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Research Article

BATTERY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLES

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Abstract – Energy storage options that are adaptable, controllable, and more effective have boosted interest in electric cars. Electric cars would have a driving motor that was powered by a large battery pack. It's important to comprehend the battery's power density, endurance, flexible electrochemical behavior, and temperature tolerance. Electric cars and renewable energy storage systems both require battery management systems. The study discusses issues, challenges, and battery-related solutions. The battery management system includes temperature management, battery data actuation and storage, voltage and current monitoring, charge and discharge estimates, protection, and equalization. The different cell balancing circuit types, their components, current and voltage stresses, control reliability, power loss, efficiency, size, cost, and their advantages and disadvantages were also described in this study. Second, we discuss battery management system issues and difficulties. We also point out issues and challenges that require further attention if battery management systems for electric cars and renewable energy storage systems are to be optimum and sustainable.

Keywords – Battery Management System, Electrical Vehicle, Stored Energy, Liquid Crystal Display, Essential Storage System

I. Introduction

Electric vehicles (EV), renewable energy storage, micro/smart-grid applications, etc. are just a few of the areas where the energy storage system (ESS) has gained popularity. Internal combustion engines (ICEs) can be successfully replaced by the most recent EV generations. One-third of all fossil fuel is used by ICE-based vehicles, including freight, ships, and airplanes.

The two main sources and the main contributors to the emission of carbon dioxide (CO2), sulfur dioxide (SO2), carbon monoxide (CO), and nitrogen oxides (NO) are ICE and industry [1]. The greenhouse effect is brought on by the air pollution that these gases produce. The EES in an EV power the EV motor and other devices like the air conditioner and navigational lights. Due to the EV's well-known zero-carbon emissions, the release of SO2, CO2, NO, and CO has not been noticeable when driving; nonetheless, it would be beneficial to take into account the environmental issues and the use of fossil fuels [2].

In most road/highway, rail, air, and sea-based vehicles, stored energy (SE) is used to fully or partially power EVs. ES is presently being added to modern high-tech vehicles like private automobiles and city buses. The cumulative EV market today places a premium on factors including tax revenue, cost, cost-effectiveness, accessibility to e-commerce, and competitive advantage over other options for automating mobility [3].

A Battery Management System (BMS) for electric vehicles (EVs) is the digital guardian of the vehicle's power source, the battery pack. It's a sophisticated piece of technology that continuously monitors and manages the health, safety, and performance of the battery cells within the pack. By overseeing factors like voltage, current, temperature, and state of charge, the BMS ensures that the battery operates within safe limits, preventing overcharging, over-discharging, and overheating. By regulating individual cell voltages and overseeing cell health, it also significantly contributes to maximizing battery longevity. In essence, the BMS is the quiet steward that keeps EVs operating profitably while also enhancing their overall sustainability and safety, making electric vehicles a practical and environmentally beneficial mode of transportation in the future.

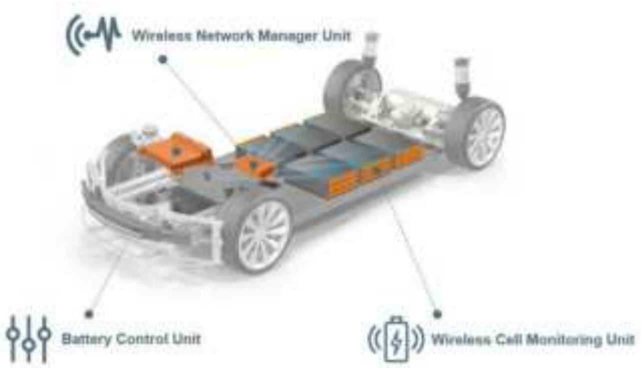

Fig. 1 The BMS system

The computerized conductor of an electric vehicle's power symphony is the Battery Management System (BMS). It serves as the battery pack's brain, performing a variety of critical duties to maintain the vehicle's smooth and safe functioning. The BMS continually monitors the voltage and temperature of each individual battery cell, preventing circumstances that may lead to overcharging, over-discharging, or overheating, which could cause damage or even represent a safety issue. It also computes the State of Charge (SOC), which provides the driver with precise information on the remaining battery capacity and driving range. Furthermore, the BMS performs cell balancing to ensure that all cells within the battery pack maintain consistent charge levels, which not only increases energy capacity but also extends the battery's total lifespan [4].

The BMS, in addition to its safety and monitoring tasks, is critical in improving the overall performance of electric cars. It adds to energy efficiency and, as a result, increased range per charge by optimizing charging and discharging patterns based on real-time data and driving circumstances. As electric vehicle technology develops, the BMS remains a crucial element in the pursuit of safer, more effective, and environmentally friendly transportation solutions. Additionally, the BMS is frequently outfitted with communication interfaces that enable it to interact with other vehicle systems, enabling intelligent features like regenerative braking, adaptive thermal management, and predictive maintenance.

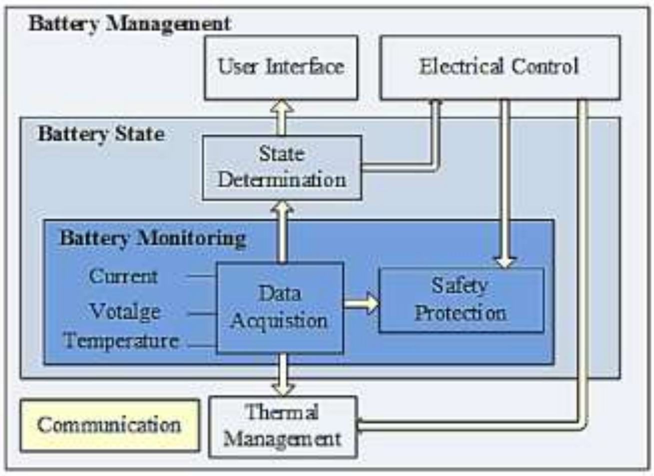

Fig 2. Schematic Diagram of BMS System

II. LITERATURE REVIEW

A.K.M Ahsan Habib and M. Kmarul Hassan addresses concerns, difficulties, and solutions related to batteries. The battery management system covers voltage and current monitoring; charge and discharge estimation, protection, and equalization; thermal management; and battery data actuation and storage. Furthermore, this study characterized the various cell balancing circuit types, their components, current and voltage stresses, control reliability, power loss, efficiency, size and cost, and their benefits and drawbacks. Secondly, we review concerns and challenges in battery management systems [5].

A. Hariprasad and I. Priyanka addresses state of charge, state of health, and state of life and also maximum capacity of a battery [6].

III. HARDWARE SPECIFICATION

Table 1 Hardware Specification

Name of hardware	**Step down transformer**
Input voltage	220
Output voltages	12volts
Current ratings	1 Ampere
Connection type	Parallel
Efficiency	94%
Name of Hardware	**Bridge Rectifier**
Input voltages	12 V AC
Output voltages	12 volts DC
Current Ratings	1 Ampere
Connection type	Parallel
Name of Hardware	**Arduino**
Model	UNO R3
Micro Controller	AT MEGA328p
Operating voltages	5-20 VDC
Purpose of use	Monitoring
Clock Frequency	16 MHz
Name of Hardware	**LCD**
Model	16x2
Input voltages	5 VDC
Purpose of use	To display results
Dimension	2 rows and 1 column
Name of Hardware	**Relay**
Input voltages	5 V DC
Type	Electromagnet
Terminal	5
Name of Hardware	**Dry Batteries**
Output Voltage	4.2 V
Capacity	1200 m Ah
Purpose of use	To store the dc current
Name of Hardware	**Node MCU**
Operating Voltage	5 V DC
Micro Controller	ESP 8266
Memory	128kBytes
Storage	4MB

IV. SIMULATION PROGRAMING

```
#include <DHT.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>
//I2C pins declaration
LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4,
SoftwareSerial NodeMCU(9, 10);
#define Batt1 A0
#define Batt2 A1
#define Batt3 A2
#define ACS A6
#define OverVoltRelay 8
#define UnderVoltRelay 6
#define DHTPIN 11
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
const float DividerFactor = 5.4;

float TemperatureLimit = 50;
float UnderVoltLimit = 10;
float OverVoltLimit = 14;
bool TikTok = false;


bool IsCooling = false;
bool IsCharging = false;
bool IsUnderVolt = false;
long temp = 0;

float getVolt(int n = 1) {
  float adc = 0;
  float volt = 0;

  if (n == 1) {
    adc = analogRead(Batt1);
    volt = adc * 5 / 1023 * 4.7;
  } else if (n == 2) {
    adc = analogRead(Batt2);
    volt = adc * 5 / 1023 * 4.8;

  } else if (n == 3) {
    adc = analogRead(Batt3);
    volt = adc * 5 / 1023 * 4.8;
  } else return 0;
  return volt;
}
```

```
float getCurrent() {
  double Voltage = 0;
  double Current = 0;

  for (int i = 0; i < 1000; i++) {
    Voltage = (Voltage + (.0049 * analogRead(ACS)));  // (5 V / 1024
(Analog) = 0.0049) which converter Measured analog input voltage to 5 V
Range
    delay(1);
  }

  Voltage = Voltage / 1000 - 2.58;
  //Serial.println("V:" + (String) Voltage);

  Current = (Voltage) / 0.100;  // Sensed voltage is converter to current

  //Serial.println("C" + (String) Current);
  Current = abs(Current);
  //Serial.println("CP" + (String) Current);

  Current -= 4.4;

  if (Current < 0)
    Current = 0.0;
  return Current;
}


void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  NodeMCU.begin(9600);
  lcd.begin(16, 2);
  pinMode(OverVoltRelay, OUTPUT);
  pinMode(UnderVoltRelay, OUTPUT);
  dht.begin();
}

void loop() {
  // put your main code here, to run repeatedly:
  float Batt1Volt = getVolt(1);
  float Batt2Volt = getVolt(2);
  float Batt3Volt = getVolt(3);
```

```
if (Batt1Volt > 1) {
  Batt2Volt -= Batt1Volt;
  Batt3Volt -= Batt1Volt;
}
if (Batt2Volt > 1) {
  Batt3Volt -= Batt2Volt;
}
float TotalVolt = Batt1Volt + Batt2Volt + Batt3Volt;

if (NodeMCU.available()) {
  char N = NodeMCU.read();
  if (N == 'T') {
    TemperatureLimit = NodeMCU.parseFloat();
  } else if (N == 'U') {
    UnderVoltLimit = NodeMCU.parseFloat();
  } else if (N == 'O') {


  OverVoltLimit = NodeMCU.parseFloat();
} else if (N == 'I') {
  String IP = NodeMCU.readStringUntil('\n');
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print(" IP:              ");
  lcd.setCursor(0, 1);
  lcd.print(IP);
  delay(3000);
} else if (N == 'L') {
```

```
    int n = NodeMCU.parseInt();
    if (n == 100) {
      if (TotalVolt > UnderVoltLimit)
        digitalWrite(UnderVoltRelay, HIGH);
    } else if (n == 10) {
      digitalWrite(UnderVoltRelay, LOW);
    }
  }
}

if (TotalVolt <= UnderVoltLimit) {
  digitalWrite(UnderVoltRelay, LOW);
  if (!IsUnderVolt) {
    lcd.setCursor(0, 0);
    lcd.print("Battery Volt Low");
    lcd.setCursor(0, 1);
    lcd.print(" Load Turned Off");
    delay(1500);
    IsUnderVolt = true;
  }
}

float ChargingVolt = getVolt(3);
float Current = getCurrent();
float Temperature = dht.readTemperature();

NodeMCU.println("T" + (String)Temperature);
NodeMCU.println("C" + (String)Current);
NodeMCU.println("X" + (String)Batt1Volt);
NodeMCU.println("Y" + (String)Batt2Volt);
NodeMCU.println("Z" + (String)Batt3Volt);
```

```
Serial.println("T" + (String)Temperature);
Serial.println("C" + (String)Current);
Serial.println("X" + (String)Batt1Volt);
Serial.println("Y" + (String)Batt2Volt);
Serial.println("Z" + (String)Batt3Volt);

if (Temperature >= TemperatureLimit) {
  digitalWrite(OverVoltRelay, LOW);
  if (!IsCooling) {
    if (IsCharging) {
      lcd.setCursor(0, 0);
      lcd.print(" Temperature Up ");

      lcd.setCursor(0, 1);
      lcd.print("  Chargin Off   ");
      delay(1500);
    }
    IsCooling = true;
  }
} else {
  if (IsCooling) {
    IsCooling = false;
  }
}

if (millis() - 5000 > 0) {
  if (ChargingVolt >= OverVoltLimit) {
    digitalWrite(OverVoltRelay, LOW);
    if (IsCharging) {
      lcd.setCursor(0, 0);
      lcd.print("Charging Volt Up");
      lcd.setCursor(0, 1);
      lcd.print("Stoping Charging");
      delay(1500);
      IsCharging = false;
      IsUnderVolt = false;
    }

  } else {
    if (!IsCooling && TotalVolt <= UnderVoltLimit) {
      digitalWrite(OverVoltRelay, HIGH);
      if (!IsCharging) {
        lcd.setCursor(0, 0);
        lcd.print("Battery Charging");
        lcd.setCursor(0, 1);
        lcd.print(" Volt: " + (String)TotalVolt + "
        delay(1500);
        IsCharging = true;
        IsUnderVolt = false;
      }
    }
  }
}
```

```
if (millis() - temp >= 3000) {
  if (TikTok) {
    lcd.setCursor(0, 0);
    lcd.print("B1:" + (String)Batt1Volt + " B2:" + (String)Batt2Volt + "
     ");
    lcd.setCursor(0, 1);
    lcd.print("B3:" + (String)Batt3Volt + " A:" + (String)(Batt1Volt +
Batt2Volt + Batt3Volt) + "          ");
    delay(1500);
    TikTok = false;

      } else {
        lcd.setCursor(0, 0);
        lcd.print("C: " + (String)Current + " A           ");
        lcd.setCursor(0, 1);
        lcd.print("T: " + (String)Temperature + " °C      ");
        delay(1500);
        TikTok = true;
      }
      temp = millis();
    }
  }
```

V. METHODOLOGY

The proposed system is composed of microcontrollers, sensros, a control system and a battery storage system. The main purpose of this research work is to design IoT controlled Battery Management System for EVs. The whole system is operated through desktop application. Which shows the status of each battery individually, temperature of batteries, load on the batteries and charging status of the batteries. The software also predicts the how long battery backup will be available.

A DHT sensor, an ACS712 current sensor, and dry batteries are all used as part of a complete methodology for a Battery Management System (BMS) in an Electric Vehicle (EV) to assure the effective and secure functioning of the EV's power source. The DHT sensor keeps an eye on the temperature and humidity levels inside the battery compartment, which helps to keep everything in the right balance for the best performance and longevity of the batteries. The ACS712 current sensor detects the current entering and leaving the battery pack in the meanwhile, providing accurate tracking of charge and discharge rates. This information is used by the BMS to control the dry batteries' charge, health, and general performance. The BMS can maximize the battery's performance, avoid overcharging or over-discharging, and send real-time data to the EV's management system by continuously assessing these parameters. This helps to ensure a dependable and secure power source for electric propulsion. This approach is essential for improving the performance of the EV, increasing battery life, and encouraging environmentally friendly mobility.

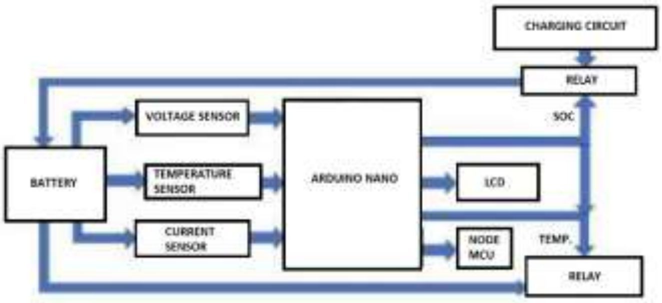

Fig 3. Methodoloy of BMS for Evs

A. *Prototype Analysis*

This part will describe the development of the prototype hardware that we implemented in accordance with the original hardware's likeness. Our prototype hardware's functionality is nearly entirely dependent on that of the original hardware. Since we are aware that there is always a reason for a hardware prototype's inadequacies, the primary issue is that the prototype is so small that we intentionally reduce the voltage to show the project's functionality.

B. *Implementation Procedure*

In the implementation of this prototype hardware, the basic technique followed is to stabilize the voltage level by using charging circuit. The microcontroller checks the state of charging of battery, either it is charged or not. After checking it will engage the charging circuit, which starts providing current to the batteries. Once the battery stores the enough current, which set by system the control stop the flow of current. Meanwhile control system analyzes the temperature of batteries. If temperature exceeds the sets limit, system stop the charging.

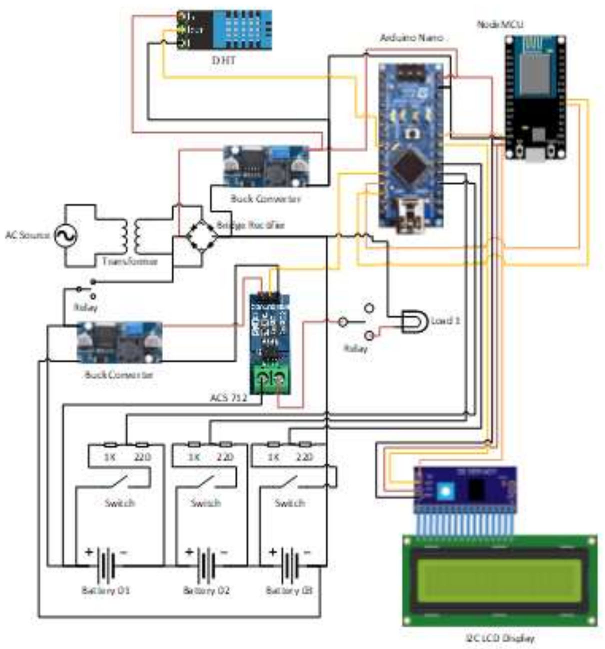

Fig 4. Circuit Diagram

VI. RESULT AND ANALYSIS

A. *Presenting of the finding*

The main goal of this project is to manage the batteries. The Arduino Uno R3 is used to control the entire circuit. The load on the circuit is measured using the current sensor ACS 712. DC lights are used in the hardware design to show load. The Arduino detects the state of charging of batteries and their temperature. The Arduino-attached LCD displays the voltage of each battery. The Desktop application is developed in the Visual Studio to demonstrate result in effective way. The software received the values using internet. For this purpose, a Node MCU is employed into the system.

B. *Hardware Results*

For an Electric Vehicle (EV), the hardware outcomes of a Battery Management System (BMS) are essential for guaranteeing the performance, lifespan, and safety of the vehicle's battery pack. Here are some significant hardware-related findings and BMS for an EV features:

Voltage Monitoring: The voltage levels of certain cells or groups of cells inside the battery pack are continually monitored by the BMS. Precise voltage measurements made using hardware aid in the identification of cell imbalances, overvoltage situations, and undervoltage scenarios.

Current Sensing: The BMS detects the current flowing into and out of the battery pack during charge and discharge cycles using current sensors like the ACS712. For state-of-charge assessment, energy management, and protection against overcurrent situations, accurate current data is crucial.

Temperature Monitoring: The temperature of the battery cells and the entire battery pack is tracked using temperature sensors included into the BMS, such as the DHT sensor. For thermal management, reducing overheating, and improving charging and discharging rates, hardware results offer real-time temperature data.

Safety Feature: In case of overvoltage, overcurrent, or other fault circumstances, the battery pack is isolated by hardware-based cutoff switches or relays that are part of the BMS hardware. These security measures shield the battery and the car from potential dangers.

C. *Discussion of the finding*

In this phase of the study, we will discuss about the findings of the study Battery Management System for Electrical Vehicle. The findings of the purposed hardware are listed below.

1. The proposed system helps to provide protection against under and over voltage.
2. The intended system contributes to monitor batteries in real time.
3. The purposed system monitors the temperature of the batteries.
4. The purposed system will help to monitor load on the batteries.
5. The system works with the Desktop application.

D. *Future Recommendaton*

After finishing the hardware and merging all of the software results. We may now recommend that others employ the approaches we learned during hardware implementation. The recommendations we are making are as follows:

- Use Lithium-Ion batteries
- Use latest micro controller
- Use Radio Frequency Modules
- Use ZMCT for current sensor

V. CONCLUSION

A Battery Management System (BMS) for Electric Vehicles (EVs) is an important component that ensures the safe, efficient, and dependable operation of the vehicle's battery pack. To improve performance and protect the battery's health, it checks several factors such as voltage, current, temperature, and state of charge. The BMS prevents overcharging, over discharging, and temperature concerns, increasing the battery's lifespan and preserving its capacity. While BMS technology has improved tremendously, it still faces issues like as accuracy, complexity, and scalability. Nonetheless, it is an essential component of current EVs, helping to their long-term viability and broad acceptance. As the EV market evolves, BMS technology will be critical in improving battery performance, resolving safety problems, and accelerating the move to cleaner, more sustainable transportation alternatives.

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