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Design and Development of a Battery Monitoring System for EV Applications

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Abstract: *For electric vehicle (EV) applications, a battery monitoring system is essential for assuring the performance, dependability, and safety of the vehicle. We demonstrate the effectiveness of the electric car in this project. A battery is an electric vehicle's only energy source, but as the quantity of energy delivered to the vehicle declines over time, the vehicle's performance degrades. The manufacturing of batteries is quite concerned about this. In order to do the monitoring directly, it is suggested in this study that IoT approaches be used to monitor the functioning of the vehicle. The user interface and the monitoring device are the two main components of the proposed IoT-based battery monitoring system.*

The widespread adoption of electric vehicles (EVs) has led to an increased demand for battery monitoring systems (BMS) that can accurately and reliably monitor the health of battery packs. With the advent of the Internet of Things (IoT), it is now possible to create BMS solutions that are more powerful, flexible, and cost-effective than ever before. IoT-based BMS solutions typically consist of a network of sensors, microcontrollers, and communication interfaces that work together to measure and analyze the performance of battery packs. These systems can provide real-time monitoring of battery health, which can help to prolong battery life, reduce maintenance costs, and increase safety.

One key advantage of IoT-based BMS solutions is their ability to leverage the power of cloud computing. By connecting the BMS to the cloud, it is possible to store and process large amounts of data, and to access this data from anywhere in the world. This allows manufacturers and operators to monitor the performance of their batteries in real-time, and to make informed decisions about how to optimize their usage. Another advantage of IoT-based BMS solutions is their ability to support remote diagnostics and maintenance. By accessing the data stored in the cloud, technicians can identify and diagnose faults in battery packs from a remote location. This can save time and money, as it eliminates the need for technicians to travel to the location of the battery pack.

IoT-based BMS solutions can also support predictive maintenance, which involves using data analytics and machine learning algorithms to predict when a battery pack is likely to fail. By monitoring the performance of batteries over time, it is possible to identify patterns and trends that can be used to predict when a battery pack is likely to fail. This can help manufacturers and operators to schedule maintenance and replacement activities in advance, which can reduce downtime and maintenance costs. One key challenge in developing IoT-based BMS solutions is ensuring the security and reliability of the system. Battery packs are critical components in EVs, and any failure or malfunction can have serious consequences. Therefore, it is essential to ensure that the BMS is designed to be secure and reliable.

One way to address this challenge is to use secure communication protocols to transmit data between the battery pack and the cloud. This can include using encryption and authentication mechanisms to ensure that data is not intercepted or tampered with during transmission. Another approach is to use redundancy and fault-tolerance mechanisms to ensure that the BMS can continue to operate even in the event of a failure or malfunction. This can include using multiple sensors and communication interfaces and implementing failover mechanisms to ensure that data is always available.

In conclusion, IoT-based BMS solutions are powerful tools for monitoring the health of battery packs in EVs. By leveraging the power of cloud computing, these systems can provide real-time monitoring, remote diagnostics, and predictive maintenance capabilities. However, it is essential to ensure that these *systems are secure and reliable, in order to prevent any failure or malfunction that could have serious consequences. As the adoption of EVs continues to grow, the development of reliable and efficient BMS solutions will be critical to the success of this industry. The system is able to recognize experimental outcomes' degraded performance and alerts the user for further actions.*

Keywords: *EVs*

I. INTRODUCTION

1.1 INTRODUCTION

Since fuel prices are rising, electric vehicles are becoming more and more common. Many automakers are searching for alternative energy sources to petrol as a result of these possibilities. Since there is less pollution, using electrical energy sources may help the environment. Additionally, electric vehicles have several benefits for the environment and for conserving energy. Since lithium-ion batteries are smaller than lead-acid batteries, provide continuous power, and have an energy cycle that is 6 to 10 times larger than that of lead-acid batteries, they are utilized in the majority of electric vehicles (EVs). Deep charges and charging can both affect the lifespan of lithium-ion batteries.

On the other hand, because of the size of the battery and the body structure, electric vehicles often have a restricted range of travel. Now, the safety of current battery technology is a key factor that restricts application [1]. As an illustration, overcharging a battery can result in a significant safety incident like a fire [2-4]. To avoid the aforementioned issues, an EV battery monitoring system that can alert the user to the battery's condition is required.

1.1.1 Motivation

The previous battery monitoring system could only monitor, detect, and alert the user through a battery indicator within the car when the battery was in bad shape. Internet of Things (IoT) technology may be utilized to inform the manufacturer and consumers about the battery state with the help of improvements in notification system design. This might be viewed as one of the maintenance support procedures that the manufacturer could carry out. Beyond traditional applications, IoT makes advantage of internet connectivity to link a wide variety of objects and daily items, putting the entire world at the user's fingertips. The suggested design and development of a battery monitoring system utilizing IoT technology is motivated by the challenges mentioned above.

1.1.2 Objectives

Our project aims at developing an efficient and accurate system to monitor battery parameters and predict battery SOC. A system that can provide real-time monitoring of the battery can help the user know when to get their battery checked in case of irregular charging/discharging cycles or overheating. Such a system can also help to trigger the safety protocol in case of emergency to reduce the chances of battery explosions. We aim to make a system that uses effective methods to predict the battery health accurately hence reducing the safety concerns related to EVs.

1.1.3 Scope of the Work

The battery monitoring system consists of an ESP-32 module utilized along with other components such as a voltage sensor module, a current sensor, GPS, an SD card module, Node MCU, relay, optocoupler, resistors, and a load. The system is designed to monitor the state of charge (SOC) of a 3S lithium-ion battery with a nominal voltage of 11.1V. The SOC is a critical parameter that indicates the amount of energy remaining in the battery. The voltage sensor module is used to measure the battery voltage, while the ACS712 current sensor is used to measure the battery current. By integrating these two measurements, the system can estimate the SOC of the battery with high accuracy. To enhance the functionality of the system, a GPS module is integrated to provide location-based information, which is useful for tracking the vehicle's movement and calculating its energy consumption. The system also includes an SD card module to store the data collected by the sensors for later analysis. To ensure the safety of the battery and the vehicle, the system incorporates a relay and optocoupler to control the load and protect against overvoltage, overcurrent, and short-circuit conditions. Overall, the battery monitoring system developed in this project provides an efficient and reliable way to monitor the SOC of an EV battery, which is critical for optimizing the vehicle's performance and extending its battery life.

1.2 ORGANIZATION OF THESIS

1. **INTRODUCTION** : The introduction discusses the need for economical and dependable BMS technology for electric and hybrid cars. It analyzes current cutting-edge technologies, finds gaps in the literature, and provides the research issues that the article will attempt to answer.
2. **LITERATURE SURVEY**: This section provides an in-depth examination of the literature on Battery Monitoring Systems (BMS) for electric and hybrid cars. It examines present technology as well as the problems that must be overcome in order to increase the efficiency and reliability of converters.
3. **PROPOSED SYSTEM**: The suggested IoT-based BMS design and operating methodology are presented in this section. It discusses the main benefits and characteristics of the system, such as its high efficiency, the low voltage stress on switches, and its high voltage gain transfer ratio.
4. **EXPERIMENTAL SETUP AND RESULT**: The suggested IoT-based battery monitoring system's experimental setup and findings are presented in this section. The system has the ability to identify experimental results with decreased performance and warn the user of additional steps.
5. **CONCLUSION**: The conclusion summarizes the research paper's key findings and examines the implications of the proposed Battery Monitoring System for electric vehicle applications. It also discusses the study's weaknesses and gives recommendations for further research.

II. PROJECT DESCRIPTION

2.1 OVERVIEW OF PROJECT

The properties of a battery, State-of-Charge (SoC) and State-of-Health (SoH), are significant because they have a direct impact on how well the battery performs. Thus, the battery management system we developed has an in-built monitoring system and the data is sent via an app to our phones.

2.2. MODULES OF THE PROJECT

The Battery Monitoring System consists of hardware components integrated with a Software App. In a nutshell, this project contains two modules each contributing to forming an efficient monitoring system.

2.1.1 Module 1

The hardware module and its working is illustrated using the flowchart below:

A battery consisting of 3 cells with each cell having a voltage of 3.7V is arranged to form a 3S pack. When the device is turned on, the battery supplies voltage to the current and voltage sensors. The current and voltage sensors, connected in series and parallel respectively to the battery pack, send the voltage to the buck converter. The buck converter steps down the voltage(from 11.1V to 5V) and generates the input voltage for the microcontroller. The ESP32 module has multiple connections. Firstly, it is connected to the GPS which has a patch antenna to detect the location coordinates better. Secondly, it is connected to an SD card module which stores the data generated for further research. Thirdly, it is connected to a relay. The relay ensures that an overvoltage problem does not occur and cuts off the voltage at 10V. Fourthly, the load (LED strip of 10W) and finally a display showing the output is connected to the module.

2.1.2 Module 2

The software component of the project comprises a Blynk app integrated into the hardware circuit. The inbuilt Wifi module of the Node MCU allows us to do this. To satisfy the objective of real-time monitoring, the parameters can be sent to the Blynk website as well as our phone(Blynk App). The code is executed using Arduino IDE. Furthermore, the SD card module is used for storing data, which is also coded in the IDE. The app or website displays the voltage of the battery(present), current of the battery(present), SOC of the battery and the coordinates of the location of the battery(present). Moreover, the coordinates generate a link which is connected to google maps for easier accessibility to the location.

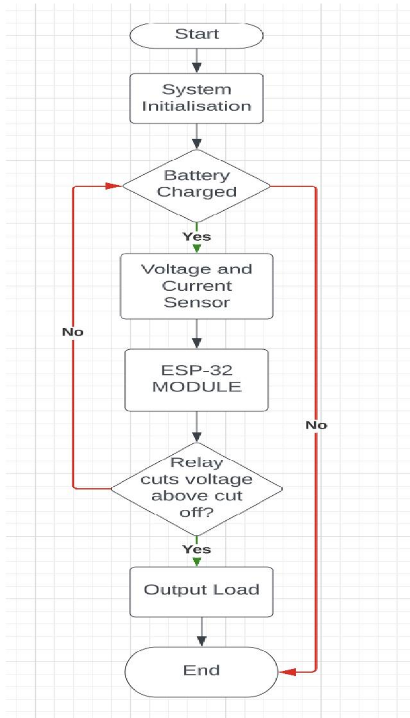

Figure 1: Hardware Flowchart

2.3 LITERATURE SURVEY

In paper[1], The paper provides an overview of the current status and development trends of batteries for electric vehicles (EVs). The authors first discuss the importance of EVs in reducing greenhouse gas emissions and dependence on fossil fuels. They then describe the various types of batteries used in EVs, including lead-acid, nickel-cadmium, nickel-metal hydride, and lithium-ion batteries. The authors analyze the advantages and disadvantages of each type of battery and compare their performance in terms of energy density, cycle life, cost, and safety. They also discuss the challenges facing battery technology, such as the need to improve energy density, reduce cost, and enhance safety. Finally, the authors present their view on the development trends of batteries for EVs, including the increasing use of lithium-ion batteries, the development of new electrode materials, and the improvement of battery management systems. They conclude that the development of battery technology is critical for the widespread adoption of EVs and that significant progress has been made in recent years, but there is still much room for improvement.

In paper[2], discusses the importance of a battery management system (BMS) for ensuring the safety and reliability of the battery system in electric vehicles (EVs). The paper describes the key functions of a BMS, including state estimation, balancing, and protection, and analyzes the different techniques used to perform these functions. The authors discuss the state estimation and balancing techniques used to estimate the state of charge (SOC) and equalize the SOC of each battery cell to improve performance and extend the lifespan of the battery pack. The authors also present the protection functions of a BMS, including overvoltage protection, under voltage protection, overcurrent protection, and over-temperature protection. Finally, the authors summarize the current status and future trends of BMS development, emphasizing the need for further research and development in BMS technology to meet the increasing demands of the EV market.

In paper[3], a battery management system (BMS) based on the Local Interconnect Network (LIN) bus protocol for electric vehicles (EVs). The paper describes the hardware and software architecture of the BMS and the communication protocol used to transmit data between the battery pack and the BMS. The authors present experimental results showing the accuracy and reliability of the BMS for measuring the state of charge (SOC), state of health (SOH), and battery temperature, and for providing protection against overvoltage, undervoltage, and over-temperature conditions. The paper concludes by highlighting the advantages of the BMS based on the LIN bus, including low cost, high reliability, and compatibility with other automotive systems, and suggests further research to improve the efficiency and performance of BMS for EVs.

In paper [4], proposes a new generalized battery management system (BMS) designed to be compatible with various battery technologies and sizes. The paper describes the key functions of a BMS, including state estimation, balancing, and protection, and highlights the importance of BMS for electric vehicles and renewable energy systems. The authors present the design and implementation of the BMS based on a modular architecture and describe the hardware and software components of the BMS, including the battery sensors, state estimation and balancing algorithms, and protection circuitry. The paper also presents experimental results of the BMS using lead-acid and lithium-ion batteries, demonstrating the accuracy and reliability of the state estimation and balancing functions, and protection against overvoltage, undervoltage, and over-temperature conditions. The paper concludes by summarizing the advantages of the proposed BMS and suggesting future research to improve its performance and efficiency.

In paper [5], proposes the importance of monitoring battery performance in industrial settings and outlines the key parameters that need to be monitored, including voltage, current, temperature, and state of charge. The authors describe the hardware and software components of the battery monitoring system, including the PLC, analogue-to-digital converter (ADC), sensors, and user interface. The paper presents experimental results demonstrating the accuracy and reliability of the battery monitoring system for real-time measurement of the voltage, current, and temperature of lead-acid batteries. The paper concludes by highlighting the advantages of using PLC for battery monitoring, including flexibility, scalability, and ease of integration with other industrial systems, and suggests future research to improve the system's performance and functionality.

In paper [6], proposes a GA-based approach to cluster power networks for analysis and control. The authors present a GA-based clustering algorithm that optimizes power network clustering by minimizing inter-cluster power flow and maximizing intra-cluster power flow. The paper describes the fitness function, chromosome representation, and genetic operators used in the optimization process. Experimental results demonstrate the effectiveness of the GA-based clustering approach for power networks with different sizes and topologies, showing the accuracy and efficiency of the algorithm in producing optimal clustering solutions. The paper concludes by emphasizing the advantages of GA-based clustering, including its ability to handle complex nonlinear optimization problems and incorporate various constraints and objectives. The authors suggest future research to improve the performance and applicability of the GA-based clustering approach in real-world power systems.

In paper [7], proposes an Internet of Things (IoT)-based battery management system (BMS) for hybrid electric vehicles (HEVs). The paper emphasizes the importance of BMS for the efficient operation of HEVs and presents a novel approach to address the limitations of conventional BMS.The authors describe the design and implementation of the proposed IoT-based BMS, which includes sensors for measuring battery parameters, a microcontroller unit (MCU) for data acquisition and processing, and a wireless communication module for transmitting data to the cloud. The paper also includes a detailed analysis of the data obtained from the BMS, highlighting the effectiveness of the proposed approach in monitoring the state of the battery and predicting its remaining life.The paper concludes by emphasizing the advantages of the proposed IoT-based BMS, including real-time monitoring, remote access, and predictive maintenance capabilities. The authors suggest future research to enhance the performance and scalability of the proposed BMS for large-scale HEV applications.

In paper [8], provides an extensive review of the key issues related to lithium-ion battery management systems (BMS) in electric vehicles (EVs). The paper emphasizes the critical role of BMS in ensuring the safe and reliable operation of lithium-ion batteries in EVs and highlights the challenges and opportunities in the field of battery management. The authors discuss various aspects of lithium-ion battery management, including cell modeling and characterization, state of charge (SOC) and state of health (SOH) estimation, thermal management, and safety issues. The paper also covers the latest developments and trends in the field of lithium-ion battery management, such as the use of artificial intelligence and machine learning algorithms for improved battery performance and management. The paper concludes by emphasizing the need for continued research and development in the field of lithium-ion battery management, particularly in the areas of battery modeling and estimation, thermal management, and safety. The authors suggest that a holistic approach to battery management, incorporating advanced algorithms and real-time monitoring, is necessary for the efficient and safe operation of lithium-ion batteries in EVs. In paper [9], presents the design and implementation of a smart wireless battery monitoring system (BMS) for electric vehicles (EVs). The paper highlights the importance of BMS in ensuring the safe and efficient operation of EVs and presents a system that utilizes wireless communication and smart sensors to monitor battery performance in real time. The authors describe the various components of the BMS, including the smart sensors, a microcontroller unit (MCU), a wireless transceiver, and a user interface. The paper also presents the design and implementation of the battery management algorithm, which uses data from the smart sensors to estimate the state of charge (SOC) and state of health (SOH) of the battery. The paper includes experimental results demonstrating the effectiveness of the wireless BMS in accurately estimating battery performance parameters and detecting faults in the battery system. The authors conclude by highlighting the potential of the wireless BMS to improve the safety, reliability, and efficiency of EVs and suggesting future research directions, such as the integration of machine learning algorithms for improved battery management.

In paper [10], presents the design and implementation of an Internet of Things (IoT)-based battery monitoring system (BMS) for electric vehicles (EVs). The paper highlights the importance of BMS in ensuring the safe and efficient operation of EVs and presents a system that utilizes IoT technologies to monitor battery performance in real time. The authors describe the various components of the BMS, including the sensors, microcontroller, Wi-Fi module, and cloud platform. The paper also presents the design and implementation of the battery management algorithm, which uses data from the sensors to estimate the state of charge (SOC) and state of health (SOH) of the battery. The paper includes experimental results demonstrating the effectiveness of the IoT-based BMS in accurately estimating battery performance parameters and detecting faults in the battery system. The authors conclude by highlighting the potential of the IoT-based BMS to improve the safety, reliability, and efficiency of EVs and suggesting future research directions, such as the use of artificial intelligence and blockchain technologies for improved battery management.

2.4 TASKS AND MILESTONES

Sr no	Dates	Title	Description
1.	1/11/22	Completion of research and selection of components and technologies	Completed Literature Survey and decided objectives and goals of the project
2..	24/11/22	Review 1	The project was undertaken as our idea was pitched onto the panel for further acceptance of the project and on how it was to be implemented
3.	15/01/23	Completion of MATLAB prototype and Initial Stages of Hardware Development	Research and selection of components and technologies, such as microcontroller boards, sensors, communication protocols, and cloud platforms
4..	08/02/23	Review 2	This review entailed the simulation and further work that needed to be done for the completion of the project
5.	26/02/23	Starting of Hardware Prototype development	• Design and development of the hardware prototype, including the integration of sensors, power management, and wireless

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			communication. ● Design and development of the software for the microcontroller, such as firmware for reading sensor data, managing power consumption, and controlling the relay.
6.	10/03/23	Completion of cloud platform integration	Integration of Blynk App with the hardware prototype
7.	15/03/23	Completion of testing and validation	Testing and validation of the system, including the calibration of sensors, verification of power efficiency, and evaluation of user experience.
8.	08/04/23	Review 3	A review which dealt with the project in itself and of any more touch-ups that could be done to improve the project
9.	25/04/23	Final Review	The final review of the project

III. DESIGN AND DEVELOPMENT

3.1 DESIGN APPROACH

Battery packs are rapidly being used in a wide range of electrical gadgets, from portable power banks to electric cars. As a result, efficient battery management has become critical, particularly in terms of monitoring and managing current and voltage levels. The battery pack used has three cells connected in series. Each cell has a nominal voltage of 3.7 volts, for a total nominal voltage of 11.1 volts. The aim here is to get higher voltage levels which this configuration provides. Sensors which are placed parallel to the battery pack are used to monitor the battery pack's current and voltage levels accurately.

The voltage output from the battery pack is stepped down to 5 volts using a buck converter to achieve a lower stable regulated voltage level. The NodeMCU, which is linked to the buck converter, is in charge of receiving and processing data from the current and voltage sensors. It is also connected to a relay which in turn uses an optocoupler to switch high voltages and currents. The display is linked to the NodeMCU and displays the battery pack's current and voltage levels. The GPS is connected to the NodeMCU, along with a patch antenna, to give location data. Finally, the output is connected to the NodeMCU, which regulates the power supply to the various devices.

3.1.1 Codes and Standards

OCV Method

```
#define BLYNK_PRINT Serial
#define BLYNK_TEMPLATE_ID "TMPLHLEOw13e"
#define BLYNK_TEMPLATE_NAME "Battery Management system"
#define BLYNK_AUTH_TOKEN "zFlTAqkCIye4wo1kf6fb0T0xyj1r4pWc"

#include <WiFi.h>// function related to wifi
#include <WiFiClient.h>// function related to data connection to server
#include <BlynkSimpleEsp32.h> // function related to blynk connections

#include <LiquidCrystal_I2C.h> //function for lcd
#include "sd_card.h" //sd card
#include <TinyGPSPlus.h> //gps function
```

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```
TinyGPSPlus gps;

float lat = 0.0;
float lng = 0.0;
int relay = 27; //pinno.27
const int sensorIn = 33;  // pin where the OUT pin from current sensor is connected on Arduino
int mVperAmp = 185;     // this the 5A version of the ACS712 -use 100 for 20A Module and 66 for 30A Module
int Watt = 0;
double Voltage = 0;
double VRMS = 0;
double AmpsRMS = 0;
int battery_read_count = 0;
float sensorValue = 0.00;
float b_voltage = 0.00;
float read_battery_voltage();
float getVPP();
void system_log(String t); //log to save in sd card
void displayInfo();

// initialize the LCD library with I2C address and LCD size
LiquidCrystal_I2C lcd(0x27, 16, 2);

// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
char auth[] = "zFlTAqkCIye4wo1kf6fb0T0xyj1r4pWc";

// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "Diyasha's Iphone";
char pass[] = "diya1234";

BlynkTimer timer;
  Serial.println("sending data ");

  Serial.println("");
  Voltage = getVPP();
  VRMS = (Voltage / 2.0) * 0.707;       //root 2 is 0.707
  AmpsRMS = ((VRMS * 1000) / mVperAmp);  //0.3 is the error I got for my sensor

  Serial.print(AmpsRMS);
  Serial.print(" Amps RMS  ---  ");
  Watt = (AmpsRMS * 240 / 1.2);
   Serial.print(Watt);
  Serial.println(" Watts");
  lcd.setCursor(0, 0);
  lcd.print(AmpsRMS);
  lcd.print(" Amps ");
```

```
lcd.setCursor(0, 1);
lcd.print(b_voltage);
lcd.print(" voltage ");
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("Lat: ");
lcd.print(lat);
//Here cursor is placed on first position (col: 0) of the second line (row: 1)
lcd.setCursor(0, 1);
lcd.print("lng: ");
lcd.print(lng);
delay(2000);

int SOC = 0;
if (b_voltage > 12.45) {
  SOC = 100;
} else if (b_voltage >= 12.33 && b_voltage < 12.45) {

  SOC = 95;
} else if (b_voltage >= 12.25 && b_voltage < 12.33) {

  SOC = 90;
} else if (b_voltage >= 12.07 && b_voltage < 12.25) {

  SOC = 85;
} else if (b_voltage >= 11.95 && b_voltage < 12.07) {

  SOC = 80;
} else if (b_voltage >= 11.86 && b_voltage < 11.95) {

  SOC = 75;
} else if (b_voltage >= 11.74 && b_voltage < 11.86) {

  SOC = 70;
} else if (b_voltage >= 11.62 && b_voltage < 11.74) {

  SOC = 65;
} else if (b_voltage >= 11.56 && b_voltage < 11.62) {

  SOC = 60;
} else if (b_voltage >= 11.51 && b_voltage < 11.56) {
  SOC = 55;
} else if (b_voltage >= 11.45 && b_voltage < 11.51) {
  SOC = 50;
} else if (b_voltage >= 11.39 && b_voltage < 11.45) {
  SOC = 45;
} else if (b_voltage >= 11.36 && b_voltage < 11.39) {
```

```
  SOC = 40;
 } else if (b_voltage >= 11.30 && b_voltage < 11.36) {
  SOC = 35;
 } else if (b_voltage >= 11.24 && b_voltage < 11.30) {
  SOC = 30;
 } else if (b_voltage >= 11.18 && b_voltage < 11.24) {
  SOC = 25;
 } else if (b_voltage >= 11.12 && b_voltage < 11.18) {
  SOC = 20;
 } else if (b_voltage >= 11.06 && b_voltage < 11.12) {
  SOC = 15;
 } else if (b_voltage >= 10.83 && b_voltage < 11.06) {
  SOC = 10;
 } else if (b_voltage >= 9.82 && b_voltage < 10.83) {
  SOC = 5;
 }
 read_battery_voltage();
 Blynk.virtualWrite(V1, AmpsRMS);
 Blynk.virtualWrite(V0, b_voltage);
 Blynk.virtualWrite(V2, SOH);
 String url = "http://maps.google.com/maps?q=" + String(lat, 6) + "," + String(lng, 6);
 Serial.println(url);
 Blynk.virtualWrite(v3, url);
 String log_temp = "voltage" + String(b_voltage) + "v , " + "current: " + String(AmpsRMS) + " A , " + "SOC: 
" + String(SOH) + " %  " +"lat:"+String(lat)+"lng: "+String(lng);
 appendFile(SD, "/system_log.txt", log_temp.c_str());
}

void setup() {
 // Debug console
 Serial.begin(9600);
 Serial2.begin(9600);
 pinMode(relay, OUTPUT);

 Blynk.begin(auth, ssid, pass);
 timer.setInterval(1000L, Send_sensor_data);
 Serial.println("ACS712 current sensor");
 lcd.begin();
 lcd.backlight();
 lcd.clear();
 lcd.setCursor(3, 0);
 lcd.print("BMS SYSTEM");
 delay(1000);
 lcd.clear();
 sd_card_init();
}

void loop() {
```

```
 Blynk.run();
 timer.run();  // Initiates BlynkTimer
 if (b_voltage < 10) {
   digitalWrite(relay, HIGH);
 } else {
   digitalWrite(relay, LOW);
 }


 while (Serial2.available() > 0)
   if (gps.encode(Serial2.read()))
     displayInfo();
 if (millis() > 5000 && gps.charsProcessed() < 10) {
   Serial.println(F("No GPS detected: check wiring."));
   while (true)
     ;
 }
}float getVPP() {
 float result;
 int readValue;        // value read from the sensor
 int maxValue = 0;     // store max value here
 int minValue = 4096;  // store min value here ESP32 ADC resolution

 uint32_t start_time = millis();
 while ((millis() - start_time) < 1000)  //sample for 1 Sec
 {
   readValue = analogRead(sensorIn);
   // see if you have a new maxValue
   if (readValue > maxValue) {
     /*record the maximum sensor value*/
     maxValue = readValue;
   }
   if (readValue < minValue) {
     /*record the minimum sensor value*/
     minValue = readValue;
   }
 }
 // Subtract min from max
 result = ((maxValue - minValue) * 3.3) / 4096.0;  //ESP32 ADC resolution 4096

 return result;
}

float read_battery_voltage() {

 uint32_t start_time = millis();
 while ((millis() - start_time) < 1000)  //sample for 1 Sec
 {
```

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```
  float v_temp = analogRead(32);
  sensorValue = sensorValue + v_temp;
  battery_read_count = battery_read_count + 1;
 }

 sensorValue = sensorValue / battery_read_count;
 // print out the value you read:
 // Serial.println(sensorValue);
 Serial.print("sensorValue: ");
 Serial.println(sensorValue);
 b_voltage = map(sensorValue, 2380, 2791, 10.3, 12.0);
 Serial.print("voltage: ");
 Serial.println(b_voltage);

 sensorValue = 0;
 battery_read_count = 0;


 // Serial.print("ADC sensorValue: ");
 // Serial.println(v_temp);
 Serial.print("ADC tt sensorValue: ");
 Serial.println(sensorValue);
 // delay(1);  // delay in between reads for stability
 battery_read_count = battery_read_count + 1;
 Serial.print("ADC count: ");
 Serial.println(battery_read_count);
 //   b_voltage = map(sensorValue, 2380, 2791, 10.3, 12.0);
 //   Serial.print("voltage: ");
 //   Serial.println(b_voltage);

 //   sensorValue = 0;
 //   battery_read_count = 0;
 // }
 return b_voltage;
}
void displayInfo() {
 Serial.print(F("Location: "));
 if (gps.location.isValid()) {
  lat = gps.location.lat();
  lng = gps.location.lng();

  Serial.print("Lat: ");
  Serial.print(lat);
  Serial.print(F(","));
  Serial.print("Lng: ");
  Serial.print(lng);
  Serial.println();
 } else {
```

```
    Serial.print(F("INVALID"));
  }
}
void updateSerial() {
  delay(500);
  while (Serial.available()) {
    Serial2.write(Serial.read());  //Forward what Serial received to Software Serial Port
  }
  while (Serial2.available()) {
    Serial.write(Serial2.read());  //Forward what Software Serial received to Serial Port
  }
}
```

Coulomb Counting Method

```
double calculate_soc_coulomb(double current, double capacity, double time_elapsed, double last_soc) {
   /*
    * Calculates the state of charge (SOC) of a Li-ion cell based on coulomb counting.
    *
    * Parameters:
    *  - current: the cell current in amperes (A)
    *  - capacity: the cell capacity in ampere-hours (Ah)
    *  - time_elapsed: the time elapsed since the last SOC measurement in hours (h)
    *  - last_soc: the last SOC measurement as a percentage (0-100%)
    *
    * Returns:
    *  - the SOC of the cell as a percentage (0-100%)
    */

   // Convert the capacity from Ah to coulombs
   double capacity_c = capacity * 3600.0; // 1 Ah = 3600 C

   // Calculate the change in charge during the elapsed time
   double delta_charge = current * time_elapsed;

   // Calculate the remaining charge and SOC
   double remaining_charge = capacity_c * (last_soc / 100.0) - delta_charge;
   double soc = (remaining_charge / capacity_c) * 100.0;

   return soc;
}
```

3.2 DESIGN SPECIFICATIONS

HARDWARE DESIGN SPECIFICATION
3 Lithium-Ion Batteries[3.7v] Nominal voltage- 3.7*3- 11.1v

Max voltage- 4.2*3= 12.6V Capacity -2.6Ah Cutoff- 8.2V (2.7*3)
Voltage Sensor (Module 25v)
Current Sensor(acs712)
GPS (Gy Neo06mv2)
NodeMCU - 32bit with 1117 IC
Relay
LED Strip (Load)
GPS (Vant communication module with RXTX connection)
SD Card Module
Display- 16x2
GSM Module
INA219 IC
SD Card
DC-DC Buck Converter

Table 1: Design Specification

- **LITHIUM ION BATTERIES:** Lithium-ion batteries (Li-ion) are rechargeable batteries that use lithium ions as the primary source of energy. They are widely used in various electronic devices, such as smartphones, laptops, and electric vehicles. The battery consists of two electrodes (anode and cathode) and an electrolyte that separates them. When the battery is charged, lithium ions move from the cathode to the anode through the electrolyte, and during discharge, the ions move back to the cathode, generating an electrical current.
  Li-ion batteries have several advantages over other types of batteries, such as high energy density, low self-discharge rate, and a longer lifespan. They are also relatively lightweight and have high specific energy, making them an ideal choice for use in electric vehicles and other portable devices. However, Li-ion batteries also have some limitations, such as their sensitivity to temperature and the potential for thermal runaway, which can result in overheating and even fire or explosion. To ensure safe and efficient operation, proper management and monitoring of the battery system are essential.

- **VOLTAGE SENSOR (MODULE 25V):** A voltage sensor is an electronic module that is used to measure the voltage level of a power source. It typically consists of a voltage divider, an amplifier, and an analog-to-digital converter (ADC). The voltage divider is used to reduce the voltage level to a range that can be measured by the ADC. The amplifier is used to amplify the voltage signal to a level that can be accurately measured by the ADC. The ADC then converts the analog voltage signal to a digital signal that can be read by a microcontroller or other electronic device. The voltage sensor module 25V is a specific type of voltage sensor that is designed

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to measure voltage levels up to 25V. It typically includes a voltage divider circuit that divides the input voltage by a factor of 5, an amplifier circuit to amplify the voltage signal, and an ADC to convert the analog voltage signal to a digital signal. The module also includes an LED indicator that lights up when the input voltage exceeds a certain level, providing a visual indication of the voltage level. Voltage sensor modules are commonly used in electronic circuits to monitor the voltage level of batteries, power supplies, and other electronic devices. They are essential components in battery management systems for electric vehicles and renewable energy systems, where accurate monitoring of the battery voltage is crucial for maintaining safe and efficient operation.

- **CURRENT SENSOR (ACS712)**: A current sensor is an electronic module that is used to measure the electric current flowing through a wire or a conductor. The ACS712 is a Hall-effect-based linear current sensor that can measure both AC and DC currents. It works by detecting the magnetic field generated by the current passing through a wire and converting this magnetic field into a voltage signal that can be measured by an analog-to-digital converter (ADC) or a microcontroller. The ACS712 current sensor is a popular choice for measuring current in electronic circuits because of its simplicity, accuracy, and ease of use. It is a fully integrated solution that includes a Hall-effect sensor, signal conditioning circuitry, and a voltage regulator, all housed in a single package. The ACS712 can measure currents up to 5A or 20A, depending on the specific model. The ACS712 current sensor is commonly used in a variety of applications, including motor control, power supplies, and battery management systems for electric vehicles and renewable energy systems. It is also used in industrial automation and robotics applications for monitoring the current consumption of motors, pumps, and other electrical loads. The output of the ACS712 is typically an analog voltage proportional to the measured current, making it easy to +3 *0interface with microcontrollers and other electronic devices.

- **GPS (GY NEO0GMV2)**: GPS (Global Positioning System) is a satellite-based navigation system that allows users to determine their exact position and velocity anywhere on Earth. It works by receiving signals from a network of GPS satellites orbiting the Earth and using these signals to triangulate the receiver's position. The Gy Neo06mv2 GPS module is a compact and easy-to-use GPS receiver module that integrates a high-performance GPS chipset and an onboard antenna. The Gy Neo06mv2 GPS module provides accurate position, speed, and time information, with a positional accuracy of up to 2.5 meters. It supports multiple GPS protocols, including NMEA 0183 and UBX, and can communicate with external devices using a serial interface. The module also features low power consumption and fast acquisition times, making it ideal for use in battery-powered applications. The Gy Neo06mv2 GPS module is widely used in applications such as vehicle tracking, navigation, and location-based services. It is commonly used in automotive and transportation systems to track vehicles and monitor their movements. It is also used in outdoor recreational activities such as hiking and camping to provide users with location and distance information. With its small size, low power consumption, and high accuracy, the Gy Neo06mv2 GPS module is a versatile and reliable GPS solution for a wide range of applications.

- **NodeMCU - 32 BIT with 1117 IC**: The NodeMCU is a popular open-source platform based on the ESP32 System on Chip (SoC) that includes Wi-Fi and Bluetooth connectivity. It is widely used for developing Internet of Things (IoT) applications due to its low cost, ease of use, and support for programming with the Arduino IDE. The NodeMCU board features a 32-bit microcontroller with a clock speed of 160 MHz, which allows for fast execution of code and high-speed data transfers. It also includes a voltage regulator (1117 IC) that ensures a stable supply voltage for the microcontroller and other components on the board. The NodeMCU board has several digital and analogue input/output (I/O) pins, which can be used to connect sensors, actuators, and other peripherals. It also has built-in support for Wi-Fi and Bluetooth connectivity, which enables it to connect to the internet and other devices wirelessly. Overall, the NodeMCU board is a

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powerful and versatile platform for developing IoT applications that require wireless connectivity and real-time processing capabilities.

- **RELAY**: A relay is an electrical component that is used to switch or control high-power circuits using low-power signals. It consists of an electromagnet that controls one or more sets of contacts, which can be normally open (NO) or normally closed (NC). When an electrical signal is applied to the relay's coil, it creates a magnetic field that pulls the contacts together, completing the circuit and allowing the high-power circuit to be turned on or off. When the signal is removed, the contacts return to their original state. Relays are commonly used in a variety of applications, including in automotive systems, industrial machinery, and home automation systems. They can be used to control motors, lights, heating and cooling systems, and other electrical devices. Relays come in many different shapes, sizes, and configurations, including electromagnetic, solid-state, and thermal relays. They can also be classified based on their contact configuration, coil voltage, and current rating, among other factors.

- **LED STRIP**: An LED strip is a flexible circuit board that contains multiple light-emitting diodes (LEDs) arranged in a linear pattern. They are typically used as decorative or accent lighting and can be cut to fit a specific length or shape. LED strips come in various colors and can be controlled using different methods, such as remote controls, smartphone apps, or even voice commands. They are typically low voltage and consume less power than traditional incandescent bulbs, making them more energy-efficient. LED strips are easy to install and can be attached to a variety of surfaces, including walls, ceilings, and furniture. They are often used in home and commercial lighting applications, as well as in automotive lighting, theater productions, and special effects. LED strips can be powered using a variety of sources, including battery packs, power supplies, and even USB ports. They are also available in waterproof or weather-resistant versions for outdoor use.

- **GPS (Vant communication module with RXTX connection)**: The Vant GPS communication module is a GPS receiver module that communicates with other devices through an RX/TX connection. It is designed to provide accurate position, time, and velocity information for various applications such as navigation, tracking, and timing. The module uses a highly sensitive GPS chipset to receive signals from GPS satellites and calculates the location, speed, and time information based on those signals. The Vant GPS module supports multiple satellite systems, including GPS, GLONASS, and Beidou, and has a high positioning accuracy of up to 2.5 meters. The module comes with a built-in antenna and requires an external power source of 3.3V to operate. It communicates with other devices through a serial UART interface and supports different communication protocols, including NMEA, UBX, and RTCM. The module can also be configured to output different data formats, baud rates, and update rates to meet different application requirements. Overall, the Vant GPS communication module is a reliable and versatile solution for GPS-based applications that require accurate position and time information.

- **SD CARD MODULE**: ESP32 is a powerful microcontroller that includes an SD card slot, which can be used to store and retrieve data. The ESP32 uses SPI (Serial Peripheral Interface) to communicate with the SD card. The SPI communication protocol is a synchronous serial communication protocol used for communicating with peripherals over short distances. The SPI interface uses four wires: SCLK (Serial Clock), MOSI (Master Output Slave Input), MISO (Master Input Slave Output), and SS (Slave Select). To use the SPI protocol for SD card communication, the ESP32 microcontroller is configured as the master device, and the SD card is configured as the slave device. The master initiates the data transfer by sending a request to the slave, and the slave responds by sending the requested data back to the master. The ESP32 uses an SPI library to communicate with the SD card. The library provides functions for initializing the SD card, reading and writing data to the SD card, and handling errors that may occur during data transfer. Overall, the ESP32 with SD card SPI communication protocol provides a convenient and efficient way to store and retrieve data in various applications, such as data logging, multimedia applications, and more.

- **DISPLAY- 16x2**: ESP32 Display module is an OLED display module that is designed to work with the ESP32 microcontroller. It is based on the I2C communication protocol, which allows for fast and efficient data transfer between the microcontroller and the display module. The module consists of an OLED display, a controller, and an I2C interface. I2C, also known as Inter-Integrated Circuit, is a synchronous, serial communication protocol used for communication between microcontrollers and peripheral devices. It is a two-wire protocol that uses a clock signal to synchronize data transfer between devices. The ESP32 microcontroller supports the I2C communication protocol, making it compatible with the ESP32 display module. With the ESP32 Display module, users can easily display text and graphics on the OLED display using the ESP32 microcontroller. It is commonly used in various applications, such as IoT devices, portable devices, and wearable devices. The module is also easy to use, with a simple connection to the ESP32 microcontroller through the I2C interface, making it a popular choice among developers and hobbyists.

  The ESP32 is a microcontroller that can be used to control relays using the General Purpose Input/Output (GPIO) pins. GPIO pins are digital input/output pins that can be used to control various devices, including relays. To use the ESP32 to control a relay directly through the GPIO, the relay must be connected to the ESP32 using a circuit that includes a transistor and a diode. The transistor acts as a switch, allowing the ESP32 to control the flow of current to the relay, while the diode helps to protect the ESP32 from voltage spikes that can be generated when the relay is turned off. Once the relay is connected to the ESP32 through the transistor and diode circuit, the GPIO pin can be used to control the relay by setting it to either a high or low state. By using the ESP32 to control the relay directly, it is possible to automate various processes such as turning on or off lights, motors, or other electronic devices. The ESP32's GPIO pins provide a simple and flexible way to control relays and other devices, making it a popular choice for automation and control projects.

- **GSM MODULE**: A GSM module is a device that enables communication over a GSM network. It can be used to send and receive SMS messages, make and receive calls, and connect to the internet. The module typically consists of a SIM card holder, a power supply, a microcontroller, and a GSM module. The microcontroller is responsible for controlling the module and managing communication with the external world. The GSM module communicates with the network using standard AT commands, which are sent over a serial interface. The module can be connected to a microcontroller or any other device that has a serial interface. GSM modules are commonly used in a variety of applications, including home automation systems, security systems, and remote monitoring systems. They are also used in GPS trackers and other location-based services, as well as in vending machines, ATMs, and other self-service kiosks. The main advantage of GSM modules is their widespread availability and compatibility with most mobile networks around the world.

- **INA219 IC**: The INA219 is a high-precision, bi-directional current and power monitoring IC (integrated circuit) from Texas Instruments. It can accurately measure voltage and current levels in a circuit and calculate power consumption. The device operates from a single 3-5.5V power supply and communicates via an I2C interface. It has an internal shunt resistor for current sensing, and the voltage across the shunt resistor is amplified by a programmable gain amplifier (PGA). The INA219 also has an on-chip precision voltage reference and can measure both positive and negative voltage signals with a range of ±320mV. It provides high accuracy with up to 0.1% precision for voltage measurement and 1% for current measurement. The device also has configurable alert thresholds for overvoltage, undervoltage, and overcurrent conditions, which can trigger an interrupt to the microcontroller. The INA219 IC is commonly used in battery management systems, power supply monitoring, and energy-harvesting applications.

- **DC-DC BUCK CONVERTER**: A DC-DC buck converter is an electronic circuit that is used to efficiently convert a higher DC voltage to a lower DC voltage. It operates by turning the input voltage on and off in a controlled manner and then smoothing it out using capacitors and inductors. The output voltage of the buck converter is typically lower than the input voltage, and the ratio between the input and output voltages is known as the "duty cycle." Buck converters are commonly used in electronic devices to step down the voltage from a power source, such as a battery or AC adapter, to a lower voltage level that is suitable for powering the device's electronics. They are also commonly used in power supplies and voltage regulators. DC-DC buck converters offer several advantages over traditional linear voltage regulators, including higher efficiency, smaller size, and lower heat dissipation. They can also be designed to be very efficient at specific loads, making them ideal for battery-powered devices where energy efficiency is critical.

IV. PROJECT DEMONSTRATION

4.1 INTRODUCTION

Here the outcome is to successfully manage the battery power supply by precisely measuring and monitoring current and voltage levels, giving location data, and managing the power supply to the electronic devices.
Another crucial aspect incorporated here is to read the GPS coordinates onto the Blynk app due to the connection of the former to the NodeMCU. This function allows the user to follow the electronic device's position and offers vital data for future applications such as fleet management, asset tracking etc. In this project, we have incorporated our data visualization and coordinate mapping in the Blynk application interface.
Blynk is a mobile application that allows users to control and monitor connected devices remotely. It works with a variety of hardware platforms and communication protocols, including Arduino, Raspberry Pi, ESP8266, and Bluetooth. The app offers an easy-to-use interface to create custom user interfaces (UI) for connected devices, which can be customized with widgets such as buttons, sliders, gauges, and graphs. Users can create multiple projects within the app and share them with others through QR codes or email. Blynk also provides a cloud-based platform to store and analyze data generated by connected devices. Blynk offers a variety of features including real-time data visualization, push notifications, data logging, and email alerts. It also has a large community of developers who have created a range of libraries and example projects, making it easier for users to get started with their projects. Blynk can be used for a wide range of applications, from home automation and robotics to industrial control and monitoring. It is available for both iOS and Android devices and has a free and paid subscription model.

4.2 ANALYTICAL RESULTS

For measuring the SOC of a battery, there are various textbook methods. Direct methods of measuring battery properties involve measuring physical
characteristics such as terminal voltage and impedance.
Considering the complexity we opted for the OCV method. The open circuit voltage (OCV) method for Li-ion batteries is a technique used to estimate the state of charge (SOC) of a Li-ion battery based on its open circuit voltage. The OCV of a Li-ion battery is the voltage measured across the battery terminals when the battery is not under charge or discharge. The OCV of a Li-ion battery varies with its SOC, so measuring the OCV of the battery can provide an estimate of its SOC.
The OCV method typically involves measuring the OCV of the battery and comparing it to a lookup table or mathematical model that relates the OCV to the SOC of the battery. The lookup table or mathematical model is typically derived from measurements of the battery's OCV at different SOC values.
The method is simple and easy to achieve as it involves just data mapping. But the OCV method does not produce accurate results because, in Li-ion batteries, the SOC does not have a linear relationship with the voltage.
Due to the major drawback of accuracy in the previous method, we have opted for the Coulomb Counting method which comes under the bookkeeping estimation of SOC.

Coulomb counting is a method for estimating the state of charge (SOC) of a battery by measuring the amount of electric charge that flows in or out of the battery over time. The basic principle is that the amount of charge that flows into a battery during charging is equal to the amount of charge that flows out during discharge.

It's important to consider the demerits of coulomb counting. Compared to the direct methods, though the accuracy might be better, the SOC is not 100% accurate, especially for batteries that have been in use for a long time or have undergone many charge/discharge cycles. Inaccuracies can also arise from variations in temperature, age, and other factors that affect battery performance. or impedance analysis, to get a more accurate estimate of the battery's state of charge.

Qn/Q(t) is a ratio that represents the state of charge (SOC) of a battery at a given time t, expressed as a percentage of the battery's nominal capacity Qn. It can be calculated using the formula:

$$\frac{Qn}{Q(t)} x100 = SOC\% \quad ..i)$$

Where:

- Qn is the nominal capacity of the battery, usually measured in ampere-hours (Ah).
- Q(t) is the actual capacity of the battery at time t, usually measured in ampere-hours (Ah).

To estimate the actual capacity, the formula is as follows:

$$Q(t) = Qn * (\frac{SOC(t-1)}{100}) - \Delta Q \quad ..ii)$$

Where:

- $Q(t)$ is the estimated remaining charge of the battery after delta_charge has been removed or added, measured in ampere-hours (Ah).
- Qn is the nominal capacity of the battery, measured in ampere-hours (Ah)
- $SOC(t-1)$ is the previous state of charge of the battery, expressed as a percentage.
- ΔQ is the amount of charge removed or added to the battery, measured in ampere-hours (Ah).

ΔQ is given by

ΔQ= I x t ..iii)

Where:

- I is the current flowing during the cycle.
- t is the time elapsed.

After finding the parameters in equation ii) and iii), the SOC can be estimated using i).

4.3 HARDWARE SETUP

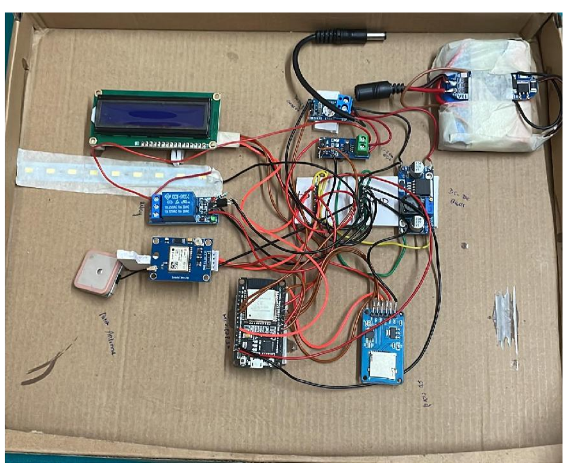

Figure 2: Hardware Setup

4.4 RESULTS

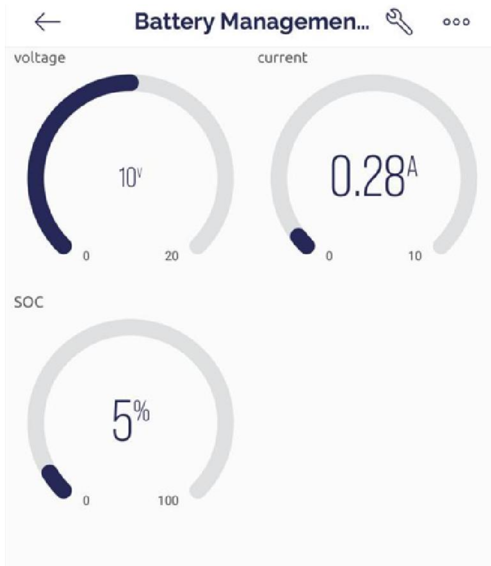

Figure 3: Output from the Blynk App when the battery discharges

As the battery discharges (providing the output to the load), the SOC of the battery goes down. As the battery connection has a nominal voltage of 11.1V, a dip in the battery voltage causes a huge SOC fall.

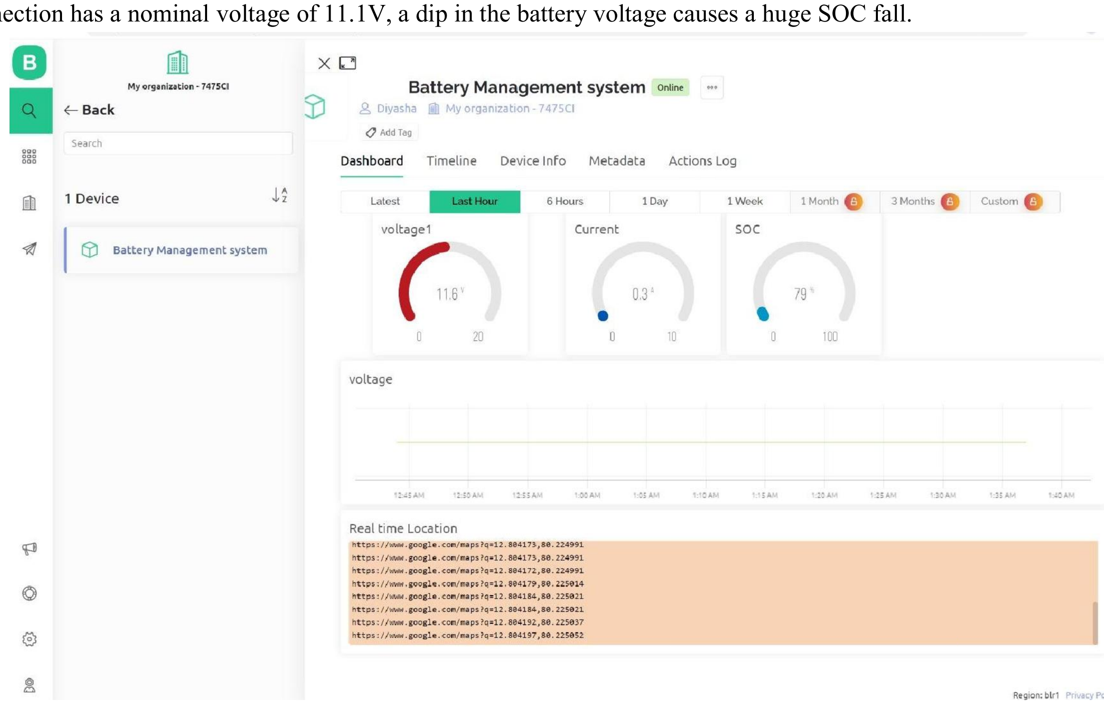

Figure 4: Output from the Blynk App when the battery charges

During the charging cycle, the SOC of the battery increases so does the voltage.

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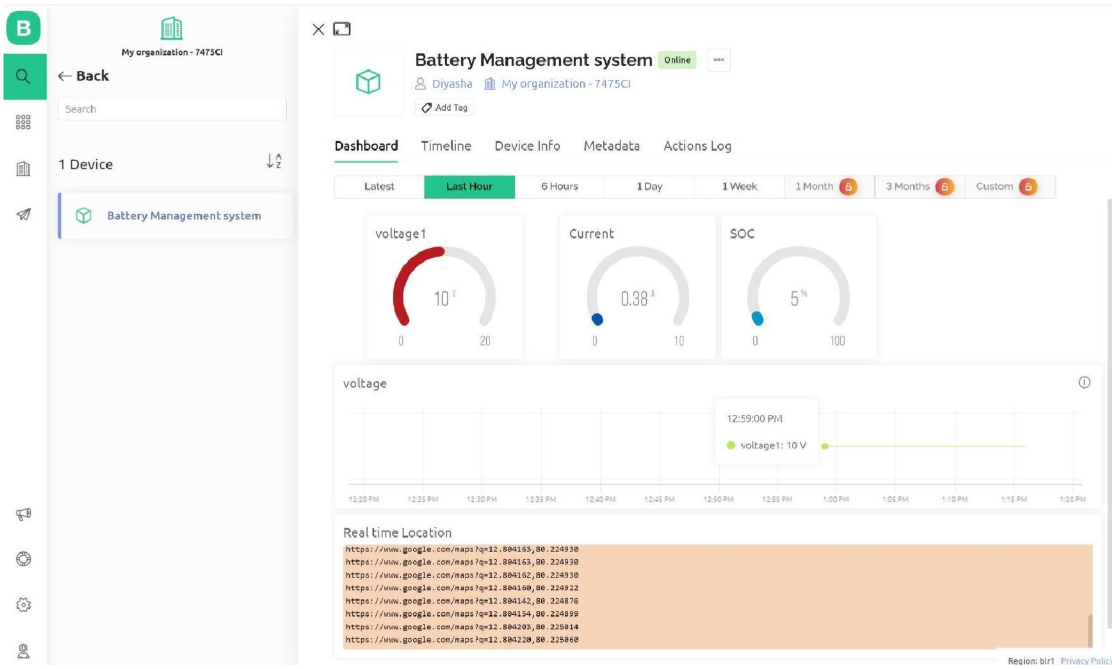

Figure 5: Real-Time Location Monitoring

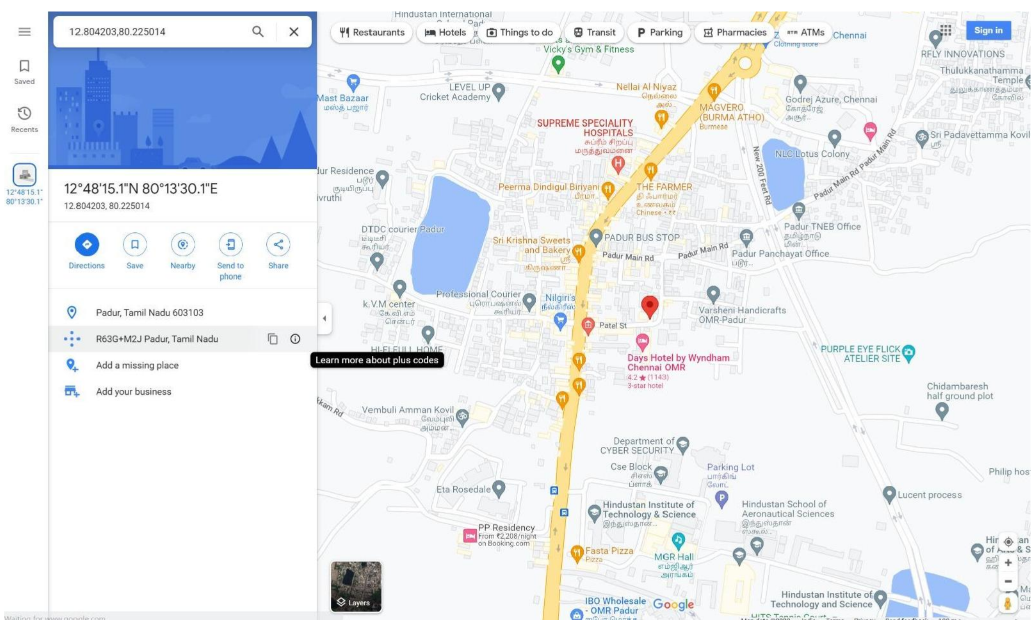

Figure 6: Location in Google Maps

As a part of real-time monitoring, the GPS obtains the coordinates of the BMS and sends them to the Blynk App with the help of Node MCU. A patch antenna is attached to the GPS for accurate coordinates. The coordinates are then sent to the Blynk app which generates a link. Once the link is clicked, Blynk sends the coordinates to Google Maps and the location can be accessed.

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V. CONCLUSION

5.1 COST ANALYSIS

The hardware prototype was self-funded and was shared by the team members.
The cost of the Hardware components are as follows:

HARDWARE COMPONENT	PRICE (in Rs.)
3 Lithium-Ion Batteries[3.7v]	600
Voltage Sensor (Module 25v)	120
Current Sensor(acs712)	225
GPS (Gy Neo06mv2)	270
NodeMCU - 32bit with 1117 IC	380
LED Strip (Load)	250
GPS (Vant communication module with RXTX connection)	245
Relay	50
SD Card Module	100
Display- 16x2	247
Temperature sensor DHT22	180
GSM Module	1100
INA219 IC	116
SD Card	359
DC-DC Buck Converter	299
TOTAL	4533

Table 2: Cost price of hardware components

5.2 SCOPE OF WORK

The battery performance being tracked online will help the user/ admin in keeping in mind to change the battery and prevent any unwanted circumstances. The user interface for the created battery monitoring device is made to let the user or administrator monitor battery degeneration so that a notice may be delivered to the user of a battery monitoring device.

By including new functionalities, the system may be further modified to be improved. By creating a smartphone application that can assist users in battery monitoring and serve as a reminder for battery degeneration, the method may be employed in smartphones. Ethernet may be utilized to improve the internet connection and provide a superior one to GPRS. To ensure that the battery performance deterioration could be tracked online, the article outlined the design and implementation of an IoT-based battery monitoring system for electric vehicles. The goal is to demonstrate the viability of the idea's basic premise. The hardware for the battery monitoring device and a web-based user interface for battery monitoring are being developed as part of the system's development. The system incorporates a GPS to identify the coordinate and display it on the Google Maps application, allowing it to display information such as position, battery life, and time over the internet.

5.3 SUMMARY

The BMS is a critical component in EV applications, ensuring the safe and efficient operation of the battery pack. The design and development of a BMS involve the selection of components, hardware and software design, and testing. The BMS is designed to be modular and scalable, allowing for easy integration with different EV platforms. The BMS provides real-time monitoring of the battery pack's performance, enabling early detection of any faults or abnormalities. Overall, the development of a reliable and efficient BMS is essential for the widespread adoption of EVs.

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