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Artificial Intelligence-Powered Electric Vehicle's Battery Management System with IoT

Nageswara Rao Gali[1], Singamaneni Krishnapriya[2] , G. Kirubasri[3] , Mahendra T. Jagtap[4], A. V. G. A. Marthanda[5], Mohammad Shahid[6]

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Abstract: As a key part of electric vehicles, batteries are the maximum important parts of electric vehicles because of their charging and discharging functions.They supply the electricity that drives the vehicle's motor. A vehicle powered by electricity could not function without batteries. The vehicle fails to operate smoothly if the batteries aren't functioning properly. The current and voltage variations affect the battery system.So we cannot predict the accurate voltage and current measurement. The objective of this study is to observe and optimise the efficiency of battery energy management systems (BEMS) by using the Internet of Things (IoT) and Artificial Intelligence (AI). Additionally, the research aims to investigate strategies for effectively managing batteries in electric cars. Lithium-ion battery used in this system because of greater energy density compared to other conventional batteries. The costliness of batteries in electric vehicles offers significant opportunity for the enhancement of battery State of Health (SOH) and State of Charge (SOC) predictions via the use of AI-Powered Cloud Services. This improvement aims to enhance cost-effectiveness and durability. A system driven by artificial intelligence and hosted on a cloud platform has the capability to adapt to evolving changes in battery health resulting from operational conditions. It then provides updated information to the battery management system, enabling it to make continually improved management choices. The neural network algorithm is built using a Python script. Node-RED designed the user interface and login for the web server. Concerning embedded devices, sensors, and mobile apps, the Internet of Things plays a significant role. MQTT is a reasonably lightweight messaging protocol.

Keywords: *Battery management system (BMS), embedded system, IoT, notification, messaging protocol*

1. Introduction

The monitoring of battery life, charging and discharging processes, and the operating system necessitates the implementation of a battery management system (BMS). Instruments used for quantifying physical quantities such as temperature, electric current, and battery potential difference are included under this category. The analysis of these characteristics enables the assessment of the battery's state of charge (SOC) and state of health (SOH). The reliable and safe functioning of lithium-ion batteries in electric vehicles necessitates the use of online monitoring and status assessment techniques. The use of a battery monitoring system enables car owners and service providers to conveniently assess the condition of their vehicle's batteries, regardless of their location or time constraints. Before a failing battery threatens to deplete the other good, it may be immediately discovered and replaced. The battery management system (BMS) oversees and manages the attributes of individual cells inside the battery pack via continuous monitoring. The capacity of the battery pack exhibits variation among individual cells and has an upward trend as the number of cycles involving charging and discharging increases.

As a result of advancements in notification system design, the use of Internet of Things (IoT) technology has become prevalent in providing manufacturers and customers with information on the status of batteries. This practise may be regarded as a recommended regular maintenance procedure as suggested by the manufacturer. The Internet of Things (IoT) facilitates the connection of diverse devices and commonplace objects to the Internet, hence expanding the scope of internet connectivity beyond traditional applications and giving users unprecedented access to global resources.

Electric vehicles (EVs) have become a viable option for environmentally friendly transportation. The restricted

[1]Department of Information Technology, Aditya Institute of Technology and Management,Tekkali, K Kotturu, Andhra Pradesh 532201,India. Email : gnraoaitam@gmail.com
[2]Department of Computer science / Data science, VNR Vignana Jyothi institute of Engineering and technology, Hyderabad, Telangana 500090,India. Email : singamanenikrishnapriya@gmail.com
3Department of Computer Science and Engineering ,Sona College of Technology, Salem-5. Email:kirubasri.cse@sonatech.ac.in
[4]Department of Computer Engineering , PVG's College of Engg & SSDIOM Nashik (SPPU Pune University), Nashik, Maharashtra 422004,India.Email: mtjagtap05@gmail.com
[5]Department of Electrical and Electronics Engineering,
[5]LakiReddy BaliReddy college of Engineering, Mylavaram, Andhra Pradesh 521230. India. Email: myenergysai4u@gmail.com
[6]Department of Electrical Engineering.
Galgotias College of Engineering and Technology, Greater Noida, Uttar Pradesh 201310,India, Email : eems.j87@gmail.com

travel range of EVs, which is reliant on the size and condition of the battery, is one of their biggest drawbacks. Therefore, it is essential to keep an eye on the battery's condition to maintain the safe and effective operation of EVs. The Internet of Things (IoT), which can enable real-time monitoring and remote device control, has recently attracted a lot of attention in several industries, including the automotive one. IoT integration in EVs has the potential to boost user-driving satisfaction while also enhancing battery performance and economy. This paper proposes the implementation of an Internet of Things (IoT)-based battery monitoring system specifically designed for electric vehicles. Battery sensors, a microprocessor, a wireless connection module, and a cloud server make up the system. The battery sensors collect data on the battery's voltage, current, and temperature and transmit it to the microcontroller. Data is processed by the microcontroller and sent to the cloud server through the wireless connection module. The data is saved on the cloud server, where it is analyzed to reveal information on the battery's condition. The suggested solution offers real-time monitoring of the battery's condition, allowing for performance optimization and extending battery life. Additionally, the system's data may be utilized to forecast the EV's remaining range, which can aid the driver in more effectively planning their route.

2. Related Work

Dettlaff and colleagues (2020) suggested Electrochemical methodologies, including as differential pulse voltammetry, direct current voltammetry, square wave voltammetry, and cyclic voltammetry, may be used for the detection and analysis of pyrotechnic compounds present in aqueous solutions. The potential reduction in size of the sensor may be attributed to the very quick, simple, and cost-efficient enhancements that have been developed specifically for practical and field implementations. Electrochemical techniques refer to a set of scientific methods that include the study and manipulation of chemical reactions that occur at the interface between Various approaches, including as differential pulse voltammetry, direct current voltammetry, square wave voltammetry, and cyclic voltammetry, may be used to detect pyrotechnics in aqueous environments. Due to the rapidity, simplicity, and cost-effectiveness of these developments in practical and field applications, there is potential for downsizing the sensor.

Venkata Anjani Kumar G et al. (2023) The concept was elucidated. The growing use of electric vehicles (EVs), which are nonlinear devices, is resulting in a rise in harmonics throughout the electrical grid. The use of shunt active power filters (SAPF) using the Particle Swarm Optimised Artificial Neural Network Controller (PSO-ANN) enables the mitigation of harmonics and enhancement of power quality inside distribution networks.

Zaide et al. (2019) concluded that the spallation of the negative silicon electrode during discharge operations has a significant impact on its long-term performance. During the charging stage, only the first occurrence of induced simultaneous spoliation and delamination was seen. This illustrates the connection between capacity loss and emission energy and, subsequently, the severity of damage.

Hwang et at (2019) discussed the usage of frameworks with the highest force utilization will be significantly reduced by technology. Reduced information thickness and sign results from decreased hub detecting inspection rate and transmission capacity, which may lengthen battery life.

Aissaet at (2019)the need for ongoing biochemical monitoring remains allowing for potentially instantaneous, unobtrusive patient monitoring and important insights about their welfare and prosperity. Without test sanitization, the electrical examination assessment might be done properly on the spot. This enables wearable, lightweight, purpose-of-care identification to support numerous studies and mathematical computations.

Izumi et at (2019)The whole information current range seen in the transient reaction is demonstrated via a variety of anode/sensor configurations. The device can produce several common electrochemical incitement waveforms as well as discretionary waveforms in equal and unrestricted channels evaluated while streaming.

Zhai et at (2019) Blood glucose monitoring is used for organic research, food production, and clinical testing. The presence of the tiny flower on molybdenum has the potential to enhance the electrochemical performance of the glucose sensor, resulting in improved electronic conductivity and enhanced electrocatalytic activity of the noble metal. Consequently, it has been shown that by using Au and molybdenum as electrochemical anodes, multiple concentrations of glucose may be detected in a phosphate-buffered saline solution. Preliminary data indicate that gold and molybdenum electrochemical cathodes exhibit greater reaction currents and electro-catalytic activity when compared to the two kinds of anodes.

According to Kashyapet (2019), Electrochemical detection is a cost-effective, expeditious, highly responsive, and discerning approach for measurement. Enzymatic and electro-oxidation-based electrochemical sensors have both been created for the same purpose. The dependent enzyme mono oxygenate salicylate hydroxylase has been shown to have a catalytic mechanism for converting salicylate into catechol. Numerous additional sensors, such as the electrochemical ones that use catechol as one of the reactants and are based on the enzyme salicylate hydroxylase, have been created.

Mithulkiruthik et at (2022) The SOC and SOH are thought to be crucial components of the BMS. The battery used in all.If this method is used in EVs, EV segments will last longer. The work makes use of Internet of Things (IoT) technologies to remotely warn customers. Using the Internet of Things, automatically alert others. An IOT-based battery monitoring system will be built using the Node MCU ESP8266 board, which will be programmed to communicate data about the battery's status to the Arduino IOT cloud. The voltage level and charge percentage are shown on the IOT Cloud Panel both while the battery is charging and when it is being discharged. There will be several batteries and charging and discharging will occur. The battery will start to discharge when it reaches a particular temperature, thus the EV needs coolant to stop that from happening.

Mohd Helmy Abd Wahab and colleagues (2022)The IoT-based battery monitoring system has two fundamental components, namely the user interface and the monitoring equipment. The proposed battery monitoring system based on the Internet of Things (IoT) comprises essential hardware components, including a 9V battery for power supply, an Arduino Uno microcontroller, and a SIM808 GSM/GPRS/GPS module. According to the results of the test, the system could detect a decline in battery performance and notify the user to take additional action. The experiments and system analysis are covered in this part. First, the procedures and outcomes of the test will be examined with regard to the properties of the voltage sensor and the GSM module.Then, the results of studies aimed at demonstrating battery degradation will be discussed.

In their study, P. Sivaraman and C. Sharmeela et al. (2020) discuss the monitoring circuit of the Battery Management System (BMS) and its role in monitoring essential battery parameters, including voltage, current, and temperature, throughout both charging and discharging processes. The determination of measurement-based power, State of Charge (SoC), State of Health (SoH), and wellness is reliant upon it. The capacity to balance the cell is one of the BMS system's essential elements. While balancing the cells online, it will keep an eye on each distinct cell or parallel group of cells. It also runs tests on the battery to make sure it is operating safely. The BMS will notify or sound an alert to replace a weak cell if it finds any weak cells.

S.Prabakaran et at., (2023) it should be obvious that testing is going on because this solution uses IoT technology to monitor the vehicle's display. The creation and development of a battery monitoring system with IoT capabilities. Monitoring involves keeping a close eye on crucial functioning factors including voltage, smoke, and temperature when the device is being charged or discharged. This hardware-timed sensor system monitors and reports on several parameters, including temperature, voltage, and smoke, to let you know when everything has reached the right value.

The study conducted by Dayal Chandra Sati et al. (2021) The use of Internet of Things (IoT) technology is rapidly gaining prominence in the domain of wireless battery management systems. The optimisation of battery management is crucial for enhancing the performance, dependability, and safety of battery systems. The Internet of Things (IoT) facilitates the monitoring and transmission of battery-related data to the cloud, enabling the collection of real-time information pertaining to the battery. Intelligent cloud software may create a distinct charge curve for every recharge, ensuring that the battery is charged to its maximum capacity and increasing the battery cells' lifespan. Due to its extended range and low power consumption, LoRaWAN technology might help develop and deploy an intelligent Internet of Things-based battery management system.

Dandge, Vishal J., et al. (2021) The use of technology enables the detection of declining battery performance, hence notifying the user to undertake further measures.The voltage sensor is responsible for determining the optimal voltage level that the lithium-ion battery must maintain in order to enable the proper functioning of the device. The ESP8266/GPS/GPRS shield simultaneously retrieves data from the vehicle by making use of GPS technology. The Arduino Uno microcontroller is responsible for receiving and processing the battery voltage level and vehicle position information. The processed data may be wirelessly sent to the battery monitoring interface of a device. In the event that the battery produces a diminished voltage level, the user is promptly notified through an electronic mail communication with a warning message. In addition to calculating battery voltage, the online battery system also monitors battery properties via interacting with the battery monitoring system.

Anjali Vekhande et at (2020)discussed voltage, current, and remaining charge capacity of the battery are computed in a real-time situation.A PIC-based instrument for gathering data on different measures of battery parameters. Information is also stored in a server database and shown on an Android mobile device. Prior to showing the sensor data on the LCD, the controller processes it. In addition, this data is sent to Node MCU for cloud storage. Incorporated inside the Node MCU is Wi-Fi. You may also get this information using an Android app. A write API key is used to publish data to the cloud, whereas a read API key is used to get data from the cloud for monitoring purposes.

P. S. Mali et at (2022)analyzed monitoring the battery's factors, such as voltage, temperature, current, and charge availability, can promote the use of green energy and improve the resilience of electric cars. Additionally, the Internet of Things (IoT) concept is introduced by using the cloud to display these statistics. The battery monitoring system based on the Internet of Things (IoT) has two main components. The monitoring process involves the use of certain equipment and user interfaces. The empirical findings indicate that the system has the capability to assess the performance of batteries. IoT is one of the upcoming internet technologies that focuses on the delivery of services and adjusting the way that technologies are implemented across various communication networks[17],[18].

3. Methodology

This analysis is divided into three categories such as control system, battery monitoring system and Internet of things. The Internet of Things (IoT) battery management system promptly transmits real-time battery-related information, encompassing voltage, current, and temperature, throughout both charging and discharging processes to the cloud. From there, the system analyzes the data using machine learning and artificial intelligence algorithms. Every time a battery malfunction or defect is found, the driver or service provider can be kept updated. The overall processes are demonstrated in Figure 1

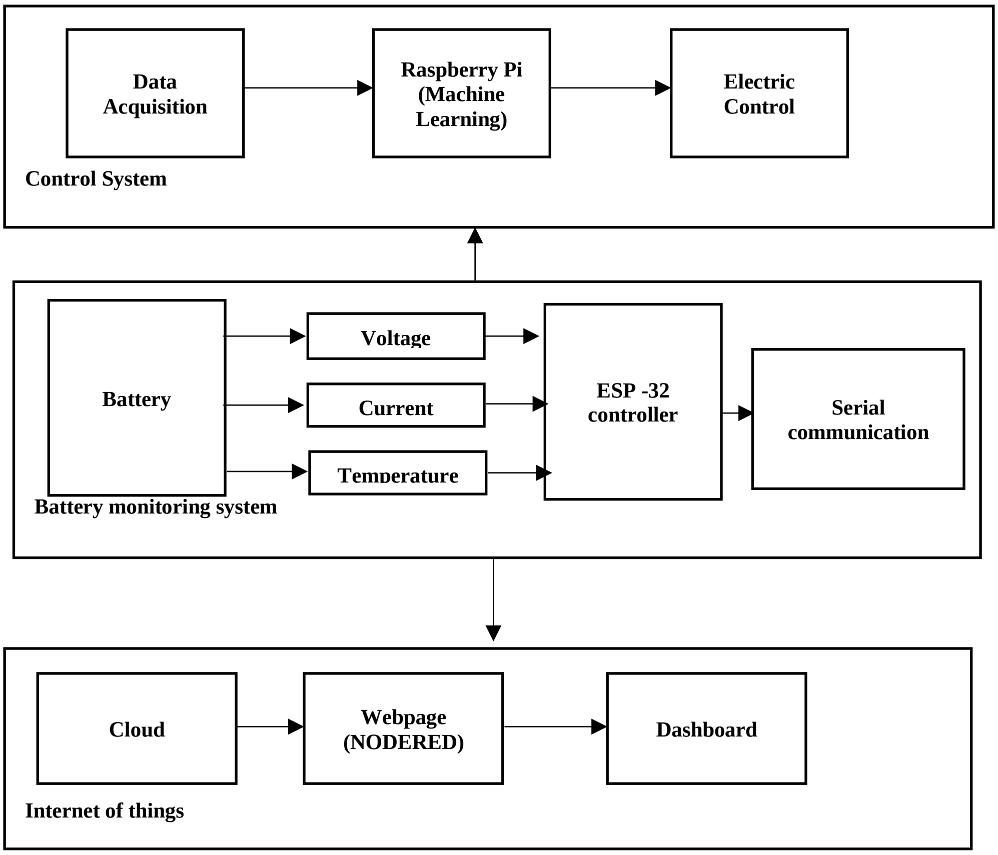

Fig. 1. Overall flow diagram battery energy management system

3.1 Battery monitoring system

A. Lithium battery

Lithium-ion batteries consist of one or more lithium-ion cells, accompanied by a protective circuit board and other components. Once the cell or cells have been integrated into a device equipped with a safeguarded circuit board, they are often denoted as batteries. Within a lithium-ion battery, the process involves the migration of lithium ions (Li+) from the cathode to the anode. Electrons exhibit a migratory behaviour in the external circuit that is characterised by a movement in the opposite direction. Since it produces the electrical current through this migration, the battery powers the item. The anode transports lithium ions to the cathode when the battery discharges, resulting in an electron flow that helps power the relevant device.

Working principle

The way a rocking chair with lithium-ion batteries works. Here, chemical energy is converted to electrical energy using redox reactions. Typically, a lithium-ion battery consists of two or more electrochemical cells that are electrically interconnected. When the battery is charged, ions have a tendency to migrate towards the anode, which is the negatively charged electrode. Upon complete discharge of the battery, the lithium ions undergo a process of returning to the positive electrode, also known as the cathode. This phenomenon demonstrates that lithium ions undergo reciprocal migration between the positive and negative electrodes of the battery during the process of charging and discharging.

Working operation

Anode and cathode electrodes are generally set up in batteries. The cathode is responsible for generating the positive terminal of the battery, while the anode is responsible for capturing the negative terminal. The cathode of a lithium-ion battery mostly consists of a lithium emulsion, whereas the anode is predominantly composed of graphite. The migration of lithium ions inside a battery occurs in the direction from the cathode to the anode, or from the positively charged electrode to the negatively charged electrode, when the battery is electrically linked. In this scenario, the battery is through the process of charging. During the discharge phase of the battery, there is a transfer of lithium ions from the anode to the cathode, which corresponds to the movement of ions from the negative electrode to the positive electrode. This process results in the generation of electrical energy.

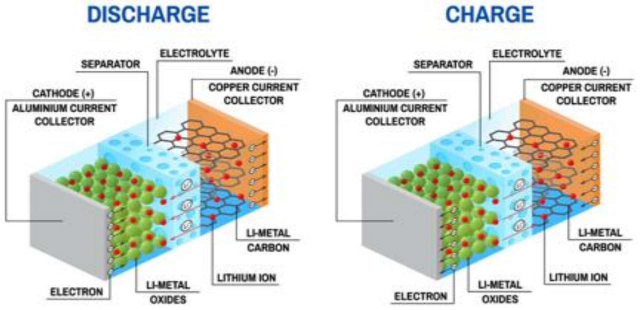

Fig. 2. Working of lithium-ion battery

B. *Voltage sensor*

The voltage force is calculated, covered, and determined using this detector. The position of AC or DC voltage may be determined with this detector. This detector may take voltage as an input and give switches, analogue voltage signals, current signals, or audio signals as its affair. Etc.

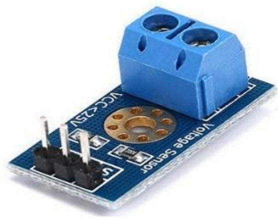

Fig. 3. Voltage sensor

C. Current sensor

For measuring the current moving across a circuit, a detector is needed the device performance is innocent by the ACS712 Current Sensor, a detector that can descry and cipher the quantum of current handed to the captain

Fig 4. Current sensor

D. Raspberry pi controller

The Raspberry Pi is a Linux-based computer with a set of GPIO (general purpose input/output) pins that make it possible to learn about and control electronic components used in physical processing.

Fig. 5. Raspberry pi controller

E. ESP 32 controller

The Expressive Systems chip is referred to as ESP32. This allows for bidirectional Bluetooth and Wi-Fi connectivity for embedded devices. Manufacturers often refer to modules and development boards that employ this device as "ESP32," however ESP32 is really just a chip.

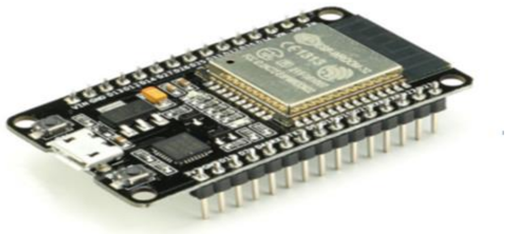

Fig. 6. ESP 32 Wi-Fi module

3.2 Control system

A. Gated recurrent unit (GRU)

A variation of the recurrent neural network (RNN) known as GRU is also used to address issues with long-term memory and gradients in backpropagation. GRU has a simpler structure than LSTM while having one fewer gate. Figure 7 makes clear that GRU only has two gates a reset gate and an update gate which results in a model that requires fewer parameters, requires less computing power, and trains more quickly. The reset gate's responsibility is to regulate the preservation of historical data.Less past data is disregarded the greater the reset gate value. The update gate is used to regulate how the current new input and the prior cell state affect the current new cell state. The steps involved in GRU's mathematical computation are as follows:

$g_r = \sigma(W_r.[s_{t-1}, x_t] + b_r)\ldots$
(1)

$g_z = \sigma(W_z.[s_{t-1}, x_t] + b_z)\ldots$
(2)

$\widehat{s_t} = \tanh\,(W_h.[g_r * s_{t-1}, x_t] + b_s)\ldots$
(3)

$s_t = (1 - g_z) * s_{t-1} + g_z * \widehat{s_t}\ldots$
(4)

The sigmoid functionis,

$\sigma(x) = \frac{1}{1+e^{-x}}$
(5)

The tan function is,

$tanh(x) = \frac{e^{2x}-1}{e^{2x}+1}$....
(6)

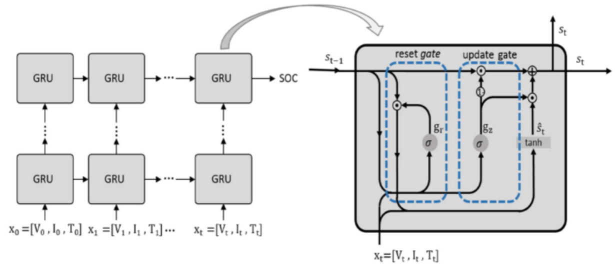

Fig. 7.GRU flow diagram

Large time series data were handled well by the GRU design, which allowed for the usage of the same parameters at different time steps. Data from batteries' voltage, current, and temperature are all one-dimensional time series data.

B. Long-Short-Term Memory (LSTM)

The memory cell of the Hidden Layer serves as the fundamental building element of a neural network, which is utilized to characterize the transient dynamics in a group of objects. The significance of packing for categorizing items is presented by Hidden Layer 1. Variants are represented by the number of connections between memory cells and gates, and hidden layer 2 controls how frequently a cell's state is updated. The output layer is constructed using an LSTM block, which is reliant on an LSTM architecture for recognizing a battery system.

Step: 1 Collection the image

$g_i(X) = \frac{K_i\, p\,(\omega_i)}{\sum_{i=1}^{L} k_1 p(\omega)}\ldots$
(7)

Step: 2 A subset of Hidden Layers is chosen using a set of criteria (feature selection).

$g_i(X)$=$g_i(X)\ldots$
(8)

Step: 3 Split the training and testing data set from the remote sensing image.

Step 4: Evaluation model for training data

Step 5: Classified output.

C. MQTT protocol

The lightweight MQTT (MQ Telemetry Transport) open messaging protocol makes it easy for network clients with minimal resources to exchange telemetry data in low-bandwidth settings. Used for machine-to-machine (M2M) communication, the protocol is based on a publish/subscribe communication model.

4. Conclusion

The present research encompasses a comprehensive examination of the battery management system, focusing on two fundamental factors: status of charge and condition of health. The primary objective of this initiative is to identify the most advanced AI technology for battery management systems. Consequently, a comprehensive review of the relevant literature pertaining to the specific AI technologies is conducted, with a particular focus on the challenges encountered. The selection of Li-ion batteries as the ideal energy storage solution for electric vehicles is primarily driven by their extended lifetime, reduced discharge rates, superior efficiency, and enhanced power and energy densities. Our research endeavours are specifically focused on investigating and analysing these key characteristics. In order to ensure the secure and reliable functioning of batteries in electric cars, this study provides a comprehensive analysis of the primary parameters and their respective roles in facilitating the safe operation and operating cycle of a battery management system. These parameters are updated on the webpage and notifications are on the dashboard. The IoT and Artificial intelligence based on battery energy management system is efficient

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