IoT Enabled Battery Status Monitoring System for Electric Vehicles

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***Abstract*—Nowadays, many types of electric vehicles are coming to market for reducing the consumption of non-renewable sources which are mainly the source of emitting harmful gases after getting used in any kind of vehicle or machine. Now, mainly battery packs are divided into four sections i) Thermal design, ii) Mechanical design, iii) Electrical design, and iv) BMS. Our energy usage is rising dramatically as generations change. Almost seldom is a continuous source of energy possible. Devices that can efficiently manage and store energy are required in such circumstances. This stored energy has to be watched over, secured, and practical. The energy that has been stored is safeguarded against overloading and overheating by an easy-to-use battery management system. In this paper, a battery balancing technique for electric vehicles is proposed. With an increase in the number of EV batteries connected directly to relays. The system's operation is to short-circuit any modules that aren't working properly and might harm the car's performance. This method effectively minimizes the cost because the complete battery wouldn't need to be changed frequently due to a damaged Module. The use of this technique lengthens the battery's lifespan and improves charging, discharging, overcharging, and other circumstances. This study proposes and implements a precise and efficient Node-RED electrical battery management system.**

Keywords—Battery Management System, Electric Vehicle, Internet of things, Lithium Ion, Node-Red

I. INTRODUCTION

Electric vehicles (EVs) will replace conventional fossil fuel-powered automobiles (diesel/petrol) at an exponential rate in the upcoming years. However, this exponential rate will increase the advancement in technology and better management system. An electric vehicle (EV) is a type of vehicle that runs on electricity instead of gasoline or diesel fuel [1]. There are several benefits to owning and driving an electric vehicle. First, EVs produce zero emissions, meaning they do not produce harmful pollutants or greenhouse gases that contribute to air pollution and climate change. This makes EVs a more environmentally friendly option compared to traditional gasoline-powered vehicles. Second, EVs are typically cheaper to operate and maintain compared to traditional vehicles, due to lower fuel costs and less maintenance required. The cost of charging an electric vehicle is usually much less than the cost of filling up a tank with gasoline or diesel. Additionally, EVs have fewer moving parts and require less maintenance, which can result in lower repair costs. Third, EVs offer a more comfortable and quiet driving experience. They are typically equipped with features that make driving more enjoyable, such as smooth and quiet acceleration, instant torque, and a cabin that is free from engine noise. Fourth, EVs help to reduce dependence on oil and improve energy security. Since EVs are powered by. electricity, they can be charged using a variety of sources, including renewable energy sources like wind and solar power. This reduces our dependence on finite and often imported oil supplies and helps to improve energy security. However, there are also some challenges associated with EVs. For example, the initial cost of an EV can be higher than a traditional vehicle and charging infrastructure is still limited in many areas. Additionally, the range of some EVs is limited, which can be an issue for long-distance driving [2]. One of the key problems is battery optimization, which involves keeping the module of the battery's health state and alerting the user or client. Other problems include the battery's limited load-bearing capacity, inability to climb steep inclines, and its overall high maintenance and repair costs [3].

BMS (Battery Management System) was introduced as a solution to these problems. Currently, there is no way to detect a specific broken cell module in a battery using the traditional BMS architecture [4]. As a result, we are recommending a new feature for the BMS Architecture that makes use of AI and ML, allowing the BMS to identify the precise cell module that is malfunctioning (over the course of a battery's normal life-cycle) from among all the other cell or battery modules and disconnect it from the others [5]. By doing this, we lower the cost of battery maintenance since the client or user now just needs to replace that one module of faulty cells. A collection of battery cells is protected, monitored, and equalized by each of the Smart Battery Modules (SBMs) in BMS. Assurance of the battery when any kind of fault occurs in the system [6].

A Battery Monitoring System (BMS) is a device that is used to monitor the health and performance of a battery or a battery bank. It is commonly used in applications such as electric vehicles, renewable energy systems, backup power systems, and data centers, where the performance and reliability of batteries are critical. The main functions of a BMS are to monitor battery voltage, current, temperature, and State of Charge (SOC) to protect the battery from over-charging, over-discharging, and over-temperature conditions. Balance the charge across individual battery cells in a multi-cell battery bank. Provide real-time performance data and alerts to the user or system operator. A typical BMS consists of several components, including Battery sensors: These sensors measure the voltage, current, temperature, and SOC of the battery. Control module: This module processes the data from the battery sensors and determines the state of the battery. Protection circuits: These circuits protect the battery from over-charging, over-discharging, and over-temperature conditions. Balancing circuit: This circuit equalizes the charge across individual battery cells in a multi-cell battery bank. Communication interface: This interface allows the BMS to communicate with other devices, such as a battery charger, inverter, or remote monitoring system. A well-designed BMS can help to prolong the life of a battery, improve its performance, and reduce the risk of safety hazards. It can also provide valuable data for system optimization and troubleshooting. A Smart Battery Management System (BMS) is a technology that is used to monitor and manage the performance of batteries. Batteries are commonly used in a variety of applications, such as electric vehicles, renewable energy systems, and consumer electronics. The performance of a battery depends on several factors, such as temperature, state of charge, and age. A Smart BMS continuously monitors these parameters and adjusts the charging and discharging of the battery, to optimize performance and extend its lifespan. Smart BMS technology uses sensors, microcontrollers, and software algorithms to collect and analyze data on the battery's state of health, and to make decisions on how to charge or discharge the battery. For example, the BMS may adjust the charging rate based on the temperature of the battery, or limit the depth of discharge to prolong the life of the battery. Smart BMS can also communicate with other devices or systems, such as electric vehicle chargers or renewable energy systems, to optimize the performance of the entire system. For example, the BMS can adjust the charging rate of an electric vehicle to match the output of a renewable energy system, to ensure that the vehicle is charged with clean energy. The benefits of a Smart BMS include improved battery performance, longer battery life, and increased safety, as the BMS can detect and prevent overcharging, over-discharging, or other conditions that could damage the battery [7], [8], [9].

The idea of using Internet of Things (IoT) techniques to monitor performance of the vehicle is proposed to carry out the monitoring directly. The two main components of the proposed IoT-based battery monitoring system are the user interface and the monitoring device [10]. The online monitoring terminal includes a GPRS data transmitter unit and an upper computer with software for the battery online monitoring system for measuring battery parameters. It can evaluate the status of the battery, create a database to make data storage and retrieval simpler, and measure the various operating parameters of the battery in real-time [11].

The Internet of Things (IoT) is a system of interconnected computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The IoT allows physical objects to be connected to the internet, enabling them to collect and exchange data, perform automated tasks, and interact with other devices or systems. This technology has a wide range of applications, including home automation, smart cities, industrial automation, healthcare, agriculture, and environmental monitoring. IoT devices are often equipped with sensors, which enable them to gather data on their environment, such as temperature, humidity, motion, and light. This data can then be used to automate tasks, optimize performance, and enhance efficiency. However, the increased connectivity and data sharing of IoT devices also raise concerns about privacy, security, and the potential for misuse or hacking.

Industrial IoT (IIoT) refers to the use of Internet of Things (IoT) technologies in industrial settings, such as manufacturing, energy, transportation, and logistics. The goal of IoT is to improve operational efficiency, reduce costs, and enhance productivity by connecting machines, equipment, and processes to the internet, and enabling them to exchange data and communicate with each other. This can lead to better decision-making, improved asset utilization, and increased production capacity. IIoT devices often use sensors and other technologies to collect data on various aspects of the production process, such as temperature, pressure, vibration, and energy consumption. This data is then analyzed in real-time or stored for later analysis, to identify patterns, anomalies, or opportunities for optimization. Examples of IIoT applications include predictive maintenance, where sensors are used to monitor the health of machines and equipment and predict when maintenance is required before a breakdown occurs. Another example is asset tracking, where RFID tags or GPS sensors are used to track the location and movement of products or materials, throughout the supply chain. IIoT also raises cybersecurity concerns, as increased connectivity and data sharing can expose industrial systems to cyberattacks, and potentially compromise safety and productivity. Therefore, security and privacy are important considerations in the design and implementation of IIoT systems [12].

II. Methodology

A. Wireless Battery Monitoring System

The battery monitoring system collects the data for real-time analysis. The PLC-based monitoring system uses SCADA and GSM modules if any temperature changes. In Industry the continuity of the power supply should be maintained which is supplied by wireless communication monitoring system. Various studies on the development of monitoring the battery wireless communication system [13].

The wireless battery monitoring system has two modules. Transmit module monitors the batteries and the controller module receives the status of the battery. This design is applied by developing a battery monitoring system of 2.4GHz. Wireless battery management system increases the reliability of the battery, consumes less power, low cost and collect data related to voltage, current, and temperature in addition to Wi-Fi communication [13].

B. Safety of Li-ion Batteries

First, a method for evaluating the safety of lithium-ion batteries by making use of data found online. Preventing irreversible damage and maintaining the safety of the battery, energy storage system requires precise predictions in advance of a failure. Method for risk assessment and an idea for research to create high-safety battery systems. Both internal and external factors can lead to lithium-ion battery failure. The internal explanation primarily suggests the possibility of the error in physical and chemical changes. The primary external factors are thermal and electric abuse, which are brought on by over-charging, over-discharging, high-power charging, overheating, and supercooling, all of which are regarded as damage [14].

C. Identification of Damaged Module

The battery management system detects the basic parameters like current, temperature, and voltage with the help of the controller and sensors [7]. In Second Method, the damaged module is identified by the ESP32 relay module. The signal is sent to the relay to separate the identified damaged module of the battery. Relays attached to the damaged module will get a signal to switch off. The remaining relays will be intact. We could dynamically isolate the broken module from the main battery as per our proposed work as explained in Fig.1.

The proposed work is to monitor each battery module. The Module voltage is sensed in the interval of 15 minutes and measured. When the vehicle switched ON, the voltage information is communicated to an ESP32/Node MCU in every 15 minutes. The output of modified data of voltage sent from the ESP32/Node MCU to a Raspberry Pi utilizing Node-Red [12].

D. Detection of the fault in the modified Battery Module

When the damaged module disconnected from the main battery, the ESP32 gives the signal to temperature and current sensors to get full detailed information about the whole battery and damaged isolated module. The same information is conveyed to the admin simultaneously. Now, admin will send a notification to the cloud server as it is a record of a particular vehicle from the purchase date to the scrap date of any vehicle which is connected to this monitoring system. It will help to get the details of the fault or loopholes of any mechanism or making of any vehicle. As per our research point of view, it can help to increase the precision of the system connected to the Raspberry Pi which is installed on our side. Simultaneously, one notification sends to the LCD of the vehicle to warn the customer to change the battery module from the near service center of that vehicle.

E. Capability of the Battery Module

The customer would also receive a notification through email that one of his battery modules in the vehicle had been disconnected for security reasons. The data would be saved in the cloud and can be used for data for future improvements for increasing the efficiency and reliability of the battery. This will allow us to train and enhance our model for categorizing the cell modules using machine learning and artificial intelligence in the future.

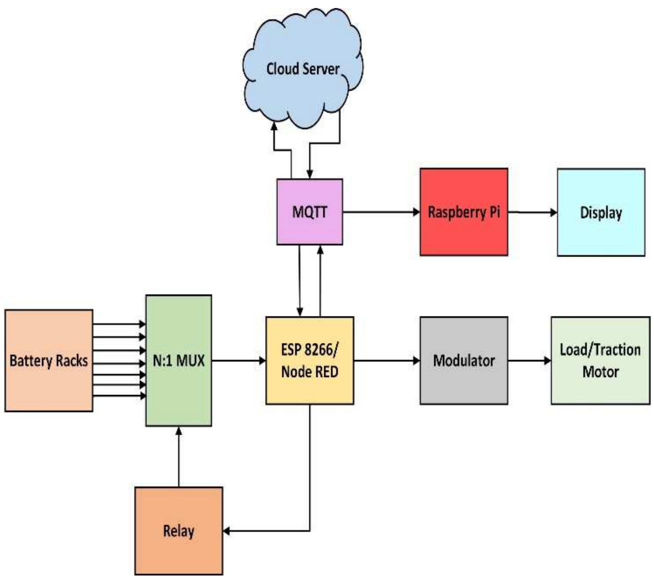

Fig. 1. Block Diagram of Modified Battery Module

III. Flow Chart of the Modified Battery Module

Fig. 2 describes the flow chart of the proposed work. The first step is to initialize ESP32 and all the systems connected to it. The second step is to sense the voltage of each module of the battery. The third step is to find the fault in the battery. If the module of the battery is not working properly then go to the fourth step and sixth steps otherwise go back to the second step. In the fourth step observe the current and temperature of the whole battery. The fifth step is the information of the isolated module is sent to the admin and sends the message to the customer and goes to the final step. The sixth step is to send the signal to the relay. The seventh step is to disconnect the selected faulty module. The final step will end the process. With this whole process, we can get the exact value of the individual modules as well as we can store it in the cloud for future improvement as references.

IV. Results and Discussion

The eight battery modules demonstrate the battery of the electric vehicle. Twelve cells make up each battery module. Since each cell is thought to have a nominal voltage of 3.7V, the nominal voltage of a battery module will be 44.4V when it is fully charged at 4.2V to 4.35V, as shown in Fig.3. The monitoring system begins sensing the voltage of the entire battery, specifically of each battery module, when the

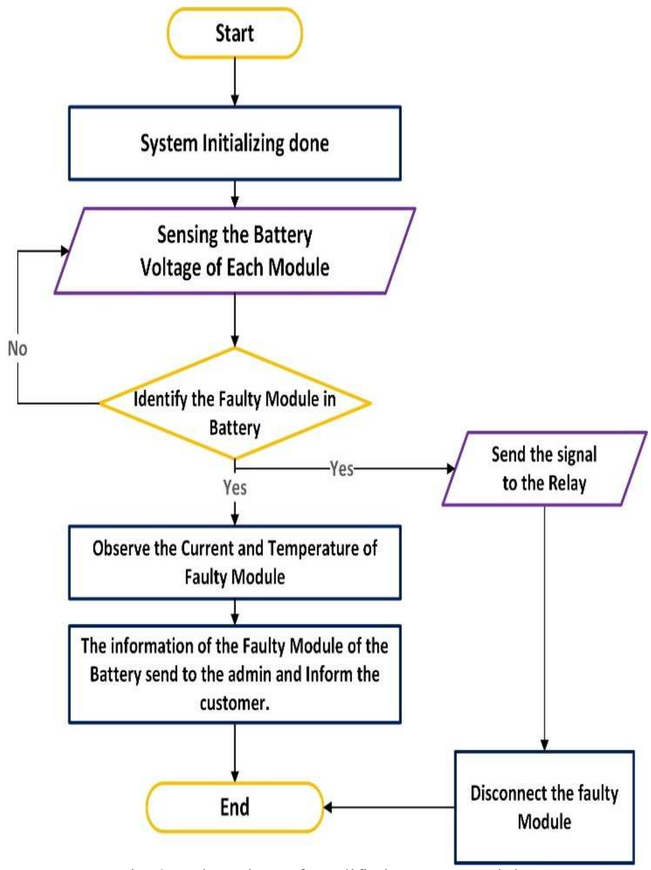

Fig. 2. FlowChart of Modified Battery Module

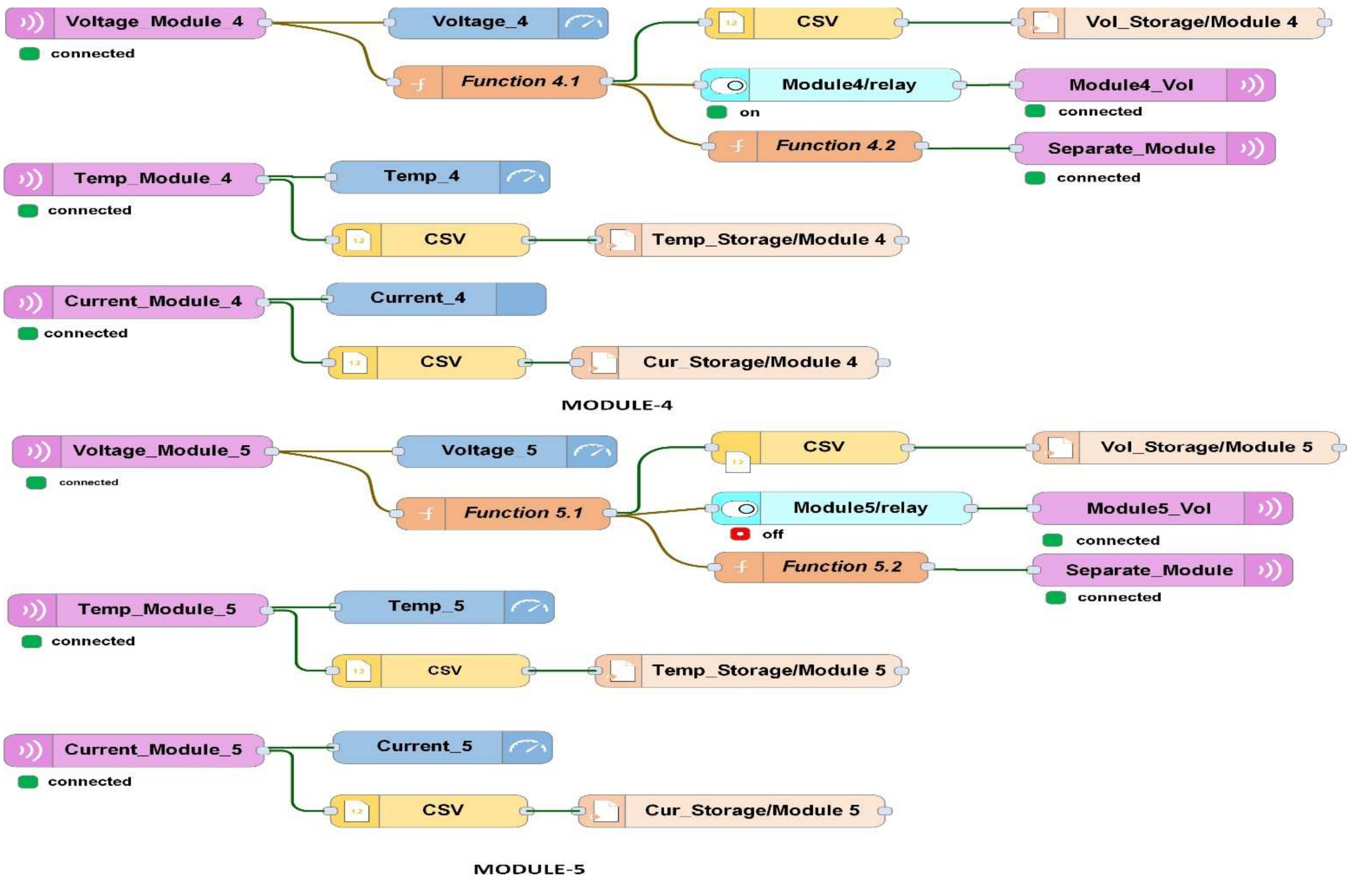

Fig. 3. Representation of Modified Battery Modules

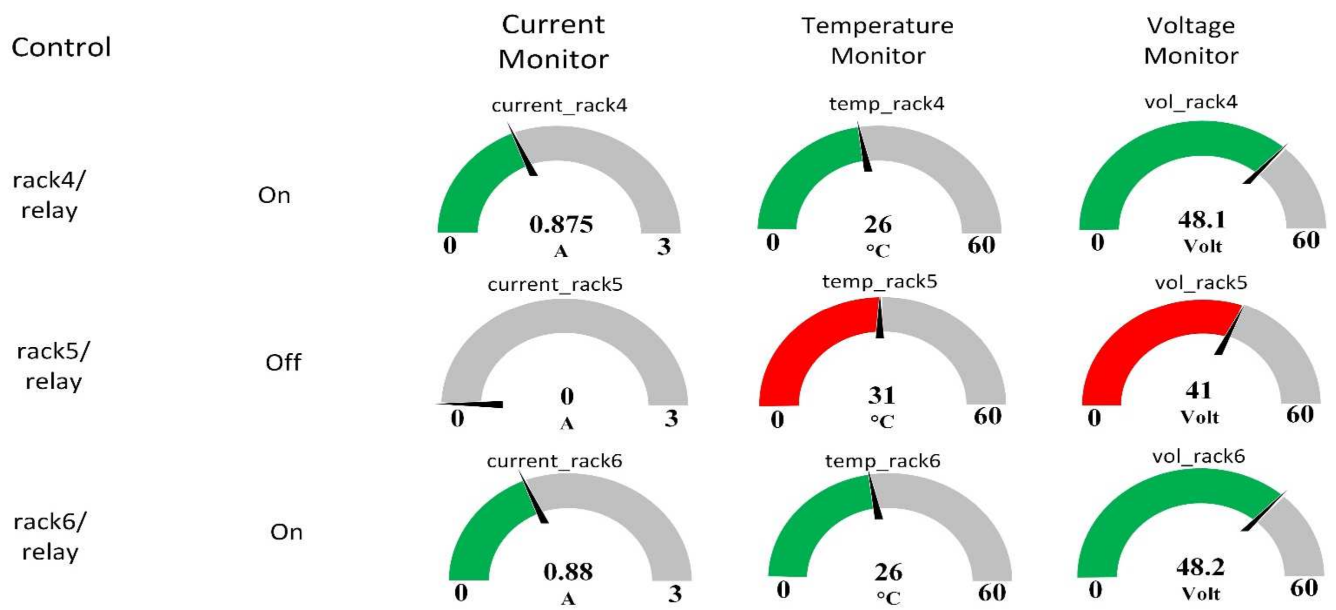

Fig. 4. Monitoring of C,V &T of Rack 4,5,6

vehicle's power is turned on through the owner's switch or keys. The voltage sensor is sensing each module. Through the ESP32/Node MCU, the signal is transmitted to the relay for use. If the fault is not found in the first module, check the second module of the battery. If the fault is found in the first module, the signal for isolating the first module will be received by the relay. The loop is made up of the entire process. This procedure continues until the final battery module. When the error is identified ,the faulty module is released from the relay module, which is controlled by the ESP32/Node MCU, that uses the MQTT protocol to communicate with the cloud server, the Raspberry Pi, and send the notification. The data about every particular problem with the vehicle is stored using both a Raspberry Pi and a cloud server. Only two modules are shown in the Fig. 3, with module 4 functioning and module 5 being disconnected by

Fig. 5. Monitoring of Current voltage and Temperature

relay after the defective module was identified. Fig. 5 is showing the monitoring status of current ,voltage and temperature for clear appearance of the same figure only 3 racks is shown in Fig. 4.

V. CONCLUSION

Overall, electric vehicles offer several advantages over traditional gasoline-powered vehicles and are an important step toward a more sustainable future. As technology continues to improve and the charging infrastructure expands, more and more people will likely switch to EVs. The charging infrastructure includes a charging station powered by batteries. EVs will use batteries for electricity, but there will be increasing demand in the near future. The proposed work is emphasising more on the battery of the EV while running and it is connected to the cloud server. The status of the battery is monitored by ESP32/Node MCU. The voltage of each module is obtained and if the fault is detected then that module is isolated. As per the proposed work, the load (Motor of the EV) is still able to run after the isolation of the faulty module.

A. Abbreviations and Acronyms

MCU Microcontroller unit.
MQTT Message queuing telemetry transport.
IoT Internet of things.
UART Universal asynchronous receiver/transmitter.
GPS Global positioning system.
API Application-programming interface.
CA Cloud analytics.
SOH State of health.
BMS Battery management system.
EV Electric vehicle.
Li-ion Lithium ion.
LCO Lithium cobalt oxide
HEV Hybrid electric vehicle.
CAN Control area network.
ECU Electronic control unit.
EMF Electromotive force.
SOC State of charge.
OCV Open-circuit voltage.
AI Artificial Intelligence
ML Machine Learning

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