DESIGN AND DEVELOPMENT OF INTELLIGENT BATTERY MANAGEMENT SYSTEM

20EEPJ801-PROJECT PHASE-II REPORT

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ABSTRACT

The widespread adoption of Electric Vehicles (EVs) has underscored the critical importance of Battery Management Systems (BMS) in ensuring the safety, reliability, and longevity of lithium-ion batteries. This abstract provides an overview of an advanced BMS designed for EVs, addressing challenges related to thermal management, fire prevention, and predictive maintenance through the integration of machine learning.

The proposed BMS employs real-time monitoring of key parameters, including cell temperature, voltage, and current, to proactively detect and mitigate thermal risks. Through the implementation of sophisticated thermal management algorithms, the system optimizes cooling strategies, preventing overheating and significantly reducing the likelihood of thermal runaway events, thereby enhancing overall safety.

By the most existing technology Internet of Things (IOT), using ESP 8266 controller which transfer the data and present conditions to the driver so that they identify the problem before it is too late. Also, this project includes a Machine Learning (ML) Algorithm in our system which predicts the lifespan of the battery by using the data collected in the controller so that the user can know the lifespan of the battery.

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INTRODUCTION

1.1 BACKGROUND RESEARCH:

Charging and Discharging:

Similar to how batteries can only operate safely and efficiently within a certain range of temperatures, the act of battery charging must also be performed within a temperature range to prevent damage to the battery or charging system. Lead-acid batteries can generally discharge safely between -20°C and 50°C, but at lower temperatures, charging can be a more delicate process. For this reason, charging should ideally take place between -10°C and 30°C for optimal charging time .

'Smart' battery chargers, such as the one used in this design, are active in one of two modes: constant current (CC) and constant voltage (CV). For the majority of the charging process, the battery charger will maintain a constant current to the batteries, charging them quickly within 5 to 8 hours for a 70% to 80% charge. For the remaining charging process, the charger may take an additional 7 to 10 hours, where it applies a constant voltage across the battery terminals. CV-mode charging is slower than CC-mode charging, but it is necessary to perform to avoid overcharging or otherwise damaging the batteries .

Internet of Things:

The internet of things, or loT, is The method of interconnected engineering devices, digital machines and objects with the ability to transmit information to the system without involving human-to-human or human-to computer action. IOT relates to the large amount of "happenings" that are connected to the internet so they will get information with different things - IoT applications, connected devices, industrial machines and more. Internet-connected devices have built-in sensors to gather information and, in some instances, to work on it. Realworld Internet of Things examples range from the smart house that automatically adapts heat and lighting to a smart plant that monitors business machines to search for questions, so it automatically adjusts to avoid failures. Innovations in the field of IoT is not limited to just the development of new technologies but also includes all aspects of the application. This includes: smart home technology-such as thermostats, timers and other.

THINGSPEAK:

ThingSpeak is an IoT (Internet of Things) platform for collecting, storing, visualizing, and analyzing sensor data. Different Channels to store sensor data streams. Visualization tools to create dashboards and graphs. Programming APIs to integrate with various devices and applications. Alerts and notifications based on user-defined threshold. A BMS can be interfaced with an MCU (microcontroller unit) like Arduino or ESP boards. The MCU reads battery data from the BMS and transmits it to ThingSpeak via WiFi or cellular connectivity. ThingSpeak stores the data securely and allows users to Monitor battery health remotely from any device with internet access, Analyze trends in battery performance over time. Set up alerts for critical events like low voltage or high temperature. Developed applications based on the collected data (e.g., predictive maintenance).

1.2 PROBLEM STATEMENT:

Challenges in Battery Management System for Electric Vehicles (EVs)As the world transitions towards sustainable transportation solutions, Electric Vehicles (EVs) have emerged as a promising alternative to traditional combustion engine vehicles. However, the widespread adoption of EVs is not without its challenges, particularly in the realm of Battery Management Systems (BMS). The BMS, responsible for monitoring and controlling the lithium-ion battery pack, faces several critical issues that need urgent attention for the seamless integration and widespread acceptance of electric mobility. Lithium-ion batteries, while offering high energy density, are susceptible to overheating, voltage spikes, and potential thermal runaway. These safety concerns pose a significant risk, leading to accidents and hindering the overall confidence in the safety of EVs.Safety is paramount in any mode of transportation. Instances of battery-related safety issues can lead to a loss of public trust, hampering the widespread adoption of electric vehicles.The lifespan of lithium-ion batteries in EVs is a critical factor influencing the overall cost of ownership. Factors such as overcharging, deep discharging, and temperature variations contribute to a shortened battery lifespan.Shortened battery lifespan results in increased replacement costs, making EV ownership less economically attractive. This limitation also raises concerns about the environmental impact of frequent battery replacements.Many EV users lack sufficient awareness about the status of their vehicle's battery health. Limited real-time information on voltage levels, current status, and temperature can result in uninformed decision-making.Users may unknowingly engage in practices detrimental to battery health, leading to avoidable issues. Lack of awareness also contributes to anxiety among EV users regarding the reliability of their vehicle.The electric vehicle is not a perfect prototype of a tractor-trailer engine system due to the reduced output of the generator in the vehicle compared to a truck alternator. In addition, as mentioned elsewhere in this report, the current system is not capable of switching correctly between the natural state (with the generator off) and the charging state due to an issue with obtaining the battery state of charge reading. This means that, at present, the vehicle cannot operate in a completely automatic manner, requiring a manual switch. Addressing these challenges is crucial for the widespread acceptance and successful integration of Electric Vehicles into the mainstream automotive market. A comprehensive solution in the form of an advanced and robust Battery Management System is imperative to ensure the safety, longevity, and efficiency of EV batteries, ultimately contributing to the continued growth of sustainable transportation.

1.3 OBJECTIVES:

- To Create a comprehensive system to continuously monitor the energy percentage and temperature of electric vehicle (EV) batteries during charging and discharging cycles.

- To Utilize Internet of Things (IoT) technology, specifically the EPS8266 controller, to establish a wireless connection for real-time data transfer from the battery monitoring system to the user.

- To Enable prompt reporting of battery conditions to the driver, allowing them to identify and address potential issues before they escalate, thus enhancing the safety and reliability of electric vehicles.

- To Incorporate a Machine Learning (ML) algorithm into the system to analyze the collected data and predict the lifespan of the battery. This predictive capability will empower users with insights into the longevity of their EV batteries.

- Aims to mitigate the risk of battery failure and explosions by proactively identifying anomalies in energy percentage and temperature through continuous monitoring and data analysis.

- To Develop a user-friendly interface that presents battery conditions in a clear and understandable manner, ensuring accessibility for drivers to monitor and interpret the status of their EV batteries effortlessly.

- To Ensure that the developed system is compatible with a variety of electric vehicle models, making it a versatile solution for a broad range of EV users.

- To Enable remote monitoring of the EV battery conditions, allowing users to access real-time data and predictions through a connected platform, improving convenience and accessibility.

1.4 SCOPE OF THE STUDY

The transition to a pollution-free environment is a pivotal focus for numerous countries globally, driving the accelerated adoption of Electric Vehicles (EVs) as an alternative to traditional fuel vehicles. Many regions have already successfully implemented alternative mobility modes, laying the foundation for a cleaner and sustainable future. However, in the realm of heavy-load carrying EVs, significant challenges emerge, particularly concerning battery overheating issues. The excessive heat generated under heavy loads can significantly reduce the lifespan of batteries, posing a hindrance to the seamless integration of electric transport for heavy-duty applications.

In response to this critical challenge, an innovative solution has been devised—combining the power of the Internet of Things (IoT) with machine learning (ML) algorithms within a Battery Management System (BMS). This integrated system not only identifies but also rectifies potential issues related to battery overheating in heavy-load electric vehicles. By employing ML algorithms, the BMS gains the capability to predict and analyze patterns of battery behavior, offering insights into potential heating problems before they escalate.

The implementation of IoT BMS with ML algorithms is a game-changer for both drivers and users. Drivers are equipped with real-time information about the battery's health, allowing them to identify and address any issues promptly. Simultaneously, end-users benefit from a user-friendly interface that facilitates easy troubleshooting and problem resolution, ensuring a seamless experience with their electric vehicles.

By addressing the challenges associated with battery heating in heavy-load EVs, this innovative approach not only enhances the overall reliability of electric transportation but also extends the lifespan of batteries. This, in turn, contributes significantly to the sustainability and viability of electric vehicles in heavy-duty applications, paving the way for a future where electric mobility is not only eco-friendly but also robust and efficient in meeting the demands of diverse transportation needs. As we progress towards a cleaner future, the integration of IoT BMS with ML algorithms stands as a testament to the commitment to overcoming challenges and propelling electric vehicles into the mainstream of modern transportation solutions.

1.5 SIGNIFICANCE OF THE STUDY

The significance of a study on Battery Management Systems (BMS) is multifaceted and extends across various domains due to the crucial role batteries play in modern technology and energy storage. Here are some key aspects of the significance of such a study:

Efficient Energy Storage: Batteries are fundamental to energy storage in various applications, including electric vehicles, renewable energy systems, and portable electronics. An effective BMS ensures the efficient use of stored energy, maximizing the performance and lifespan of batteries.

Performance Optimization: BMS plays a critical role in optimizing the performance of batteries. It monitors and controls parameters such as voltage, current, and temperature, ensuring that the battery operates within safe and efficient limits. This optimization is vital for the overall functionality of systems relying on battery power.

Safety Concerns: Safety is a paramount concern when dealing with batteries. A BMS helps in preventing overcharging, over-discharging, and overheating, which can lead to safety hazards such as fire or explosions. Understanding and improving the safety aspects of BMS contribute to the overall safety of battery-powered devices and systems.

Battery Life Extension: Batteries degrade over time, and their lifespan is influenced by various factors. A well-designed BMS can implement strategies to mitigate degradation, such as balancing cells, avoiding extreme operating conditions, and managing charge-discharge cycles. Extending the life of batteries is essential for economic and environmental reasons.

Environmental Impact: As the demand for electric vehicles and renewable energy systems increases, the environmental impact of batteries becomes a significant concern. Research on BMS can lead to more sustainable battery technologies, reducing the environmental footprint through improved efficiency and recyclability.

Integration with Renewable Energy: BMS is crucial for the integration of batteries with renewable energy sources like solar and wind. It helps manage the intermittent nature of these sources by storing excess energy when available and releasing it when needed. This enhances the reliability and stability of renewable energy systems

1.6 JUSTIFICATION OF SDG

The project of developing an Battery Management System (BMS) for Electric Vehicles (EVs) that focuses on preventing heating, fires, and predicting battery lifespan using machine learning aligns with several United Nations Sustainable Development Goals (SDGs). One or more of the following SDGs can be associated with this project:

1. SDG 7: Affordable and Clean Energy:

The project contributes to SDG 7 by promoting the adoption of electric vehicles, which are a key component of transitioning to cleaner and more sustainable energy sources. An efficient BMS helps optimize the use of energy stored in EV batteries, making electric mobility more viable and contributing to a reduction in greenhouse gas emissions.

2. SDG 9: Industry, Innovation, and Infrastructure:

It contributes to SDG 9 by fostering technological innovation, improving infrastructure related to electric mobility, and supporting the growth of sustainable industries.

3. SDG 11: Sustainable Cities and Communities:

Electric vehicles play a crucial role in creating more sustainable and cleaner urban environments. The project contributes to SDG 11 by addressing challenges related to the safety and reliability of EVs, which are integral to building resilient, sustainable cities with reduced environmental impact.

Imagine the Future and

Make it happen!

Together let's build a better world where there is NO POVERTY and ZERO HUNGER.
We have GOOD HEALTH AND WELL BEING QUALITY EDUCATION and full GENDER EQUALITY everywhere.
There is CLEAN WATER AND SANITATION for everyone. AFFORDABLE AND CLEAN ENERGY
which will help to create DECENT WORK AND ECONOMIC GROWTH. Our prosperity shall be fuelled
by investments in INDUSTRY, INNOVATION AND INFRASTRUCTURE that will help us to
REDUCE INEQUALITIES by all means. We will live in SUSTAINABLE CITIES AND COMMUNITIES.
RESPONSIBLE CONSUMPTION AND PRODUCTION will help in healing our planet.
CLIMATE ACTION will reduce global warming and we will have abundant,
flourishing LIFE BELOW WATER, rich and diverse LIFE ON LAND.
We will enjoy PEACE AND JUSTICE through STRONG INSTITUTIONS
and will build long term PARTNERSHIPS FOR THE GOALS.

For the goals to be reached, everyone needs to do their part: governments, the private sector, civil society and **People like you.**

Together we can...

Sai Prakash Leo Muthu

Chairman & CEO – Sairam Institutions

CHAPTER2

LITERATURE REVIEW

- Shreyas Maitreya, Himami Jain and Priyanka Paliwal, “Scalable and Decentralized Battery management system for parallel operation of multiple battery packs ”

  It proposed a system for the approach of battery management system in large scale which require multiple lithium ion battery pack operating in parallel.The approach does not require master slave configuration of battery packs and does not require any centralized hardware to manage battery packs.

- Aixiang Zhang1, Shizhan Song1, Chuanyong Wang1, Jian Zhang1, Kun Wang1, and Liwei Li2, “Research of Battery Management System for Integrated Power Supply”

  It proposes the two-stage control structure which is composed of a battery management unit and central management unit in order to improve the monitoring and management technology of integrated power supply in the power system.

- Yeqin Wang1 and Yixing Liu2 , “Electronic Control System Design and Test of Pure Electric Vehicle Battery Management System”

  Designed as a dispersed battery management system, The system devised the BMU and LECU electronic control system based on C8051F040 microcontroller, it can effectively gather the battery parameters of battery voltage and current and temperature and so on in real-time.

- Li Ran1,, Wu Junfeng 1, Wang Haiying1 and Li Gechen 1 ,“Design on Battery Management System of LiFePO4 Power Battery Based on
  μC/OS-II”

  It describes a management system(BMS) using MPC5510 and LF2407 as the core, POWER PC and the DSP as the main body to build the hardware platform of the battery management system.Embed μC / OS-II in POWER PC and DSP respectively as the real-time operating system.

- Hongjie Wu1 ,”Hardware-in-Loop verification of Battery Management System”

  It introduced a battery pack of level HIL system developed based on CAN bus, which can simulate a Lithium-ion battery pack. Also, some other components which are in connection with BMS are simulated in the HIL system.

- Yang Wenrong, Li Lulu, and Zhan Junyi,”Design for Power Lithium Battery Management System of Electric Vehicle”

  A kind of battery management system aimed at powering lithium batteries within electric vehicle is introduced in this paper. The bottom detection module is discussed, including the voltage measurement module, temperature measurement module and current measurement module.

- Sandro Martin, Passoukwende Minoungou, Eugene Moss, Sagarkumar Patel, “Battery management system”

  It provides a comprehensive study on the state-of-the-art of Li-ion batteries including the fundamentals, structures and overall performance evaluations of different types of lithium batteries. A study on a battery management system for Li-ion battery storage in EV applications is demonstrated.

- M. A. Hannan, , M. M. Hoque, Aini Hussain, Yushaizad Yusof and P. J. Ker, “State-of-the-Art and Energy Management System of Lithium-Ion Batteries in Electric Vehicle Applications: Issues and Recommendations ”

  In order to achieve the full and efficient use of battery power,this paper designed the dispersed battery management system, The system devised the BMU and LECU electronic control system based on C8051F040 microcontroller, it can effectively gather the battery parameters of battery voltage and current and temperature and so on in real-time, and estimate the battery SOC,and implement the fault diagnosis and alarming according to the battery status.

- YI TAN, GUO-JI ZHANG, “The application of machine learning algorithm in underwriting process”

  The applications of machine learning algorithms in the underwriting process.

- Gaurav Meena, Deepanjali Sharma and Mehul Mahrishi. “Traffic Prediction for Intelligent Transportation System using Machine Learning ”

  It proposes a battery monitoring and management system (BMMS) for battery driven public transit. It enables the battery to be effectively managed by reducing the frequency of rapid charge, and the transit operation center to continuously monitor the state of charge of all the vehicles with the aid of information & communication technology

CHAPTER3

METHODOLOGY

3.1 EXISTING METHODOLOGY:

The existing methodology for a Battery Management System (BMS) in Electric Vehicles (EVs) involves a comprehensive set of functions and algorithms to ensure the safe, efficient, and reliable operation of the battery pack. While the exact implementation can vary between different BMS designs, the following outlines a generalized existing methodology with key components shown in Fig 1:

1. Voltage Monitoring
2. Current Monitoring
3. Communication Interface
4. State of Charge (SOC) Estimation
5. State of Health (SOH) Monitoring

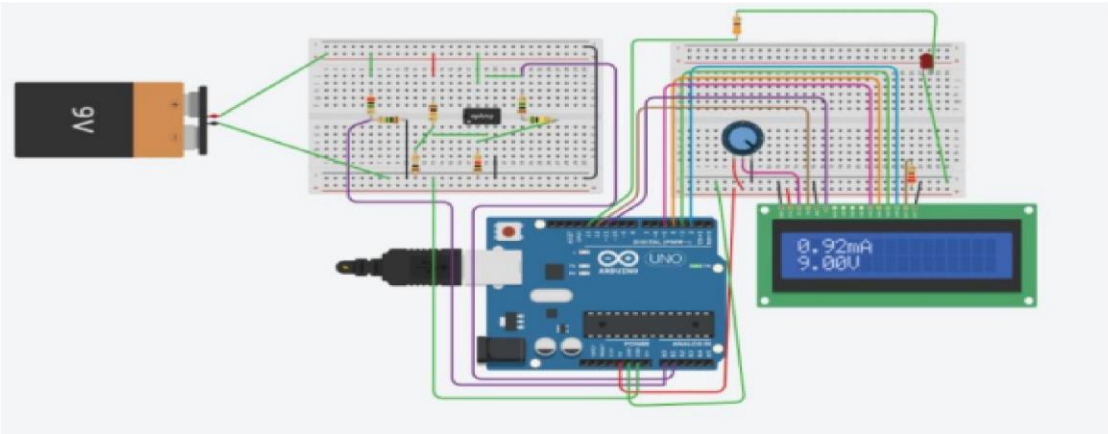

Fig 1 Existing system of Battery Management System

3.2 DESIGN AND FABRICATION:

Designing and fabricating a Battery Management System (BMS) that incorporates Machine Learning (ML) algorithms involves a more complex and dynamic approach. ML can enhance the BMS by allowing it to adapt and optimize its performance based on real-time data.

Requirements:

A Lithium-ion (Li-ion) battery pack is a common energy storage solution used in various applications such as electric vehicles, portable electronics, and renewable energy systems. A Battery Management System (BMS) is essential for monitoring, controlling, and ensuring the safe and efficient operation of Li-ion battery packs. Here are key considerations for integrating a Li-ion battery pack into a BMS:

1.Cell Monitoring:

- Individual cell voltage monitoring: Li-ion cells can have varying voltages, and monitoring each cell's voltage ensures balanced charging and discharging.
- State of Charge (SOC) estimation: Accurate SOC monitoring provides information about the remaining charge in the battery pack.

2.Balancing:

- Implement balancing circuits: Balancing ensures that individual cells in the battery pack are charged and discharged uniformly, preventing overcharging or over-discharging of specific cells.

3.Temperature Control:

- Temperature sensors: Integrate temperature sensors to monitor the temperature of each cell and the overall battery pack.
- Thermal management: Implement cooling or heating systems to maintain optimal operating temperatures and prevent overheating.

4.Safety Features:

- Overvoltage and undervoltage protection: Implement safeguards to prevent the battery from reaching voltage extremes.
- Overcurrent protection: Protect against excessive charging or discharging currents.
- Temperature protection: Disconnect or modify charging/discharging rates to prevent overheating.

5.State of Charge (SOC) Estimation:

- The BMS uses sophisticated algorithms to estimate the State of Charge, indicating the remaining available capacity of the battery.
- Accurate SOC estimation is crucial for providing reliable information to the vehicle's energy management system.

6.State of Health (SOH) Monitoring:

- The BMS assesses the State of Health of the battery, indicating the overall health and degradation level.
- This information helps predict the remaining lifespan of the battery and facilitates preventive maintenance.

7.Safety Protocols:

- The BMS incorporates safety protocols to mitigate risks associated with overcharging, over-discharging, overheating, and other potentially hazardous conditions.
- These protocols may involve reducing charging rates, disconnecting faulty cells, or initiating emergency shutdown procedures.

8.Cell Balancing:

- To address imbalances in voltage and capacity among individual cells, the BMS employs cell balancing algorithms.
- This ensures that cells within the battery pack are uniformly charged and discharged, promoting longevity and performance consistency.

System Architecture:

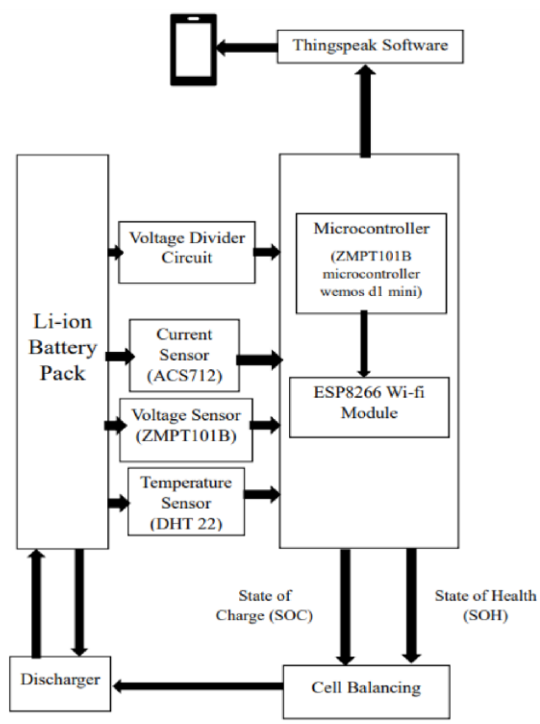

Fig 2 System Architecture

ESP 8266

ESP8266 is a chip which is used in a microcontroller Wemos D1 mini. It is a 32-bit Wi-Fi enabled controller. Due to its wide range in operating temperature, it can operate effectively in a variety of environmental settings. ESP8266 is designed for Internet of Things (IoT) applications, wearable electronics, and mobile devices. It uses a combination of various unique technologies to achieve low power usage. There are two ways to program the ESP8266 module. One is by LUA scripting and the other is by Arduino programming by connecting it with the Arduinos. The ESP8266 boards' power supplies range from 2.5 V to 12 V. ESP32 is also like ESP8266 which has GPIO’s and faster WI-FI. This paper uses ESP8266 as it is less complex than ESP32.

Current sensor

A current sensor is a device that detects current and converts it into an output voltage that is simple to measure and proportional to the current flowing through the path being measured. Current sensor is an electrical device that measures the flow of electric current. It uses a magnetic field to detect the current and it will yield a proper output when the current flows in a conductor. It is commonly based upon hall effect technology. The measuring range of this sensor is 5A to 60A.The generated signal either could be analog or digital output. It is basically divided into digital and analog sensors. The digital sensor reads the current flowing through the conductor and uses a switch to display(as shown in Fig 2) whether the current is running at the deliberate ampere which is set by the user, where the analog sensor displays the range consumed.

Voltage sensor:

A voltage sensor is a sensor that determines how much voltage is present. Both the DC and AC voltage can be determined using it. This can output a sine wave or a pulse, and it can also occasionally produce outputs for amplitude modulation, pulse width modulation, or frequency modulation. Voltage divider is the foundation for the measurement. There are two types of voltage sensors: resistive type and capacitive type. Up to 25V of voltage can be measured Li-Ion Battery Charger:

Li-ion battery charger requires a constant current and constant voltage until it reaches its final voltage, where it should get changed at a certain current level. If it is overcharged it could result in battery failure. It is capable of providing stable control loops for the maintenance of current and voltage.

DHT 22:

It measures the temperature and converts the input data into electrical signals. The voltage which is across the diode will determine the working of the temperature meter. It will have faster response time and this is because of lower thermal mass. The measurement of this sensor is up to 2000°C.

Voltage divider Circuit:

It is a fundamental circuit which can produce a section of its input voltage as output. It is also called a potential divider. This can be used for adjusting the signal level for active devices. It uses two resistors which are connected in series with the input voltage. This can bring out the voltage levels from a single common source but with the same current for all the components in the series circuit. The circuit for voltage divider with three resistors is shown in Fig 3.

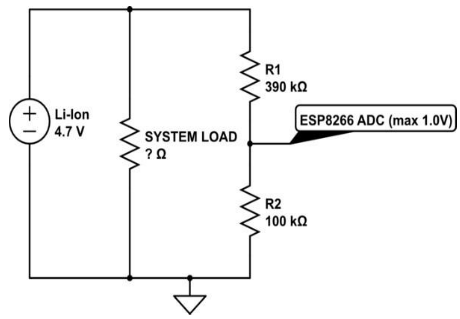

Fig 3 Voltage divider circuit

Data acquisition unit:

The sensor data is collected by a Data Acquisition Unit (DAU), which interfaces with the sensors and gathers real-time information about the battery's condition.

Machine learning subsystem:

The Machine Learning Subsystem receives data from sensors, including historical usage patterns, environmental conditions, and real-time battery performance metrics. This subsystem uses machine learning algorithms to predict the remaining useful life of the battery.

Thermal management system:

The collected temperature data is fed into the Thermal Management System, which includes algorithms for optimizing cooling strategies. This system ensures that the battery operates within a safe temperature range, preventing overheating and thermal runaway.

Fire prevention Module:

The BMS incorporates a Fire Prevention Module that analyzes various parameters, including voltage and current, to detect potential risks of thermal runaway or other conditions that could lead to battery fires. In case of anomalies, the BMS triggers safety protocols to prevent catastrophic events.

User interface:

A User Interface may be included for interaction with vehicle users or maintenance personnel. It can display relevant information about the battery's health, remaining lifespan, and any safety alerts.

Block diagram:

LIBs are becoming highly powerful and deliver EV driving power as an alternative to ICE vehicles and in clean transport worldwide. HEV and BEV systems will positively affect the universal economy and the environment. In EV technologies, devices are required to develop their competency during operational hours and safe operation, as well as to secure the ESS.

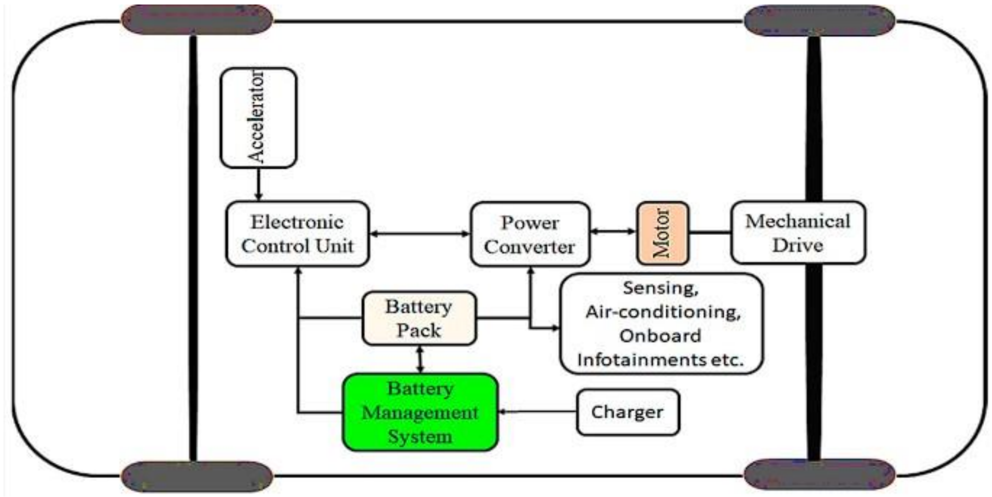

Fig 4 Block diagram

The BMS manages the ES, transmission, control, and management facilities related to EV, along with the charge equalizer, battery cell voltage control, input/output voltage controls, protection, and diagnosing and assessing errors Some BMS specifications and functions are present in. The BMS also manages the battery charging characteristics and status. The BMS controls the battery's charge and discharge and the load demand of the battery pack. The BMS calculates the lithium's cell voltage levels and saves the cells from over/undercharging. To improve battery performance and lifetime, the BMS should conduct cell balancing techniques using the charge/voltage equalization. The BMS observes the cell operating temperature at some stages, manages a power converter, and operates the battery cell in a way that keeps it healthy and safely functional despite heat. The cell protection mechanism protects the cell from short circuit, overload, current/voltage stress, etc., over time. In the EV system, the BMS analyzes and measures the energy-storage distribution processes and defects. The specifications are current and voltage monitoring in the LIB cell; the estimation and protection of LIB charge/discharge control; cell equalization; temperature, power, and heat management; data storage and acquisition; communication and networking, and fault assessment and diagnosis.EVs are compactly connected through LIB packs. The battery cells' nature can be different during run times.

Constant cell monitoring is essential to determine the state of the cells. The cell monitoring results guide the device's operating efficiency in energy management, power delivery, and safety. It manages cell monitoring under discharge and charge conditions, overcharge and undercharge protection, temperature and heat monitoring, fault detection, the data-acquisition interface, connectivity, and assessment, among other things . LIBs deliver constant voltage and current during the discharge time. The unstable cell current and voltage delivery cause cell damage or explosion. During operation, the cell voltage/current levels are required to be regulated to protect the cell from undercharging/overcharging. In addition, the battery pack's voltage and current condition are displayed for further assistance.

Monitoring and Control:

BMS is equipped with custom battery management algorithms that continuously monitor key parameters and intervene when necessary. These algorithms ensure that the battery operates within safe parameters, thereby protecting it from premature capacity loss and prolonging its lifetime.

Measuring State-of-Charge (SOC)

Calculating the state-of-charge is a fundamental function of a BMS, as it enables precise control over the charging and discharging processes, safeguarding the battery. Accurate SOC measurement is crucial for maintaining the battery's performance over time.

$$SOC = Q/Q_{max}$$

Q- remaining capacity

Q max - rated capacity

Estimating State-of-Health (SOH)

State-of-health estimation is another essential function of a BMS. It helps users enhance battery performance and provides early warning of deterioration, indicating the need for battery replacement. Knowing the SOH provides valuable insights into the battery's performance and the overall energy storage system, including efficiency and reliability.

$$R = (OCV - V)/I$$

R-internal resistance

OCV- open circuit voltage

V- voltage

I- current

Challenges in SOC and SOH Estimation

Unlike voltage or temperature, SOC and SOH cannot be directly measured as physical quantities. Instead, they require consideration of a range of factors and parameters to be assessed accurately. The following parameters are involved in calculating SOC:

- Age
- Cycle life (number of charge/discharge cycles)
- Capacity
- Internal resistance
- Energy throughput ● Temperature
- Self-discharge rate
- Voltage

Estimating State-of-Charge (SOC)

Multiple approaches can be employed to determine a battery's SOC, including direct measurements, indirect calculations, predictive techniques, and other technologies. Here are some of the most common methods:

Open Circuit Voltage (OCV) Method

This method relies on the relationship between a battery's remaining capacity or SOC and its open-circuit voltage, which is the voltage with no current load. The stronger the dependence between voltage and SOC, the more accurate the measurements. This relationship is typically represented in a discharge curve, which can be found in battery datasheets or created through experimental measurements.

The OCV method is well-suited for determining the initial SOC of a battery characteristic. Therefore, the OCV method is often combined with other measurement practices for more accurate SOC estimation in lithium battery management systems. Another method for estimating SOC is the CCV method.

Comparison between 2 methods is shown in Fig 5.

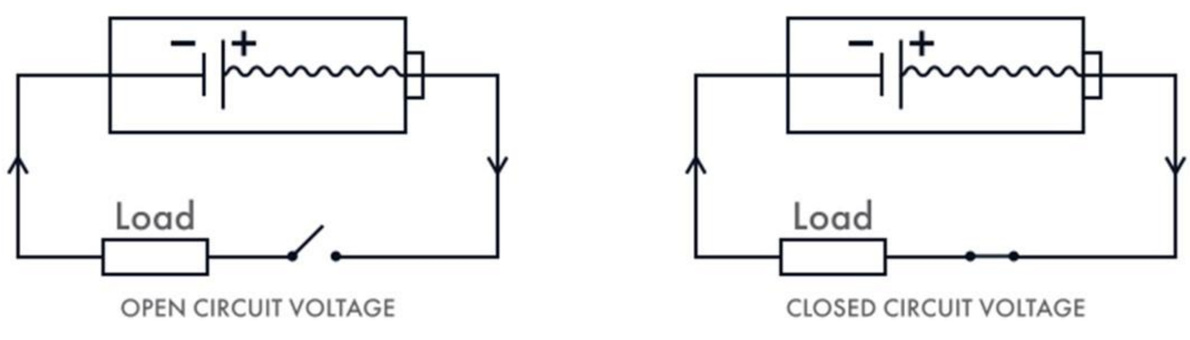

Fig 5 Comparison between OCV and CCV

Coulomb Counting (Current Integration)

This method involves calculating coulombs or the quantity of electric charge, derived from the product of current and the time it takes for the charge to flow. Coulomb counting is a widely used method, but its accuracy depends on knowing the initial SOC as a reference point. In practice, the SOC is often reset to 100% periodically in the BMS design. Accurate current measurement is also crucial for reliable SOC estimation. Linear plot between charge and time taken is shown in Fig6.

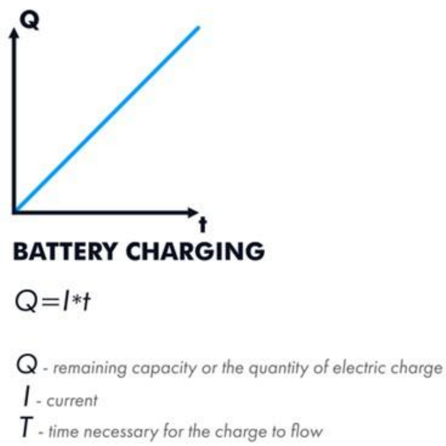

Fig 6 Plot between charge and time taken

3.3 Experimental Set up:

1 **Initialization:**

- Configure the BMS with default settings.
- Establish a baseline for the battery's initial state.

2. **Test Execution:**
    - Execute predefined test scenarios to evaluate specific aspects of the BMS.
    - Monitor and record data in real-time.

3. **Fault Injection:**
    - Simulate faults, such as a sudden increase in load or a short circuit, to assess the BMS's ability to detect and respond.

4. **Machine learning Validation:**
    - Input historical and real-time data into the machine learning subsystem.
    - Evaluate the accuracy of predicted battery lifespan compared to actual degradation.

5. **Thermal Stress Tests:**
    - Subject the battery pack to controlled thermal stress by adjusting environmental temperatures.
    - Monitor the BMS's thermal management response.

6. **Continuous Monitoring:**
    - Continuously monitor and log data throughout the experiment.

7. **Post Experiment Analysis:**
    - Analyze recorded data to evaluate the BMS's performance against predefined metrics.
    - Identify areas for improvement and optimization.

This experimental setup provides a controlled environment to assess the BMS's functionality in addressing thermal management, fire prevention, and machine learning-based lifespan prediction. The flexibility of the setup allows for iterative testing and refinement of the BMS design for optimal performance and safety in real-world electric vehicle applications.

3.4 Data acquisition system in BMS:

A Data Acquisition System (DAS) in a Battery Management System (BMS) is a crucial component responsible for collecting, monitoring, and processing data from various sensors within the battery pack. The DAS plays a key role in providing real-time information about the battery's state, facilitating the BMS's decision-making processes, and ensuring the safety and performance of the electric vehicle's energy storage system.

Functions of a Data Acquisition System in a BMS:

Real-Time Monitoring:

Continuously acquire data from temperature, voltage, and current sensors in real-time, providing up-to-date information on the battery's state.

State of Charge and State of Health Estimation:

Use voltage and current data to estimate the SOC and assess the SOH of the battery over time. These estimates help in optimizing battery performance and predicting lifespan.

Temperature Management:

Monitor temperature sensors to ensure that the battery operates within safe temperature limits. Activate cooling or heating systems based on the acquired temperature data.

Cell Balancing:

Acquire voltage data from individual cells and use it to implement cell balancing algorithms. This ensures uniform charge distribution and maximizes battery pack efficiency.

Fault Detection:

Detects anomalies or faults in the battery pack by analyzing sensor data. The DAS triggers appropriate safety measures and communicates fault information to the BMS's control unit.

Machine Learning Integration:

If the BMS incorporates machine learning for predictive analytics, the DAS provides the necessary input data for training and refinement of machine learning models. The Data Acquisition System is a critical element in the overall functionality of the BMS, enabling the system to make informed decisions based on real-time and historical data. The efficiency and accuracy of the DAS directly impact the safety, reliability, and performance of the battery pack in electric vehicles.

CHAPTER4

DEVELOPED SYSTEM

The proposed model is used to overcome all the shortcomings of the existing system. The existing BMS in EV just shows the batteries percentage. This system uses sensors to measure the voltage, current and the temperature. This system alerts the consumer to change the battery if the battery's temperature has exceeded the set value. The system uses ESP8266 chip wemos d1 mini microcontroller to store the datum as well to transfer the data to the cloud. From the cloud the data can be accessed by the user. The proposed system uses a ML prediction algorithm to predict the lifespan of the battery.To monitor voltage, current, and temperature, the proposed Battery Management System (BMS) in electric vehicles (EVs) incorporates advanced features to enhance battery health and performance. The system employs sophisticated sensors to continuously assess the state of the battery, allowing for real-time analysis and accurate predictions. By leveraging an ESP8266 chip with a Wemos D1 Mini microcontroller, the system not only captures and stores data locally but also seamlessly transfers it to the cloud for remote access.

Moreover, the inclusion of an alert mechanism ensures that users are promptly notified when the battery temperature surpasses predefined thresholds, prompting timely action to prevent potential damage or safety hazards. The cloud-based data storage facilitates convenient access for users, enabling them to monitor the battery's condition and historical performance effortlessly. The utilization of machine learning (ML) prediction algorithms takes the BMS to the next level by providing insights into the battery's remaining lifespan based on historical data and usage patterns.

Furthermore, the ML algorithm adapts and refines its predictions over time, enhancing accuracy and reliability. This predictive capability not only aids in proactive battery replacement planning but also contributes to optimizing overall system efficiency. The system's ability to learn from real-world usage patterns ensures personalized insights for users, making it a smart and adaptive solution for EV battery management. Overall, the proposed BMS stands as a comprehensive and intelligent system, addressing existing limitations and ushering in a new era of efficient and reliable electric vehicle battery management.

The proposed solution represents a comprehensive and adaptive approach to battery management in electric vehicles. By addressing thermal challenges, implementing advanced safety measures, and harnessing the power of machine learning, this BMS aims to set a new standard for the reliability, safety, and sustainability of EV battery systems. As electric mobility continues to evolve, this proposed solution strives to be at the forefront of innovations that drive the industry towards a cleaner and more efficient future. In addition to real-time monitoring of voltage, current, and temperature, the system features a self-healing mechanism to autonomously rectify minor issues, minimizing downtime.

It dynamically optimizes the charging process based on continuous monitoring, considering factors such as temperature, voltage, and current to extend battery life. The user interface is intuitive, accessible through a mobile app or web portal, providing real-time data and actionable insights for informed decision-making on maintenance and replacement. With support for remote firmware updates, the BMS stays current with the latest advancements in battery management and predictive analytics. Energy consumption analysis and integration with vehicle telematics contribute to optimizing fleet efficiency. The system provides real-time diagnostics and reporting for quick issue identification, while adaptive charging algorithms tailor the charging process to specific conditions. Open API support allows seamless integration with third-party applications, fostering collaboration within a smart and interconnected transportation ecosystem. Overall, this BMS stands as a versatile and robust solution, ensuring optimal electric vehicle battery performance and management.

To ensure effective coordination within the EV, the proposed BMS features seamless integration with the vehicle's main control unit. This includes real-time data exchange, communication of safety alerts, and collaborative decision-making to optimize overall performance. Recognizing the importance of user awareness, the BMS includes an intuitive user interface. This interface provides real-time information on battery health, alerts users to potential issues, and offers insights into the efficiency of the EV's energy storage system. It serves as a user-friendly tool for operators and maintenance personnel.

CHAPTER 5

RESULTS AND DISCUSSION

RESULT:

The goal of this initiative is to prevent accidents that happen in Electric vehicles due to poor management systems and to provide users guarantee to use EV without any fear. This project assists in automatically detecting the temperature rise in the battery and automatically notifying the user to stop using that battery whose temperature is higher than the certain level. This project also indicates how much percentage of battery and the total time left for the battery to be worn out completely. The ML prediction algorithm plays a major role here in predicting the life of a battery.

In this project, it indicates the battery percentage and the possibility of explosion of the battery whether it has to be replaced or not. It indicates the user to change or stop using the battery when the temperature of the battery increases a certain level which could be very much helpful to prevent Electric vehicle accidents which is happening very commonly nowadays. Through this system the possibility of accidents can be reduced. Using the Machine learning prediction algorithm with data sets received from the microcontroller. With this received data, it will indicate the stability of the battery like how much time will it take for that battery which is being used to be worn out completely. There will not be any failure in transferring important information to the user.

Thermal Management Evaluation:

Temperature Distribution:

- Present the temperature profiles of individual cells during different scenarios (e.g., charging, discharging, thermal stress tests).
- Analyze the effectiveness of the BMS's thermal management system in maintaining safe operating temperatures.

Heat Dissipation:

- Provide data on the BMS's ability to dissipate heat during charging and discharging cycles.
- Compare temperature rise under different operating conditions and highlight the effectiveness of the thermal management strategies.

Safety And Fault Detection

Response Time:

- Evaluate the response time of the BMS in detecting and responding to simulated faults (e.g., short circuits, abrupt load changes).
- Assess the effectiveness of safety protocols in preventing hazardous conditions.

Fire Prevention Measures:

- Report on the success of fire prevention measures implemented by the BMS.
- Showcase scenarios where potential fire risks were identified and mitigated by the BMS.

Battery Lifespan Prediction

Machine Learning Accuracy:

- Present the accuracy of the machine learning subsystem in predicting battery lifespan.
- Compare predicted lifespan with actual degradation observed during the experiment.

Overall BMS Performance

Performance Metrics:

- Display performance metrics such as State of Charge (SOC) accuracy, State of Health (SOH) accuracy, and balancing effectiveness.
- Evaluate the BMS's performance against predefined criteria.

5.1 SOH SIMULATION:

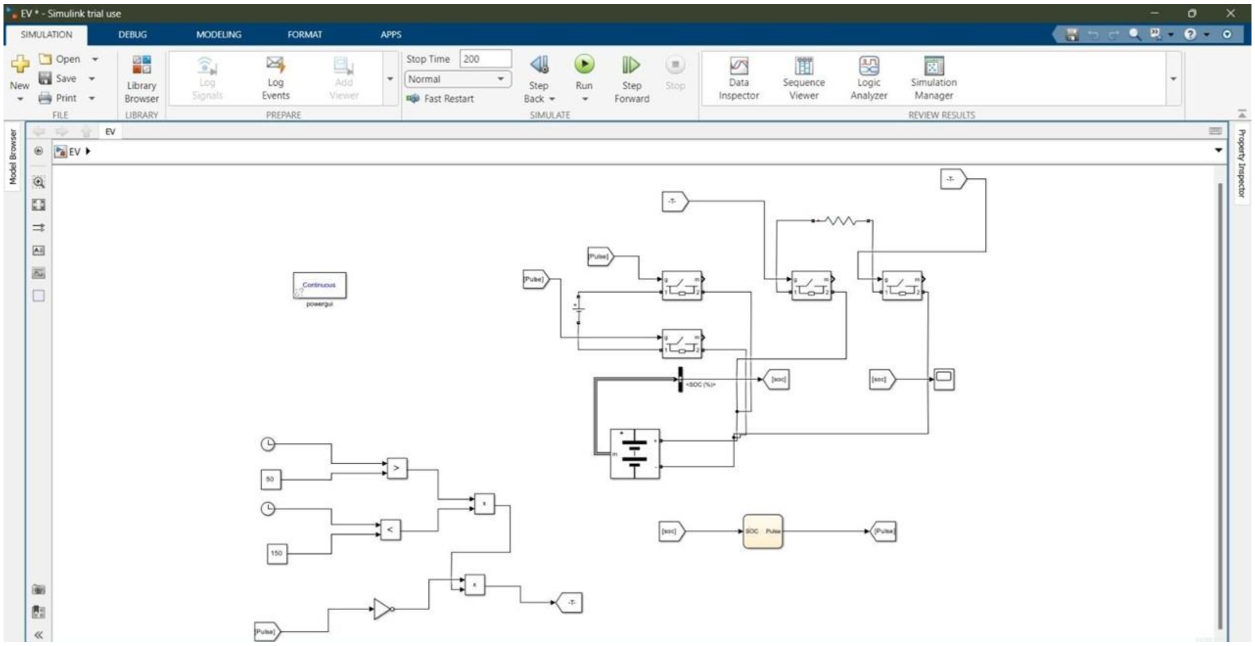

Fig 7 Matlab simulation for SOH

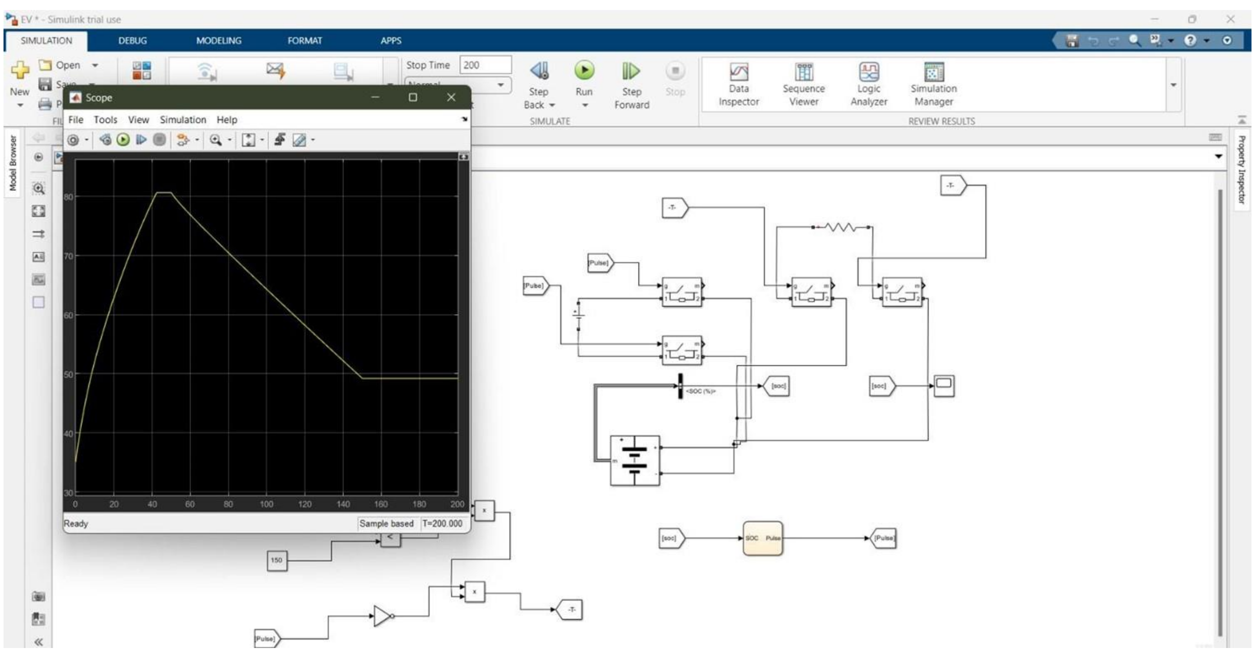

Fig 8 Output of simulation

5.2 BMS PREDICTION ALGORITHM:

```
#include<stdio.h>

int main()

{

float batteryvoltage;

int batterycurrent;

printf("Enter the Voltage rating:");

scanf("%f",&batteryvoltage);

printf("\n");

printf("Enter the Current rating:");

scanf("%d",&batterycurrent);

printf("\n");

float c;

c=(batteryvoltage*batterycurrent)/1000;

printf("The power of the battery %f",c);

float batteryCapacity, currentCharge;

float soc, socLow, socMedium, socHigh;
```

```
printf("\n");
printf("Enter the current charge in ampere-hours: ");
scanf("%f", &currentCharge);
soc = (currentCharge / c) * 100;
socLow = 20.0;
socMedium = 50.0;
socHigh = 80.0;
printf("Current Charge: %.2f Ah\n",currentCharge);
printf("State of Charge (SoC): %.2f%%\n", soc);
if (soc < socLow) {
printf("State of Charge Level: Low\n");
} else if (soc < socMedium) {
printf("State of Charge Level: Medium\n");
} else if (soc < socHigh) {
printf("State of Charge Level: High\n");
} else {
printf("State of Charge Level: Full\n");
}
return 0; }
```

EXPLANATION:

- The program starts by declaring variables for battery voltage, current, capacity, and current charge.
- The user is prompted to input the battery voltage and current.
- The program calculates the power of the battery using the formula P = VI (in kilowatts) and prints the result.
- The user is prompted to input the current charge in ampere-hours.
- The program calculates the state of charge (SoC) as a percentage and prints the current charge, SoC, and SoC level based on predefined thresholds (Low, Medium, High, Full).

OUTPUT:

```
Enter the Voltage rating:48.0

Enter the Current rating:20

The power of the battery 0.960000
Enter the current charge in ampere-hours: 10.5
Current Charge: 10.50 Ah
State of Charge (SoC): 1093.75%
State of Charge Level: Full
```

Fig 9 Output after running the code

5.3 PROTOTYPE AND MODEL

ARDUINO CODING

```
#include <DHT.h>
#include <Wire.h> // Include the Wire library for I2C
communication
#include <LiquidCrystal_I2C.h> // Include the LiquidCrystal I2C
library

// Define LCD properties
#define LCD_ADDRESS 0x27 // I2C address of the LCD
#define LCD_COLUMNS 16   // Number of columns in the LCD
#define LCD_ROWS 2       // Number of rows in the LCD

LiquidCrystal_I2C lcd(LCD_ADDRESS, LCD_COLUMNS,
LCD_ROWS); // Initialize LCD object

// Your existing code...
String apiKey = "010ZDBIS35XI0F0Q";
const char *ssid = "Yuvij";
const char *pass = "12345678";
```

```
const char *server = "api.thingspeak.com";

#define DHTPIN D2
#define MQ_PIN A0

DHT dht(DHTPIN, DHT11);
WiFiClient client;

void setup()
{
  Serial.begin(115200);
  delay(10);
  dht.begin();

  Serial.println("Connecting to ");
  Serial.println(ssid);

  WiFi.begin(ssid, pass);

  while (WiFi.status() != WL_CONNECTED)
```

```
  {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  // Initialize LCD
  lcd.init();
  lcd.backlight();
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Temperature:");
  lcd.setCursor(0, 1);
  lcd.print("Humidity:");

}

void loop()
{
```

```
float h = dht.readHumidity();
float t = dht.readTemperature();

if (isnan(h) || isnan(t))
{
  Serial.println("Failed to read from DHT sensor!");
  return;
}

int gasValue = analogRead(MQ_PIN);

if (client.connect(server, 80))
{
  String postStr = apiKey;
  postStr += "&field1=";
  postStr += String(t);
  postStr += "&field2=";
  postStr += String(h);
  postStr += "&field3=";
  postStr += String(gasValue);
```

```
postStr += "\r\n\r\n";


client.print("POST /update HTTP/1.1\n");
client.print("Host: api.thingspeak.com\n");
client.print("Connection: close\n");
client.print("X-THINGSPEAKAPIKEY: " + apiKey +
"\n");
client.print("Content-Type: application/x-www-form-
urlencoded\n");
client.print("Content-Length: ");
client.print(postStr.length());
client.print("\n\n");
client.print(postStr);


Serial.print("Temperature: ");
Serial.print(t);
Serial.print(" degrees Celsius, Humidity: ");
Serial.print(h);
Serial.print("%, Gas Value: ");
Serial.print(gasValue);
```

```
        Serial.println(". Sent to ThingSpeak.");


        // Display temperature and humidity on LCD
        lcd.setCursor(13, 0);
        lcd.print(t);
        lcd.setCursor(11, 1);
        lcd.print(h);
      }
      client.stop();


      Serial.println("Waiting...");


      // ThingSpeak needs a minimum 15 sec delay between updates
      delay(10000);
}
```

FINAL PROTOTYPE:

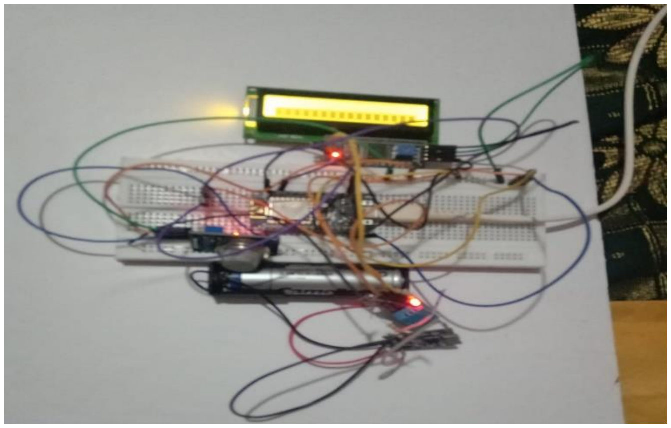

Fig 10 Prototype

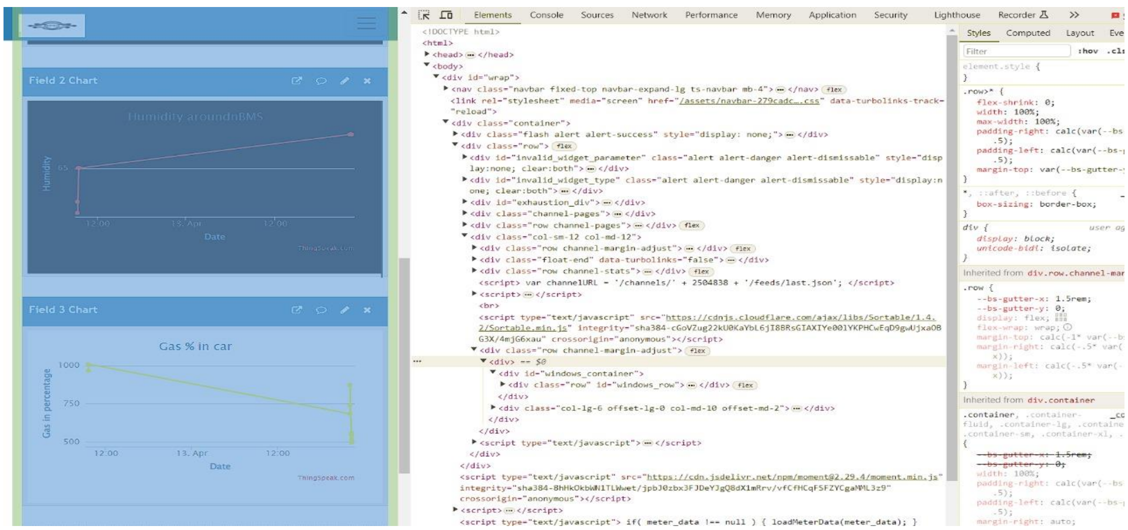

Fig 11 Output of Humidity and gas in BMS

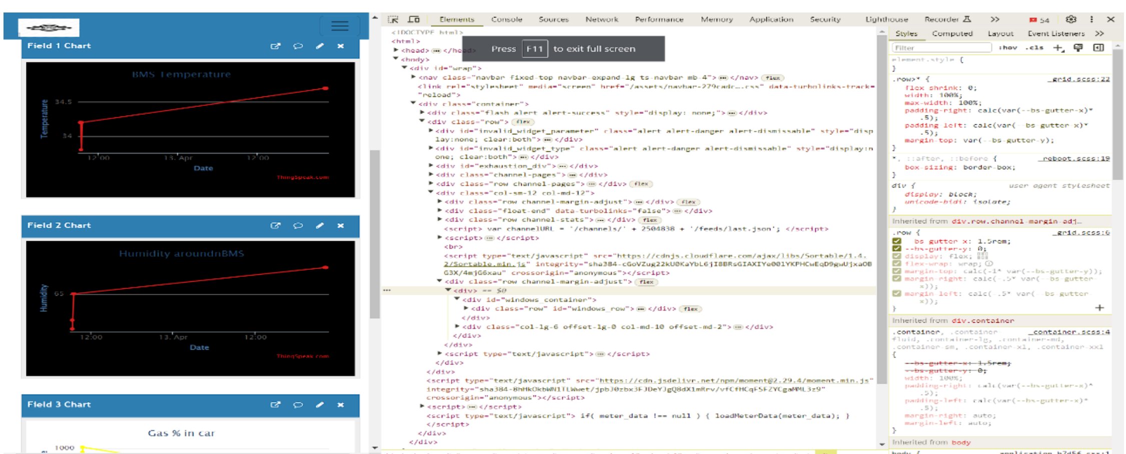

Fig 12 Output of BMS Temperature

CHAPTER 6

CONCLUSION

In conclusion, implementing a Battery Management System (BMS) using ThingSpeak offers a comprehensive solution for monitoring and managing battery performance in various applications. Leveraging ThingSpeak's platform, you can easily collect, analyze, and visualize critical battery data in real-time, enabling proactive maintenance and optimization strategies. With ThingSpeak's integration capabilities with a wide range of sensors and IoT devices, along with its customizable alerting and control features, you can tailor the BMS to meet specific requirements and ensure optimal battery health and performance. However, it's essential to prioritize security measures and thorough testing to mitigate risks and ensure the reliability and safety of the BMS in practical deployments. In conclusion, leveraging ThingSpeak with a Battery Management System (BMS) creates a powerful solution for monitoring and managing batteries. This integration offers real-time insights, facilitates data analysis for informed decisions, and enables alerts for proactive maintenance. By harnessing ThingSpeak's capabilities, you can optimize battery health, performance, and ultimately, extend its lifespan.

6.2 FUTURE SCOPE:

The integration of Battery Management Systems (BMS) with ThingSpeak holds immense potential for the future. Here are some exciting possibilities:

- **Advanced Analytics and Machine Learning:** Machine learning algorithms can be applied to historical battery data to predict future performance, remaining useful life, and potential failures. This can lead to preventive maintenance strategies and optimized charging profiles for individual batteries.
- **Edge Computing and Decentralization:** Processing power can be shifted from the cloud (ThingSpeak) to the edge (local BMS unit). This allows for faster decision-making and real-time control based on battery data without relying on internet connectivity.
- **Integration with IoT Ecosystems:** BMS data can be integrated with broader Internet-of-Things (IoT) ecosystems, allowing for intelligent control and automation of connected devices based on battery health and availability.
- **Cybersecurity Enhancements:** As BMS and ThingSpeak become more interconnected, robust cybersecurity measures will be crucial to protect sensitive battery data from unauthorized access.

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APPENDIX

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January 10th 2022

Prof. Kannan M Moudgalya
IIT Bombay

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