Implementation Of Cloud Based Smart Battery Management System Using Iot

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Abstract - As the demand for renewable energy sources increases, the use of batteries for energy storage is becoming increasingly important. With the emergence of the Internet of Things (IoT) and cloud computing technologies, a new paradigm of smart battery management systems (BMS) is emerging. In this paper, we proposed the design and implementation of a smart Battery Management System (BMS) using IoT and Cloud technologies. The proposed system aims to enhance the efficiency and reliability of battery management by providing real-time monitoring and control of battery performance, as well as optimizing battery charging and discharging operations. The system utilizes IoT sensors to collect battery data, which is transmitted to a cloud-based platform for analysis and visualization. The results of this study demonstrate that the proposed system can improve the performance and lifespan of batteries while reducing maintenance costs and environmental impact. The study also highlights the potential of IoT and Cloud technologies in developing innovative solutions for battery management in various applications.

Index Terms: B*attery, Cloud Technology, IoT Technology, Wi-Fi module, Arduino module*

I. INTRODUCTION
Due to the anticipated significant increase in electricity consumption in the coming years, the demand for renewable energy sources has never been more pressing. Consequently, the role of energy storage within the electricity system is becoming increasingly critical t [1,2]. As a facilitative technology, it has the potential to integrate a larger proportion of renewable energy sources like solar and wind into the power grid, leading to reduced electricity costs and a decreased environmental footprint t [3,4]. A battery management system (BMS) is an essential component in most real-world applications as it is responsible for monitoring the health and safety of batteries. Its importance becomes even more significant in applications involving many battery cells, such as electric vehicles and battery storage power stations. The BMS serves the critical function of ensuring that the batteries operate within their safe operating limits, preventing any potential hazards and maximizing their lifespan. Therefore, the BMS is a mandatory requirement for these types of applications, and its proper functioning is crucial for the overall safety and efficiency of the system [5, 6]. The BMS is an electronic device that monitors and protects batteries from potential damage due to usage conditions. It continually checks the battery's vital factors to ensure safe operation. The BMS's primary role is to monitor the battery's state of charge, temperature, and other critical parameters. It takes corrective actions in case of any abnormal conditions, such as reducing the charging current, limiting the discharge rate, or activating cooling systems. By doing so, the BMS helps to extend battery life, optimize performance, and ensure safe and reliable operation [7]. The primary function of a Battery Management System (BMS) is to ensure the safety and protection of batteries by establishing operational thresholds for voltage, current, and temperature while implementing cell balancing. With advancements in technology and ongoing research, BMSs have significantly improved in terms of

2173

performance, functionality, and capabilities. Modern BMSs offer a range of features that enhance the safety and performance of batteries, including cell monitoring, state of charge (SOC) and state of health (SOH) estimation, thermal management, and charging control. These integrated features allow BMSs to better manage batteries and ensure their optimal performance and lifespan. It is crucial to have a well-designed battery management system due to concerns over the safety, dependability, and performance of batteries, particularly in standalone systems (BMS). Battery models are a vital component of the BMS, which is necessary to guarantee the battery's safe and effective operation. These models are used to govern battery operation and estimate the state of charge (SOC), state of health (SOH), and functioning voltage, power, and energy capacities of the battery. To ensure dependable performance and safety, improve battery usage efficiency, and avoid malfunctions and catastrophic failures, accurate and trustworthy battery models play a critical role in the BMS. The present architecture has flaws despite recent efforts to create better BMSs. For instance, due to its limited computing power and data storage, the BMS infrastructure can only support basic battery models, such as comparable circuit models or simplified electrochemical models. Despite the use of data-driven and machine-learning approaches to create more precise electrical electrochemical models, the existing BMS architecture does not allow for their implementation.

To overcome the limitations of limited storage and computing capability, we can leverage trending technologies like the cloud and IoT. These technologies enable us to achieve real-time monitoring and control, optimize battery performance, extend battery life, and ensure safe operation, surpassing the capabilities of existing BMSs. While implementing such a system, we must prioritize data security, reliability, and scalability. This involves carefully selecting appropriate hardware and software components, conducting thorough testing and validation, and fulfilling the requirements of the cloud-based smart BMS, including battery monitoring, control, and communication. [7].

This paper will provide a comprehensive overview of the benefits of cloud-based BMS and its potential applications in renewable energy systems and electric vehicles. The methodology used for this research will include the development of a cloud-based BMS system using IoT devices, data collection, and analysis, and statistical analysis of the results. The paper will conclude with a discussion of the research findings and their implications for the future development of cloud-based BMS in renewable energy systems and electric vehicles.

II. HARDWARE

The proposed design utilizes Arduino UNO as a microcontroller prototyping platform. As shown in Fig. 1, the structure consists of four main modules: (i) power supply, (ii) sensing unit, (iii) Transferring data, (iv) user interface, and (v) controlling. These modules are integrated using Arduino UNO to ensure seamless operation.

2.1 Power Supply unit

The power adapter converts the high-voltage AC power from a wall outlet to the low-voltage DC power required by the Arduino and NodeMCU. Here the power adapter has an input voltage rating of 230 V AC, which is a standard voltage used in many countries. The output of this power adapter is 5 V DC with a maximum current output of 600 mA. So, it can supply a maximum of 600 milliamperes of current to the connected devices while maintaining a stable voltage of 5 volts. As the 5 V DC output is suitable for powering microcontrollers like the Arduino and NodeMCU, which require a stable power source to operate reliably. The 600-mA current output is also sufficient for most applications, as these devices typically consume very low amounts of power. Because it's important to ensure that the output voltage and current rating are compatible with the devices being powered. Using a power adapter with a lower current rating than what is required by the device can result in the device not functioning correctly, while using a power adapter with a higher current rating than required can lead to overheating and potential damage to the device.
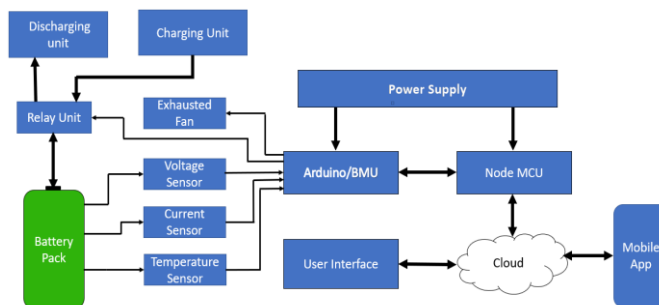
Fig. 1. Block diagram of the Cloud based smart BMS

2.2 Sensing unit

It is the essential component of the cloud-based smart battery management system. It is responsible for measuring the various parameters of the battery, such as temperature, voltage, current, and state of charge. The sensing unit consists of various sensors, including temperature sensors, voltage sensors, and current sensors.
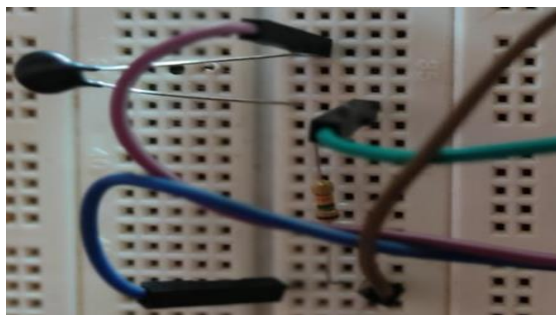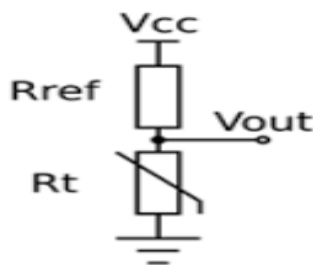
2.2.1 Temperature Sensor:

Fig. 2. Thermistor circuit

Fig. 3. Thermistor Reference circuit

The battery's temperature is gauged using the temperature sensor. It is crucial to keep an eye on the temperature of the battery since both high and low temperatures might impair the battery's function. The battery's surface is where the temperature sensor is positioned, and it continually measures the battery's temperature.

2175

2.2.2 Voltage Sensor:

Fig. 4. Voltage sensor

A voltage sensor is a critical tool for monitoring the state of charge of a battery. By continuously measuring the voltage across the battery's terminals, it provides valuable information about the battery's current level of charge. This is particularly important for maintaining the optimal performance and longevity of the battery.

2.2.3 Current Sensor

Fig. 5. Current sensor

The current sensor plays a vital role in monitoring the charging and discharging of a battery. By measuring the flow of current in and out of the battery, it provides valuable information about the battery's state of charge and overall health. The current sensor is connected in series with the battery, allowing it to continuously measure the current and provide accurate data for analysis and maintenance.
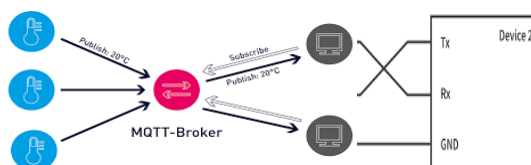
2.3 Transferring data

Fig. 6. UART & MQTT protocol
Fig. 6. MQTT

There are two important data transfer scenarios in this system between Arduino and NodeMCU and between NodeMCU and the cloud. When it comes to transferring data between the Arduino and NodeMCU, one of the most commonly used methods is serial communication. Both the Arduino and NodeMCU come equipped with built-in serial ports that enable them to communicate with each other using a serial protocol like UART. Serial communication enables the Arduino to transmit data such as battery voltage, current, and temperature readings to the NodeMCU, which are processed by the Arduino and this information is sent to the cloud for further analysis by the NodeMCU.

The NodeMCU is a microcontroller board that is often used in IoT applications, and it comes with a built-in Wi-Fi module. This module allows the NodeMCU to connect to the internet and communicate with cloud servers. To transfer data between NodeMCU and the cloud, the most common communication protocol used is Wi-Fi. Once the NodeMCU is connected to the internet, it can send data to the cloud servers. This data can be in the form of sensor readings, battery voltage, current data, or any other relevant information that needs to be monitored or analyzed. The cloud server can then use this data to perform various tasks such as analyzing battery health, predicting battery life, or optimizing charging and discharging cycles. This data can be transferred using MQTT (Message Queuing Telemetry Transport) protocol, depending on the specific requirements of the system. MQTT is a lightweight messaging protocol that is commonly used in IoT applications for sending data from sensors and devices to cloud servers. It is efficient and reliable and can handle large volumes of data without requiring significant network bandwidth or processing power.

2.4 User Interface

The user interface of the cloud-based smart BMS is designed to be simple and user-friendly. The interface provides users with all the necessary information on the state of the battery. The interface displays the state of charge, voltage, current, state, and temperature of the battery. The user interface is also designed to allow users to interact with the system. The user interface is made up of two parts; the web interface and the mobile application interface. The web interface is designed for users who access the system through a web browser. The mobile application interface is designed for users who access the system through a mobile device. The web interface is created with the help of node-red and the mobile application is created with the help of the MIT app inventor.
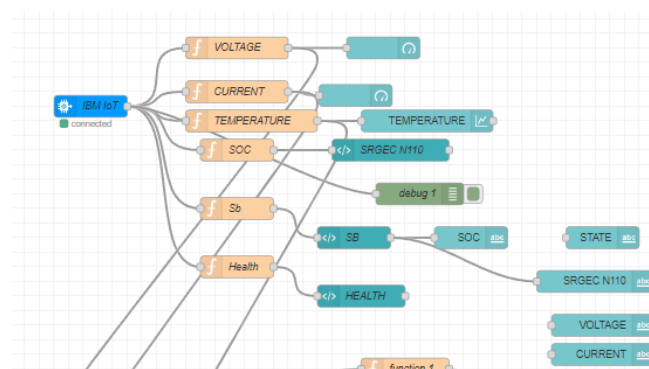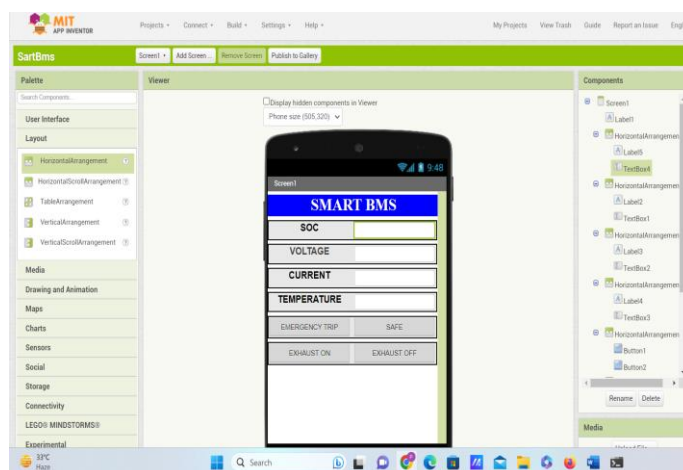

Fig. 7. Node-Red

Fig. 8. MIT app Inventor

2.4.1 Web Interface:

The web interface provides users with a dashboard that displays the state of the battery. The dashboard displays the state of charge, voltage, current, state, and temperature of the battery. The user interface also allows users to view the history of the battery's usage. The web interface also provides users with the option to control the battery. Users can control the battery's charging and discharging rates. Users can also set the battery to charge at a specific time.

2.4.2 Mobile Application Interface:

The mobile application interface provides users with a simple and intuitive interface. The interface displays the state of charge, voltage, current, and temperature of the battery. The mobile application interface also provides users with the option to control the battery. Users can control the battery's charging and discharging rates.

2.5 Controlling

Controlling mechanisms are required to ensure optimal battery performance. These mechanisms include charging and discharging control, temperature control, and state of charge (SOC) control.

2.5.1 Charging and Discharging Control

The charging and discharging of the battery need to be controlled to ensure that the battery is not overcharged or over-discharged. Overcharging can lead to thermal runaway and cause the battery to explode, while over-discharging can cause irreversible damage to the battery. The charging and discharging control can be achieved by setting the maximum and minimum voltage limits for the battery. When the battery voltage reaches the maximum limit, the charging is stopped, and when the voltage reaches the minimum limit, the discharging is stopped.

2.5.2 Temperature Control

The temperature of the battery needs to be controlled to ensure that the battery operates within a safe range. High temperatures can reduce the lifespan of the battery, while low temperatures can reduce the battery's performance. Temperature control can be achieved by setting temperature limits for the battery. When the temperature reaches the

upper limit, the charging and discharging are stopped, and when the temperature reaches the lower limit, the battery is warmed up to ensure optimal performance.
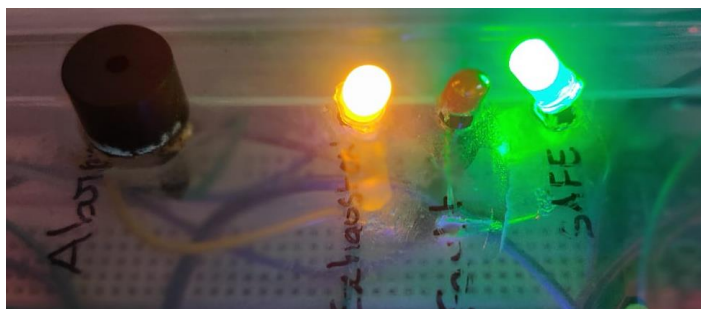

Fig. 9. Exhaust fan ON/OFF indication

2.5.3 State of Charge (SOC) Control

The SOC of the battery needs to be controlled to ensure that the battery is not overcharged or over-discharged. Overcharging or over-discharging can lead to irreversible damage to the battery. SOC control can be achieved by setting the maximum and minimum SOC limits for the battery. When the SOC reaches the maximum limit, the charging is stopped, and when the SOC reaches the minimum limit, the discharging is stopped.

III. WORKING

The proposed cloud-based smart BMS can collect real-time data from the battery unit. The local unit will gather voltage, current, and temperature data. Together with data gathering, the "Terminal Voltage Technique" is used to estimate the Soc of the battery. Then the local BMS and Wi-Fi module uses a serial communication to exchange data between them and the data will be sent to "IBM IoT W   atson" using a token authentication technique utilizing MQTT and NodeMCU. The real-time data gathered by the local unit is accessible via Node-red using IBM IoT nodes and the auth-token technique. In addition, in the event of an anomaly, we can transmit directives to the local unit. The data shown by the cloud-based BMS system demonstrates that the system was capable of gathering real-time data on battery voltage, current, temperature, and other vital characteristics. The data would be presented in an easily understood style utilizing charts and gauges by using the Dashboard nodes and custom Ui_template nodes (used to generate own models using HTML, CSS) in Node-red.
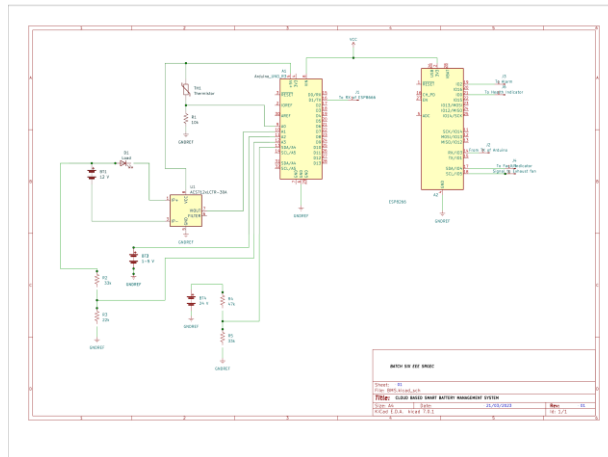
Fig.10. Proposed circuit diagram

IV. RESULTS

Here's a cloud and IoT-based smart battery management system that can be viewed and controlled remotely through the web UI and mobile app. Our project incorporates an Arduino UNO, WIFI module, and voltage, current, and temperature sensors.
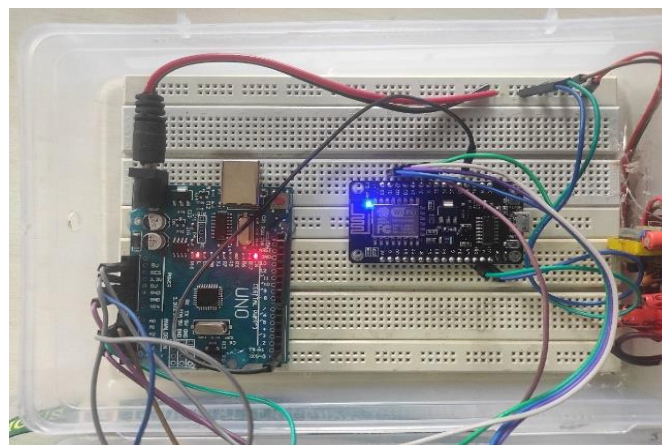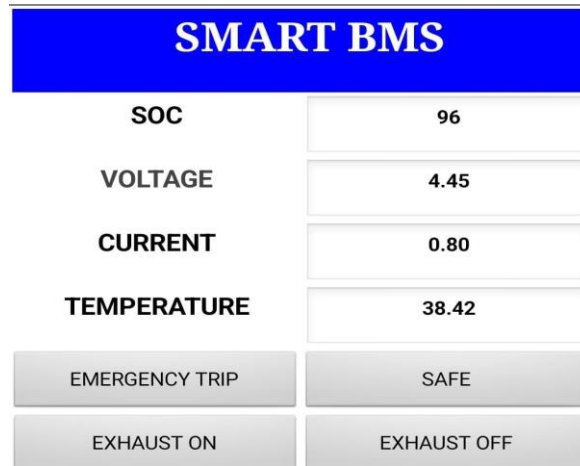

Fig. 11. Local BMU (Battery Monitoring Unit)
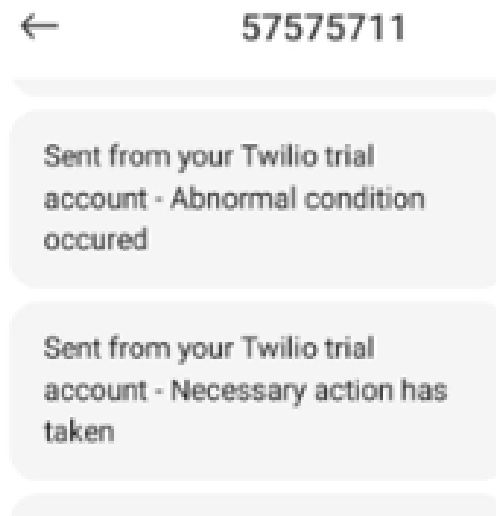
Fig. 12. Dashboard

Fig. 13. Mobile App
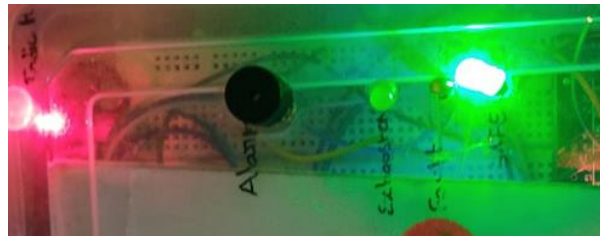

Fig. 14. Twilio Notifications

Fig. 15. Safe Indication at local BMU

Fig. 16. Fault Indication at local BMU

V. ADVANTAGES

• **Real-Time Monitoring and Control:** IoT devices enable the energy storage system to be monitored and controlled in real-time. This guarantees that energy resources are used efficiently and prevents energy waste.

• **Scalability:** Cloud-based SBMS powered by IoT devices may be readily scaled up or down dependent on energy storage needs. As a result, it is perfect for applications requiring flexibility and adaptability.

• **Remote Access:** The use of IoT devices in a cloud-based SBMS enables remote access to the energy storage system, allowing for real-time monitoring and control. This is especially beneficial for systems in remote locations or with limited access.

VI. CONCLUSION

In conclusion, the cloud-based battery management system using IoT presented in this paper is an effective and reliable solution for managing battery performance and prolonging its life. The system provides real-time monitoring of the battery's parameters and alerts in case of any issues, which allows for early detection of problems and preventive maintenance. The data analysis showed a strong correlation between the battery's state of charge and its voltage and temperature, which can be used to optimize its performance and extend its life. Our study contributes to the growing body of literature on IoT-based BMS systems and provides a valuable tool for battery management in various industries.

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