EV Battery Thermal Monitoring Using IOT BMS: A Review

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Abstract

The Battery Management System (BMS) is crucial to the Electric Vehicle (EV) as it ensures that the battery operates safely and efficiently. The BMS also allows for monitoring important battery parameters, including State of Charge (SOC), State of Health (SOH), voltage, current and temperature of each battery cell, and prevents overcharging and deep discharging to ensure battery life and mitigate fire accidents. In order to achieve the goal of enhancing battery safety, fire prevention is achieved thru use of sensors, software and IoT technology. Battery heat is monitored using temperature sensors and machine learning tools are used to anticipate battery life and possible battery failure situations. This system also records various parameters such as battery weight and current for helping to better understand system performance. Also, a cooling system is abided, which include Peltier cooling system to control the battery temperature within safe limits. As the demand for EVs continues to rise, these smart BMS and fire prevention systems significantly contribute to the safety, reliability, and longevity of EVs.

Keywords: Electric Vehicles (EVs), Lithium-Ion Batteries, Battery Thermal Management, Machine Learning,Battery Management System (BMS);

I. INTRODUCTION:

In today's rapidly growing electronics and electric vehicle (EV) industry, fault detection and safety monitoring have become extremely important. Among all the components of an EV, the battery is the most sensitive and critical part. Some important factors which mainly influence the performance and life of the battery include charging time, rate of discharge and operating temperature [6]. These parameters, if not monitored correctly, can cause loss in battery performance or the battery could become unsafe. The main concept of this work is to develop methods to detect battery fault in the EVs by utilizing the Internet of Things (IoT) technology to track relevant parameters such as current and voltage in real time [3]–[9]. Early detection of potential failure and unusual conditions can be achieved by continuously measuring the battery output.The mechanism of operation of a battery is that it transforms the chemical energy into electrical energy by electrochemical reactions. Apart from EVs, batteries are also being adopted in various other applications where uninterrupted and stable power is necessary such as UPS. Therefore, parameter monitoring of the battery circuits has to be carried out periodically to guarantee a trouble-free and uninterrupted production process. Conventional monitoring systems tends to have measurement errors and impact their accuracy and reliability. Therefore, smart monitoring systems are becoming crucial in modern industrial applications [5, 7, 8].The Battery Management System (BMS) is one of the crucial components in an electric vehicle. It monitors and controls the charging and discharging process in the battery pack to keep the battery pack safe, efficient and long lasting [4, 11]. The BMS monitors a range of parameters including voltage, temperature and State of Charge (SOC) to ensure that all battery cells are running within safe limits. Also, it is capable of ensuring data sharing with the vehicle system (V) and delivering data on the state of the battery and range of the vehicle [3], [9].

In addition, the BMS are also intended for a number of important safety actions. Cell Balancing is used to ensure that the equal voltage is kept between all the cells of the battery, thereby enhancing battery performance and life [11]. Thermal management systems can track the temperatures of batteries and adjust cooling systems to prevent thermal overload that in turn could compromise fire and/or explosion risk [2, 6]. Fault detection and diagnosis capabilities allow identifying abnormal behavior of the battery and warn the user of potential serious damage prior to the occurrence [1], [2].The battery component is one of the most critical parts in EVs where battery will not burn or be started by fire unless it is kept at a safe temperature. For safe use, the temperature of the battery should be kept at 20°C to 35°C. When proper cooling systems are used and accurate SOC monitoring is made, overcharging, overheating and over-voltage conditions are avoided [2, 6, 11]. These safety features enhance the safety of battery electrolyte ignition and the overall reliability of the EV battery system.

To wrap up, Battery Management Systems are crucial to ensure the safety, efficiency, and durability of electric vehicle batteries. Integrating vehicle-to-vehicle, vehicle-to-grid, or vehicle-to-infrastructure (V2X) communication and other sensor networks, as well as implementing fault detection and diagnosis, thermal management and fire protection strategies can lead to safer, smarter, and more reliable EVs in future transportation systems [1], [2], [3], [4], [5].

II. LITERATURE REVIEW

Y. Zhang et al. (2025) proposed a new deep learning-derived model to predict battery temperature of EVs batteries based on lithium-ion batteries [1]. Additionally, all techniques were integrated with the system including Convolutional Neural Networks (CNN), Bi-LSTM, and Attention Mechanism to enhance temperature prediction, identifying thermal runaway condition. The proposed CNN-Bi-LSTM-AM was able to deliver the correct results over traditional approaches like LSTM, CNN and ARIMA. It did manage to detect sudden increases in temperature and enhance battery thermal safety. The model, however, was found to be very compute-intensive with the need for large samples of training data, presenting a challenge in the implementation of an actual EV Battery Management System. Furthermore, the study did not take into account IoT integration and light embedded deployment.

A thermal monitoring and thermal fault detection system for lithium-ion battery packs was proposed by M. Naguib et al. (2025) that utilizes machine learning techniques [2]. The system included a Lumped Parameter (LP) thermal model, and a Feedforward Neural Network (FNN) to estimate battery temperature & detect thermal fault of cooling fan, airflow blockage and sensor fault. The model was used to continuously predict battery pack temperature based on the current, inlet air temperature and the State of Charge (SOC). During testing, the RMSE of the proposed LP+FNN model was 0.45°C to realize a high prediction accuracy of temperature and the fault detection accuracy of zero false alarm rate. However, the system is well suited and has been extensively tested in the laboratory, but has only investigated a single fault situation. The aging of battery and environmental effects in real world and various fault situations were not adequately covered.

To alleviate range anxiety and enhance battery monitoring, K. Sudheer et al. (2020) came up with an intelligent smart controller for EVs using the Internet of Things (IoT) [3]. The system was equipped with sensors which monitored the voltage, current, temperature and vehicle speed in real-time. The collected data from the hardware using the Arduino platform was sent to the cloud for remote monitoring, by implementing the following IoT technology. Additional features to enhance vehicle safety and efficiency supplemented the system, such as range estimation, battery cooling and auxiliary load control as well as alert systems. The test results indicated real-time monitoring of battery health, battery distance and battery temperature was successfully achieved. When the temperature of the battery approached a maximum safe value a cooling system was automatically turned on. On the contrary, there were no any machine learning techniques integrated for intelligent fault predictions and thermal runaways analysis.

Y. Xu et al., (2019) presented an electric bicycle Lithium battery management system based on the Internet of Things (IoT) [4]. A battery voltage monitor, current, temperature and charging control module monitored the battery during the entire process via IoT. The study can show enhanced real-time battery monitoring and battery protection. But neither was there any prediction about the advanced machine learning techniques to be used in the defect diagnosis.

Atzori et al. (2017) have introduced the concept and applications of Internet of Things (IoT) [5]. The study provided insight into how smart devices are all linked together in order to enable real-time, intelligent monitoring, automation and remote communication. The outcomes indicated that IoT technology enhances the communication system and remote monitoring features. The research presented, however, was not dedicated to the thermal monitoring or safety systems of EVs and did not analyze AI-based safety systems, specifically.C. Wu et al. (2015) investigated the effects of overcharging and over-discharging on lithium-ion batteries [6]. The paper covers the researching of internal resistance, the temperature of the battery, the voltage fluctuation and battery abnormal degradation. The results indicated that the charging current surpasses the critical value results in the battery temperature and thermal instability to overheating and failure of the battery. While the study recognizes that BMS is essential, the ability to intelligently predict battery temperature and detect battery faults using machine learning is not explored in the study.

Miguel López-Benítez et al (2017) introduced a smart monitoring framework based on the IoT concept to be used in applications with smart monitoring [7]. The system utilised sensors, wireless communication, and cloud-based solutions to enable real-time monitoring and data collection. Results confirmed reliability of communication and the efficiency of the monitoring. The work however, did not address electric vehicle batteries or thermal prediction methods.

O. A. Mohamad, et al. (2016) designed a wireless communication and a real-time tracking and monitoring system, which was equipped with an Arduino Intel Galileo board [8]. The remote monitoring and communication of sensor data was ensured to be successful. The study doesn't, however, incorporate EV battery safety and thermal management machine learning techniques or applications.

Asaad et al. [9] proposed an IoT supported Electric Vehicle battery monitoring system. The system is able to monitor real-time data of battery as voltage, current, temperature, and charging condition with IoT technologies. The outcome revealed enhancement in the capability of battery monitoring and capability of fault identification. The system, however, did not include predictive thermal monitoring and intelligent machine learning based fault diagnosis.The future demand for Battery Safety, Reliability and Optimization necessitated the choice of Battery Management System (BMS) & fire prevention systems for EV batteries. This electric vehicle battery provides ample energy and is very sensitive to various situations including overcharging, overheating, and shorts, potentially causing thermal runaway or fire incidents [1, 2, 6]. Thus, sophisticated BMS systems are needed that have the ability to continuously monitor critical battery parameters like voltage, temperature, the State of Charge (SOC) and the State of Health (SOH) [4], [11].

Another key motivation is the enhancement of battery reliability and efficiency. The key advantage of a well-designed BMS is it can control charging and discharging processes, balance the battery cells, and reduce their exposure to excessive current, undervoltage, and over voltage situations [4], [11]. This increases the battery's lifespan, vehicle performance and range. The thermal management systems are also designed to keep the battery temperature within safe limits that minimizes the risk of overheating and fire hazard [2, 6].

Moreover, the innovation and technological modernization of EV systems is the motivating factor of the project. By combining the IoT technology with machine learning algorithms, the combination of intelligent thermal monitoring, predictive fault diagnosis and real-time remote monitoring of battery systems can be achieved [1, 2, 3, 5]. These sophisticated systems can enhance EV safety, reliability and efficiency in maintenance. Besides, adhering to international safety standards and becoming environment friendly is another strong factor behind designing advanced BMS and fire prevention systems. As EVs are perceived as a cleaner, more sustainable option in the transportation industry, optimizing battery safety and efficiency can help pave the way for future EV adoption [5].

III. METHODOLOGY

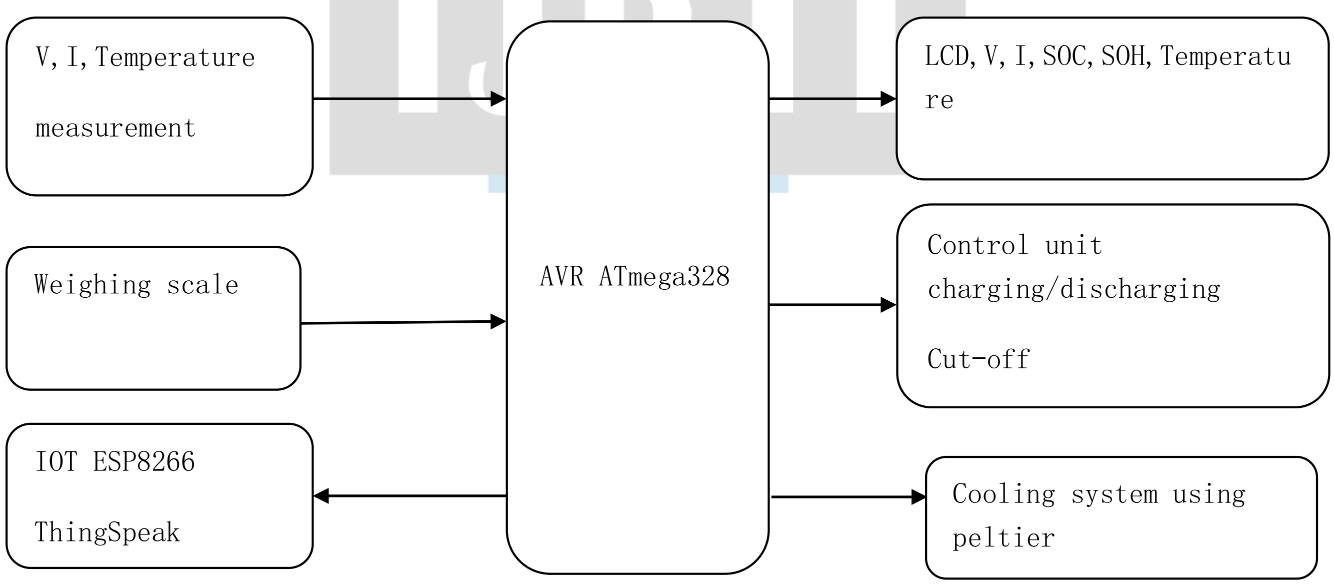

Figure 1.Block Diagram of EV battery Monitoring IOT BMS system

Battery Management System (BMS) is among the most important components of Electric Vehicles (EVs) since it enables the battery pack to be operated safely and effectively. It keeps a real-time monitoring of battery information like voltage, current, temperature, State of Charge (SOC), battery health, etc. The BMS also performs equalization operations on all the cells to check for battery overdischarging and deep discharge causing battery prematurely becoming old, and could even lead to overheating or give rise to battery fire accidents [6]. In addition to the BMS, a fire detection and control system is also critical for EVs to monitor potential sources of fire and implement protective safety features through sensors, software, and other safety measures. These advanced battery monitoring and fire prevention systems are crucial for maintaining safe and reliable EVs as their adoption is growing at a fast pace.

The intended system is going to keep tracking and in real-time store battery important parameters like voltage, current, battery charge and remaining battery capacity. Communication and remote monitoring is carried out with the help of Wireless Local Area Network (WLAN) and IoT technology. Continuous analysis of the collected data from the battery system detects abnormal behaviour of the battery, sudden charging and discharging conditions, or battery faults. Using the system, users can access battery performance data remotely via an IoT platform. When battery temperature is sensed to be above a pre-programmed value, the output from the battery is automatically disabled, and a battery cooling system is activated to prevent battery over-temperature conditions and risks of fires.

The planned protection and management of the battery system seeks to enhance both safety and performance of EVs. It is based upon the IEEE 2993 standard which gives guidelines on the safe analysis and operation of battery management systems in electric vehicles and hybrid vehicles. The BMS keeps a continuous monitor of voltage, current, temperature, SOC, and battery condition and State of Health (SOH). This information is shown on an LCD panel and IoT dashboard for real time monitoring. Besides this, machine learning is also applied to predict battery life and give more intelligent analysis for battery performance.The BMS will also maintain a balance of charging and discharging for all battery cells, further ensuring battery health and improving battery life. The fire prevention system monitors battery temperature and smoke levels in order to detect early on any potential fire problems. The system then automatically disconnects the faulty battery section and takes steps to prevent the fire from spreading if any abnormal condition is found.

In summary, the proposed battery management and fire protection system will significantly enhance the safety, intelligence, and reliability of electric vehicles. The battery health monitoring system will continuously track the health of batteries, predict battery life, control battery temperature and prevent fire hazards, thereby enhancing the overall safety, performance of EVs and giving users a safer driving experience.Show a photocopy of the hardware in question (Fig.2).Show a photocopy of the hardware that is being discussed (Fig.2).

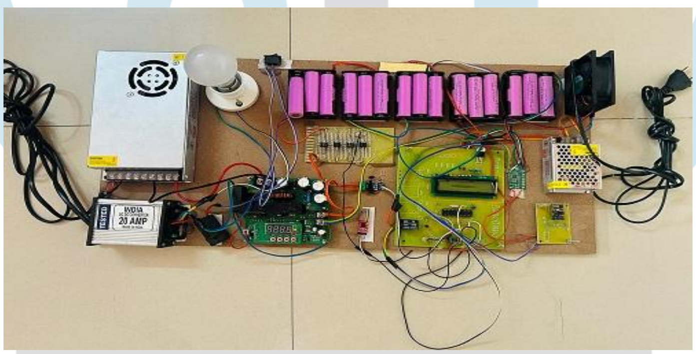

Figure 2. Photocopy of Internal setup of proposed System

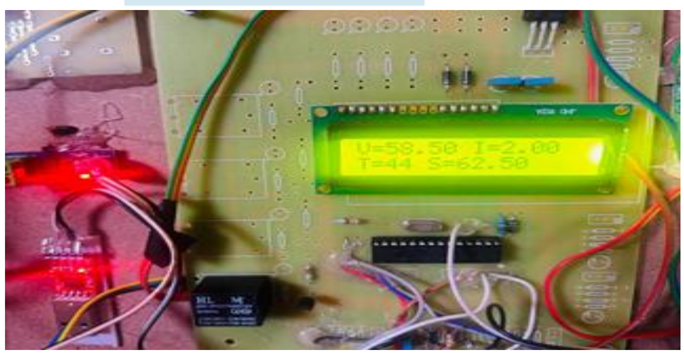

Figure 3. Photocopy of Results

The results of proposed systems which shows the voltage,current,temperature and SOC .And these values are sent it to ThingSpeak. The ThingSpeak screenshots are shown in below photocopies.

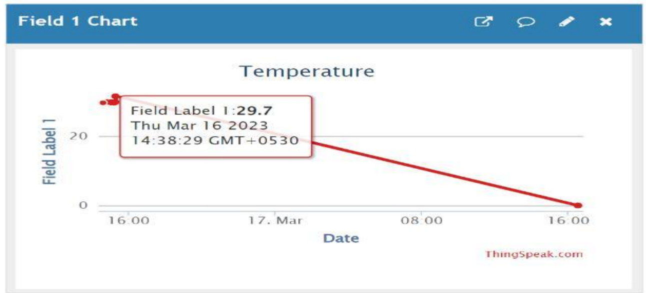

Figure 4. Photocopy of temperature graph using IOT

When the parameter is battery temperature, the graph would display the current temperature of the battery pack at different time points. It would show how the temperature changes over time, indicating the current temperature status of the battery as shown in the figure and when the overheating occurs an alert will be triggered based on the graph values.

Figure 5. Photocopy of SOC graph using IOT

Likewise, for a given parameter, this graph will depict the SUP of charge in the pack as a function of time. It would display the current SOC value at particular time as shown in figure 5 and as the SOC value changes due to charging and discharging the graph would reflect the change instantly.
It may also indicate any trends or patterns of changes in values of SOC in the graph, which can provide clues to the behaviour of the battery when it is charging or discharging. For example:

Charging Events: This graph might include data points representing the SOC when the battery is being charged, which can help identify what stages of the charging process the battery is at and how the SOC is progressing.Charging Events: This graph could contain SOC data during charging events, showing the stage and progression of the charging process. It may also display the SOC values during the discharging period to indicate the amount the battery is being discharged, and change the SOC value whilst the EV operates.

SOC Fluctuations: The graph indicates the changes in the SOC levels while driving, including changes in driving conditions, regenerative braking, and other factors influencing the charge level of the battery. These variations may be able to be identified to determine the pattern of energy usage associated with the EV (and accordingly, driving or charging behavior).
Charging and Discharging Efficiency: The graph gives an estimation of how efficient a charging and a discharging process is by measuring the amount of energy put in while charging and the amount of energy produced while discharging. This can give insight in the overall charging-discharging efficiency and lead to optimisation of charging strategies for enhancing battery performance and prolonging battery life.
The graph can give real-time information regarding the SOC of the battery; for EV operators, this could allow them to decide when and how to charge the battery, make driving manoeuvre planning decisions, and optimise energy consumption. It will also serve as the sensor to identify any anomalies in SOC, like overcharging or battery going too deep in discharge and will alert or alarm battery management system in the IoT system for immediate action. An IoT-based BMS can help to optimize the energy use of such an EV to offer a longer battery life and reliable, efficient operation of the battery SOC.

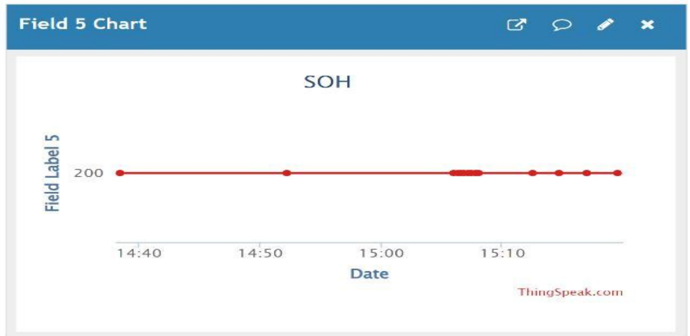

Figure 6. Photocopy of SOH graph using IOT

When the parameter being measured is SOH, the x-axis of the graph represents time, while the y-axis represents the SOH of the battery pack, typically expressed as a percentage. The graph as shown in figure 6 may display the historical SOH values of the battery over time, showing how the battery's health changes and degrades as it undergoes usage cycles and aging.

IV. CONCLUSION

This proposed system highlights the importance of EV battery thermal monitoring using machine learning to enhance safety, reliability, and battery lifespan. The integration of IoT-based sensors enables real-time monitoring of key battery parameters such as temperature, voltage, current, SOC, and SOH. Machine learning techniques provide predictive analysis for early fault detection and battery life estimation. The use of a Peltier-based cooling system helps maintain safe operating temperatures and prevents thermal runaway. Overall, the proposed approach offers an intelligent and proactive solution by using machine learning libraries such as OpenCV,TensorFlow,pySerial for advanced battery management in electric vehicles.

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