

REAL-TIME BATTERY HEALTH ESTIMATION AND PROTECTION SYSTEM FOR ELECTRIC VEHICLE APPLICATIONS

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Abstract - With the proliferation of Electric Vehicles (EVs), the requirements for advanced battery monitoring and safety solutions are growing. They use lithium-ion batteries, which have high energy density and long life. However, inadequate supervision of battery indicators can lead to waste in battery efficiency and safety issues (Bang et al., 2020). This paper proposes real-time battery health estimation and protection system as a solution which continuously monitor the battery parameters and detect the abnormal operating conditions. The processing unit processes input sensors of voltage, current and temperature using a microcontroller. At that point, it can become an accepted approach to run analysis on this data and determine the battery state of health (SOH) and state of charge (SOC). Overheat, overcharge, and deep discharge are examples of critical conditions detected from a protection scheme implemented. It responds without any user input, putting protective measures in place (i.e., autonomously shutting down the battery in extreme cases) as soon as abnormalities are detected. This system helps improve safety, monitoring accuracy and reliability of the battery operation. Some of the EV applications have confirmed the efficiency in monitoring battery parameters and prolonging life cycle as their prerequisites.

Keywords: *Electric Vehicles, Battery Management System, Battery Health Monitoring, State of Charge, State of Health.*

I. INTRODUCTION

EV is one of the biggest panacea to counter greenhouse gas emissions and dependence on fossil fuels. Pretty much everything about an EV why it has the range, performance and safety that it does relies on its battery systems, which is what makes this a crucial aspect of the car. Electric vehicles use lithium-ion batteries because of their high energy density, low self-discharge and long cycle life. Although lithium-ion batteries represented a breakthrough, they have a limited operating life and are sensitive to environmental and operational conditions like extreme heat, filtering or deep discharge. Those conditions could promote battery degradation and pose safety risks. As a result, the battery systems' real-time monitoring and protection system is critical to guarantee the reliable running of electrical vehicles (EV) usages. Designed for monitoring the parameters of a battery and preventing the violation of its safety limits, Battery Management Systems (BMS) can also be used in reference to an embedded control system. Modern BMS architectures incorporate concepts for real time battery monitoring, prediction of battery state and fault detection all towards improving the safety and performance of batteries. This paper describes a System for estimating as well as protecting the real-time health of batteries by monitoring parameters like current, voltage, temperature. It tracks the battery health and also monitors the operating conditions for safety as well.

II. LITERATURE REVIEW

Lithium-ion batteries are among the most extensively utilized of all types of battery for use in electric vehicles because they have high energy density, long cycle life and rather good energy storage efficiency. However, battery monitoring systems are crucial for maintaining the safety and performance of batteries. Even beyond that, Battery Management Systems (BMS) are used in batteries to measure parameters such as voltage, current & temperature so as to ensure the safe operation of batteries. BMS has been found to be an essential component in electric vehicles, performing an important task maintaining battery stability and preventing possible faults Zhang-lee [1]. SOC Estimation — The SOC has to be both reliable and accurate so as to help in using the battery accurately well so that it can maintain a balanced regime with energy. In this context, several researchers proposed SOC estimation methods based on mathematical model and data analysis for SOC estimation [30–36]. He et al. The SOC estimation approaches brought up in [2] have been widely accepted for use in lithium-ion battery data from dynamic situations. Similarly, Pillar et al. [3] reviewed SOC estimation methods and their role in battery performance monitoring. Another critical element of battery monitoring is the State of Health (SOH), which indicates the overall state and aging status of a given device. Berecibar et al. State of the art [4] discussed SOH estimation methods, and emphasized more efficient battery health diagnosis tools to increase their life. Research by Xiong et al. The authors also examined battery degradation modeling and state prediction according to electric vehicle applications in [5].

Things like battery safety control systems — including pack temperature monitoring and thermal management. Barre et al. Temperature changes can be a critical cause of degradation. [6] also discussed the aged mechanism of lithium-ion batteries. Santhanagopalan et al. [7] studied the modeling methodologies of battery performance and focused particularly on temperature and operating conditions that influence battery behavior. Recent efforts had focused on the synthesis of online monitoring systems incorporating embedded hardware and sensor technologies. Liu et al. The methodology proposed by Ref. [8] continue developing battery health monitoring techniques for electric vehicles equipped with real-time data collection hardware. Similarly, Wang et al. A 16-year-old article [9] proposed smart battery monitoring systems with abnormal destination detection capabilities for batteries. Recent research has specifically concentrated on diagnostic methods and battery management strategies that can contribute to the safety and reliability of EV batteries [10]-[15].

III. PROBLEM STATEMENT

Electric Vehicles: Electric vehicles (EVs) use lithium-ion batteries for energy storage and vehicle operation. But the more important key battery life determinants are overcharging, deep discharge, overheating and aging. Yet the right monitoring and control over these conditions is missing, making battery degradation possible which leads to reduced efficiency along with privacy and safety issues. Moreover the traditional battery systems are not able to provide real time accurate information regarding state of health so making early fault diagnosis of batteries increasingly difficult. And there would be no effective way to estimate key battery parameters like State of Charge (SOC) & State of Health (SOH). When you get these parameters wrong, you end up with much higher energy consumption and shorter battery life. Poor protection schemes could also expose the batteries to harmful working conditions. Therefore, developing a real-time battery health estimation and protection system to monitor the critical parameters of battery in real time, identify exact state-of-health (SOH) of battery as well as diagnose faults is crucial. The system is able to enhance battery safety, performance resiliency and service life.

IV. PROPOSED SYSTEM

The battery tracking system helps to get the health of batteries in real time as it can monitor the required parameters regularly. Proposed System is illustrated in Fig which includes sensor module, microcontroller processing unit, monitoring and protection module, display interface and protection relay. 1.

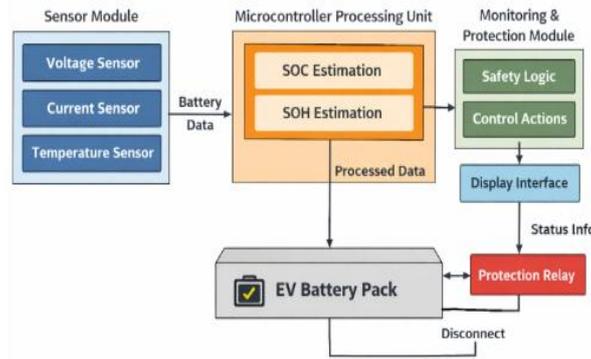


Fig 1. Block diagram of the proposed battery health estimation system

Sensor Module : It takes care of monitoring the critical battery parameters like voltage, current and temperature. The sensors continuously check the usage status of the battery and send this information to processing unit inside microcontroller. The good measure of these factors is critical to evaluate the battery performance and detect abnormal conditions. Processing unit of this system is Microcontroller. It gathers sensor data, processes it to estimate key parameters related to battery health like State of Charge (SOC) and State of Health (SOH). With SOC being state of charge and SOH still left in life battery. It then keeps an eye on whether the battery stays within safe levels considering those parameters. Next, it will use the processed data to apply safety logic and determine if there are possible out of normal operating conditions (for example hot, too much charge or discharge current). The system acts accordingly when such events gets spotted. It displays battery health in real time and shows the parameters of all the batteries easily. Furthermore, system also has a protection relay to disconnect load from battery in case of unsafe conditions. Beyond protecting your battery from damage, preventing such an incident can also help make vehicle battery systems safer and more reliable.

V. SYSTEM ARCHITECTURE

A. Sensor Module: Real-time battery parameters are collected with the help of the sensor module. All the voltage, current and temperature sensors that continuously monitor the operating condition of an EV battery collectively form an EV battery management system (BMS). These sensors provide specific information that is essential for monitoring and health estimation of the battery.

B. Microcontroller Processing Unit: Microcontroller is the core of the system. Battery management system: It is a component of battery that accepts sensor data and processes them to provide estimation for various parameters of battery such as State of Charge (SOC) or State of Health (SOH). It also executes control algorithms to monitor battery performance and faults.

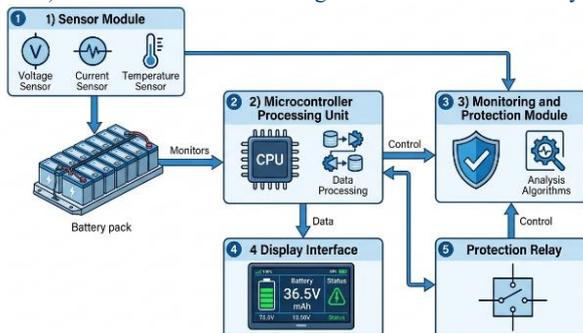


Fig 2. System Architecture of the Electric Vehicle Battery Management and Protection System

C. Monitoring and Protection Module: This sub-system/ module monitors battery parameters and uses safety algorithms to identify incorrect conditions such as overheating, over charging or deep discharge. The system generates control signals for hazardous conditions for protective actions.

D. Display Interface: The display interface displays various battery parameters (including voltage, temperature and battery-status) in live-action. It saves some pain to check the state of battery for end-users or system operators.

E. Protection Relay: The protective relay acts as a safety controller. Based on your input, here is the sentence with a human style: The relay isolates the battery from load or system to prevent damage and provide safe operation under abnormal conditions like as detected by monitoring module.

VI. METHODOLOGY

The proposed system explained: This paper proposes a method for battery state monitoring including safety through continuous data acquisition, processing, estimation of battery condition and protection systems. In this way, in real time, the battery parameters are acquired and evaluated to estimate health indicators while a safety control is activated if abnormal conditions exist.

A. Data Acquisition: It works on many steps, where in the first step get measures of the parameters of battery through sensors. Determining the operating condition of EV battery pack using voltage, current and temperature sensors as indicators It is known as battery management system which keeps a vigil on the battery and monitors its performance in real-time. This measurement is fed to the microcontroller for further processing. Data acquisition is crucial for the performance of battery monitoring and health estimation.

B. Data Processing: Data acquisition is followed by data processing, where the microcontroller processes the collected sensor data. The microcontroller serves as a first filter on the data and interprets the battery parameters. The values are compared with threshold limits for battery operation. This processing step provides fast determination of false values (e.g., too much temperature or incorrect voltage levels).

C. Battery Health Estimation: Battery health is determined from parameters such as SOC, SOH, etc. SOC is state of charge, which indicates how much battery power remains and what energy reserve can be used to propel the vehicle. SOH tells you how healthy the battery is compared to its factory capacity. The system monitors battery health and performance, shortens its life cycle using State of Charge (SOC) and State of Health (SOH) statistics.

D. Protection Mechanism: It is a auto-protective mechanism that triggers the sacrifice battery protection and system into safety without any consumption. There is a possible protective measure due to abnormal conditions in the system—for example, heating of lithium-ion cells, overcharging or excessive discharge. The management interface can produce warning alarms and/or a protection relay disconnects the battery from the load. This mechanism protects the battery from irreversible damage, which increases electrochemical safety and reliability of EV battery system.

VII. RESULTS & DISCUSSION

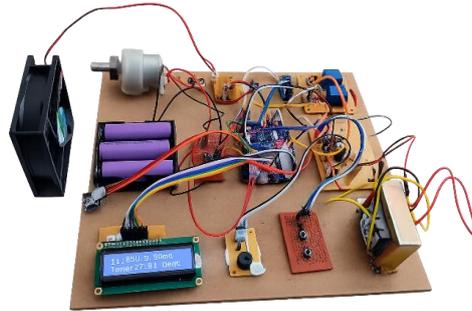


Fig 3: Hardware Prototype of the Real-Time Battery Health Estimation and Protection System

The proposed Real-Time Battery Health Estimation and Protection System was implemented with a hardware prototype composed of a battery pack, sensors, microcontroller, relay module, and display interface. Fig. The developed hardware setup is shown in Fig. 1. 3 show each of the components soldered on a prototyping board. During the operation of the system, measured battery voltage and temperature values were visible on an LCD display connected to the microcontroller.

Therefore, in the experimental setup battery voltages were accurately recorded by the voltage sensor and also monitored battery temperature during runtime to avoid overheating. A microcontroller would run a test that involves obtaining sensor data, processing that data and attempting to estimate additional battery health metrics such as State of Charge (SOC) and State of Health (SOH). The protection relay cut the battery off from load when either temperature or voltage exceeded their limits, allowing for safe operation of the whole system.

In addition to the hardware monitoring system, a battery health monitoring dashboard was developed to display parameters and state of the battery system. The dashboard interface (Fig. For that reason, 4) was used to provide elements of protection status indicators and real-time measurements of battery voltage, current, temperature, SOC and SOH.



Fig 4: Battery Health Monitoring Dashboard Interface

Battery voltage 36.5 V, current 5.2 A and temperature 32degC— all within normal operating ranges as they also show on the dashboard. The SOC reads roughly 74% state of charge while SOH shows a good lithium battery health at 86%, indicating it is running fine with low degradation. There are also alarm indicators in this dashboard, which will alert the user in case of temperature overheating or voltage surge.

To sum up the overall outcome of the experiment is that this proposed system can perform real time online battery parameter monitoring, evaluate prediction capability in term of health state along with presenting visually through dashboard simulation interface. The hardware monitoring is integrated with the dashboard visualization for both assisting battery management and maintaining operational safety to prevent uncontrolled internal faults and hazards during further enhancement of early diagnosis capability of potential battery jail inside EV deployment.

VIII. CONCLUSION

One study briefly discussed a Real time Battery health estimation and protection system for Electric Vehicle Applications. It monitors important battery parameters such as voltage, current, and temperature using sensors and evaluates this data through a microcontroller to determine the SOH (State Of Charge) and SOH (State of Health). □ A proof of concept hardware prototype was created with the goal to showcase: -- Battery monitoring and safety protection in a real-time fashion. It is commonly used in electric vehicles, the relay takes measures when the condition is abnormal and cut off the battery to avoid damaging. Table of Contents. However, this based approach is suitable in the electric vehicle applications as it would eliminate the above shortcomings of conventional battery management improving overall battery safety and reliability.

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