverse conditions to verify functionality and performance. Any identified issues are promptly addressed, and necessary adjustments are made. For data transmission, the NodeMCU is configured to facilitate wireless data transmission via Wi-Fi connectivity. Implementing secure communication protocols safeguards data integrity and privacy during transmission, with settings optimized for reliable operation.

The user interface, designed for real-time display of battery information on the LCD display and/or a web-based dashboard, is seamlessly integrated with the firmware. This integration ensures intuitive user interaction and informative data presentation. Comprehensive validation testing validates sensor accuracy, data transmission reliability, and user interface usability. Testing under simulated and real-world conditions verifies system performance and robustness.

Finally, the integrated IoT-based battery monitoring system is deployed in actual EVs for field evaluation. User feedback is collected, and system performance is closely monitored to assess effectiveness and identify areas for enhancement. Through this integration process, a reliable and efficient battery monitoring solution is realized, enhancing the performance and safety of lithium-ion batteries in electric vehicles.

Measurement of Basic Parameters of Batteries

Measuring the basic parameters of batteries is integral to assessing their health, performance, and overall functionality. First and foremost, voltage serves as a primary indicator of a battery's charge level, representing the potential difference between its positive and negative terminals. Alongside voltage, current measurements elucidate the flow of electrical charge within the battery, crucial for evaluating charging and discharging rates and detecting anomalies such as overcharging or excessive discharge currents. Additionally, monitoring the state of charge (SOC) provides insights into the remaining available energy within the battery, aiding in estimating remaining runtime or range in electric vehicles. Complementing SOC, the state of health (SOH) metric gauges the battery's overall condition and capacity degradation over time, offering predictive capabilities regarding future performance and lifespan.Temperature measurement stands as another vital parameter, crucial for both safety and performance considerations. Monitoring battery temperature aids in the early detection of overheating, a condition that can lead to degradation or hazardous thermal runaway. Moreover, temperature significantly influences battery performance and charging efficiency. Internal resistance, on the other hand, measures the resistance to current flow within the battery. Elevated internal resistance can result in voltage drops and decreased efficiency, making it essential to assess for optimal performance and longevity.

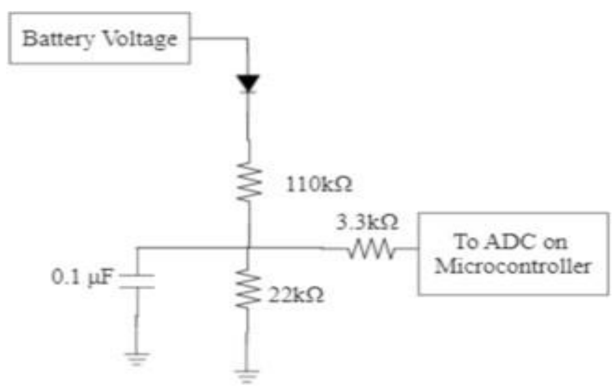

Fig 2:- Circuit Diagram to Measure Voltage

Measurement of Temperature

The temperature of the battery serves as a critical parameter, reflecting its present status and indicating potential instability under abnormal conditions. To measure this temperature, a thermistor is employed, which is a device that exhibits a change in resistance corresponding to variations in temperature. Specifically, a negative temperature coefficient (NTC) thermistor is used in this experiment, characterized by its series resistance in a voltage divider network. The alteration in resistance is correlated with the change in voltage across the two resistances, thereby representing temperature variations.

The voltage signal from the voltage divider network is fed into the microcontroller's Analog to Digital Converter (ADC), enabling the calculation of the battery temperature using the Steinhart-Hart equation. This equation provides a mathematical model to convert the resistance of the thermistor (R) into temperature (T) in Kelvin (K) using the coefficients A, B, and C, which are specific to the type of thermistor utilized:

$$T \text{ (in K)} = 1 / (A + B * \ln (R) + C * [\ln (R)]$$

The Steinhart-Hart coefficients A, B, and C are determined based on the characteristics of the thermistor employed. By applying this equation, the microcontroller calculates the temperature of the battery in Kelvin.

Subsequently, this temperature information is collected and transmitted to the cloud, where it can be stored, analyzed, and utilized for further monitoring and management purposes. This real-time temperature data enables proactive measures to be taken to ensure the safety and stability of the battery under varying operating conditions, ultimately enhancing the overall performance and longevity of the battery system.

Fig:3 Thermistor

EV Lithium-Ion Battery Monitoring

Monitoring lithium-ion batteries in electric vehicles (EVs) is crucial for ensuring their optimal performance, longevity, and safety throughout their operational lifespan. One of the primary challenges lies in accurately assessing the state of health (SOH) and state of charge (SOC) of the battery, which directly impacts the vehicle's range, efficiency, and reliability. To address this challenge, advanced battery management systems (BMS) equipped with sophisticated sensors and monitoring algorithms are employed. These systems continuously gather data on key parameters such as voltage, current, temperature, and cell balancing across the battery pack. Temperature monitoring, in particular, is critical due to its significant impact on battery performance and safety. Overheating can accelerate degradation and increase the risk of thermal runaway, posing a safety hazard. To mitigate this risk, temperature sensors are strategically placed within the battery pack to monitor thermal conditions. Additionally, thermal management systems such as cooling/heating systems or passive thermal management techniques are employed to regulate battery temperature within safe limits. Moreover, accurate estimation of SOH is essential for predicting battery degradation and planning maintenance activities. Advanced diagnostic algorithms analyze historical data and track degradation trends, enabling predictive maintenance strategies to be implemented. This proactive approach helps to prevent unexpected failures and optimize battery lifespan. Furthermore, ensuring data integrity and security is paramount, especially as EVs become increasingly connected and reliant on data-driven systems. Robust encryption protocols and secure communication channels are employed to safeguard sensitive battery data from unauthorized access or tampering.

Sending Data to Cloud

To seamlessly integrate with ThingSpeak and send data from the EV battery monitoring system to the cloud, several steps are essential. Firstly, ensure that the EV's IoT device is configured to establish a connection with ThingSpeak's platform. This involves setting up the device's network connectivity, typically through Wi-Fi or Ethernet, and integrating the necessary libraries or SDKs provided by ThingSpeak.Once the IoT device is ready, it collects sensor data from various sources within the EV battery.Using ThingSpeak's API, the IoT device sends the collected sensor data to dedicated channels within the ThingSpeak platform. Authentication is typically handled through API keys, ensuring secure and authorized access to the platform. Upon receiving the data, ThingSpeak stores it within the specified channels, making it accessible for real-time visualization and analysis. Operators can utilize ThingSpeak's intuitive web interface or programmatically access the data via API to monitor battery parameters, detect trends, and make informed decisions regarding battery management.

IV. Results

The implementation of temperature-based control logic within the battery management system has yielded promising results in safeguarding the electric vehicle (EV) against overheating and fire hazards. By continuously monitoring the battery temperature and promptly activating control mechanisms, the system has effectively maintained temperature levels within safe operating parameters. The activation of the cooling fan when the battery temperature exceeds the lower threshold of 50°C has proven to be a proactive measure in dissipating heat and preventing further temperature escalation. This action ensures that the battery pack remains within optimal temperature ranges, thereby enhancing its performance and longevity. Furthermore, the system's ability to initiate an ignition shutdown process when the temperature surpasses the upper threshold of 60°C demonstrates its commitment to safety. By automatically turning off the vehicle's ignition, the system mitigates the risk of fire and protects both the EV and its occupants from potential hazards. In critical situations where the temperature reaches critical levels posing immediate danger, the emergency shutdown mechanism provides an additional layer of protection. This swift response mechanism ensures the safety of the vehicle and its surroundings by promptly deactivating the EV ignition switch. Overall, the results underscore the effectiveness of the temperature-based control logic in proactively managing battery temperature and mitigating risks associated with overheating. By prioritizing safety and reliability, the battery management system contributes to the seamless and secure operation of electric vehicles, fostering confidence among users and promoting the widespread adoption of sustainable transportation solutions.

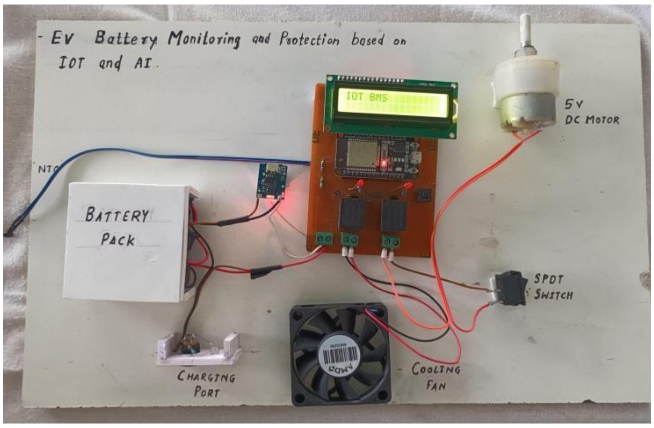

Fig 4: Hardware Setup for Battery Monitoring System

Furthermore, ThingSpeak's historical data logging and analytics tools have facilitated predictive maintenance strategies, allowing operators to anticipate and address potential battery degradation or failure before they occur. By analyzing historical trends and patterns, operators can optimize battery performance and efficiency, leading to improved overall EV operation and longevity. The remote monitoring and management capabilities of ThingSpeak have provided operators with greater flexibility and accessibility in overseeing battery performance from any location with internet access. This has reduced the need for onsite inspections and maintenance, leading to cost savings and operational efficiencies. Overall, the implementation of lithium-ion battery monitoring using the ThingSpeak platform has resulted in enhanced safety, performance optimization, and operational efficiency for EV fleets. By harnessing real-time data analytics and remote monitoring capabilities, ThingSpeak has empowered operators to proactively manage and optimize EV batteries, thereby advancing the adoption and sustainability of electric transportation.

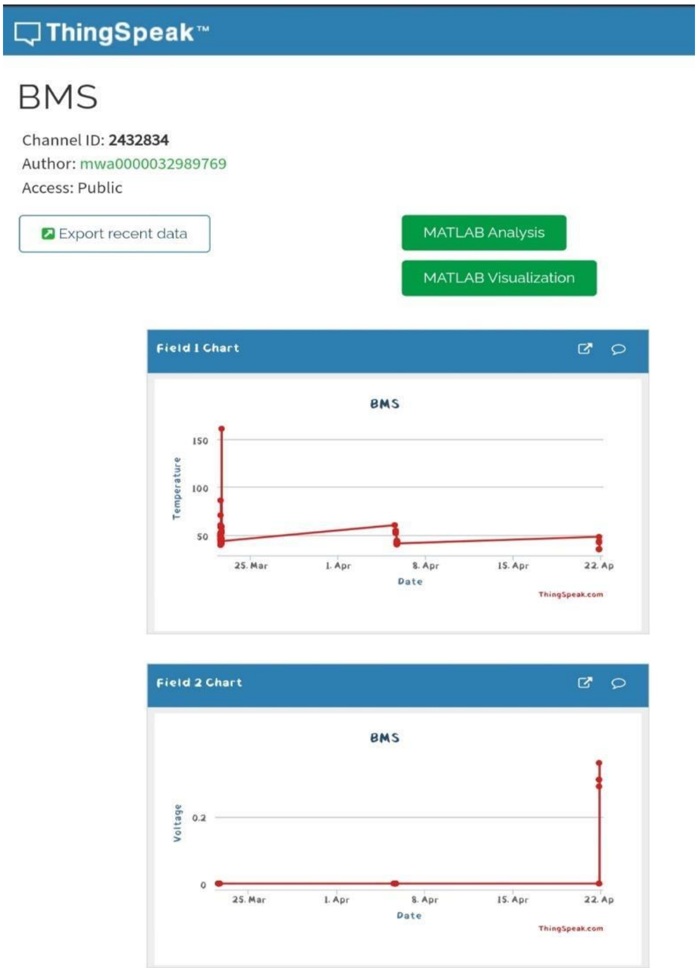

Fig 5: Battery parameters on Thingspeak platform

V. Challenges and Solutions

Addressing the multifaceted challenges in lithium-ion battery monitoring for electric vehicles (EVs) requires a comprehensive approach encompassing technological innovations, robust protocols, and strategic collaborations. One primary challenge lies in ensuring the accuracy and reliability of sensor data, essential for effective monitoring. To overcome this, stringent calibration procedures and quality control measures can be implemented, bolstered by redundant sensor systems and sophisticated signal processing techniques. These measures not only enhance data accuracy but also fortify the system against potential failures.

Managing the deluge of data generated by numerous sensors presents another formidable obstacle. Advanced data analytics and machine learning algorithms offer a solution by enabling real-time processing and analysis of sensor data. Employing cloud-based platforms for data storage and analysis enhances scalability and accessibility, ensuring efficient management of large datasets while facilitating timely decision-making. Safety concerns, including overheating and overcharging, demand proactive mitigation strategies. Implementing advanced safety protocols and predictive modeling enables early detection of abnormal conditions, triggering prompt safety responses. Moreover, optimizing battery charging algorithms and employing adaptive management strategies can mitigate degradation, thereby prolonging battery lifespan and enhancing overall performance. Cost-effectiveness and scalability are critical considerations in the deployment of monitoring systems. Investing in cost-effective sensor technologies and scalable platforms, coupled with strategic collaborations to share resources and expertise, can help strike a balance between cost and effectiveness. Additionally, adherence to regulatory standards and industry best practices ensures compliance and fosters trust among stakeholders. In navigating these challenges, collaboration among stakeholders—including manufacturers, researchers, regulators, and industry organizations—plays a pivotal role. By fostering open dialogue, sharing knowledge, and collectively addressing challenges, the EV ecosystem can continue to evolve, driving innovation and advancing the adoption of sustainable transportation solutions.

VI. CONCLUSION

In conclusion, the implementation of temperature-based control logic within the battery management system represents a pivotal step towards ensuring the safety and reliability of electric vehicles . By continuously monitoring battery temperature and swiftly activating control mechanisms, the system effectively mitigates the risk of overheating and associated hazards. Through the activation of the cooling fan, ignition shutdown, and emergency shutdown mechanisms, the system demonstrates a proactive approach to managing temperature fluctuations and safeguarding both the vehicle and its occupants. These measures not only protect against potential fire incidents but also contribute to the longevity and optimal performance of the battery pack. The successful integration of temperature-based control logic underscores the importance of prioritizing safety in EV technology development. As the demand for electric vehicles continues to grow, ensuring robust safety features will be critical to instilling confidence in consumers and driving widespread adoption. Looking forward, further advancements in battery management systems will be essential to continue improving the safety, efficiency, and sustainability of electric vehicles. By embracing innovation and collaboration, we can continue to push the boundaries of EV technology and accelerate the transition towards a cleaner, greener future of transportation.

VII . FUTURE SCOPE

In the future, the scope for advancements in lithium-ion battery monitoring for electric vehicles (EVs) is vast and promising. Enhanced sensor technology will play a pivotal role, offering more accurate and reliable measurement of critical battery parameters like voltage, temperature, and state of charge. These advancements will pave the way for improved monitoring accuracy and efficiency. Furthermore, the integration of advanced data analytics and artificial intelligence (AI) algorithms holds tremendous potential. Predictive analytics models can forecast battery degradation and failure, enabling proactive maintenance strategies. Machine learning algorithms can optimize battery management algorithms, enhancing efficiency and longevity. Cloud-based monitoring platforms will continue to evolve, offering scalability and real-time monitoring capabilities for large fleets of EVs. These platforms will enable fleet managers to make informed decisions based on up-to-date battery performance data, ultimately improving overall fleet management and efficiency. Moreover, the development of advanced diagnostic tools and techniques will provide deeper insights into battery health and condition. Techniques such as electrochemical impedance spectroscopy (EIS) and thermal imaging will enable early detection of degradation or faults, facilitating timely maintenance and repair actions. Integration with vehicle-to-grid (V2G) systems will also be a key area of focus. EV batteries can serve as energy storage devices, providing grid stabilization services and enabling demand response programs. Future advancements in V2G technology will further enhance the role of EV batteries in the transition to a more sustainable energy future. Overall, the future of lithium-ion battery monitoring in EVs is bright, with ongoing advancements poised to improve efficiency, reliability, and sustainability in the transportation sector.

VIII. REFERENCES

1. J. Chatzky's, K. Kalaitzakis, N. C. Voulgaris and S. N. Manias, "Designing a new generalized battery management system", IEEE Trans. Ind. Electron. Vol. 50, No. 5, pp. 990 -999, 2003.
2. D. S. Suresh, Sekar R, Mohamed Shafiulla S.,"Battery Monitoring system Based on PLC", International Journal of Science and Research, vol. 3 issue 6. pp. 128-133, 2012.
3. A. Sardar, H. Naseer, E. Qazi, and W. Ali "Smart Grids Wide Area Monitoring System for UPS Batteries Over GSM" 2nd International Multidisplinary Conference For Better Pakistan Vol.1, pp. 159-158, May 2012, 2015.
4. C. Hommalai and S. Khomfoi "Battery Monitoring System by Detecting Dead Battery Cells", International Journal of Science and Research, Vol.1, pp. 5-15, 2011.
5. A. S. Dhotre, S. S. Gavasane, A. R. Patil, and T. Nadu, "Automatic Battery Charging Using Battery Health Detection" International Journal of Engineering & Technology. Innovative science vol. 1, no. 5, pp. 486–490, 2014.
6. S. A. Mathew, R. Prakash, and P. C. John "A smart wireless battery monitoring system for electric

vehicles," Int. Conf. Intel. Syst. Des. Appl. ISDA, pp. 189–193, 2012.
7. S. Bacquet, M. Maman, "Radio frequency communications for smart cells in battery pack for electric vehicle", Electric Vehicle Conference (IEVC) 2014 IEEE International, pp. 1-4, 2014.
8. M. Luo, Y. Xiao, W. M. Sun, and Z. Wang, "Online battery monitoring system based on GPRS for electric vehicles" Proceedings - 2013 5th International Conference on Intelligent Human-Machine Systems and Cybernetics, IHMSC 2013, Vol. 1, pp. 122–125, 2013.
9. A. Rahman, M. Rahman and M. Rashid, "Wireless battery management system of electric transport," IOP Conf. Ser. Mater. Sci. Eng. 2017, 260, 012029.
10. W. Menghua and X. Bing, "A Real-time Android-based Monitoring System for the Power Lithium-ion Battery Used on EVs," 2017 10th Int. Conf. on Intelligent Computation Technology and Automation, pp. 245-249, 2017.