Real Time Monitoring And Protection of Lithium-Ion Batteries Using Microcontroller Based BMS

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***Abstract*—**The rapid growth of electric vehicles (EVs) has increased the need for an efficient and reliable Battery Management System (BMS) to ensure safe battery operation. The lithium-ion battery used in EVs is highly sensitive to variations in voltage, current, and temperature. Improper monitoring of these parameters can lead to reduced battery life, performance degradation, or safety hazards. This project presents the design and implementation of an Electric Vehicle Battery Backup System integrated with essential components such as a lithium-ion battery pack, BMS, voltage sensor, current sensor, and temperature sensor for accurate real- time monitoring and protection. The proposed system uses a lithium-ion battery as the primary energy storage source due to its high energy density, lightweight structure, and long cycle life. A dedicated BMS is employed to continuously monitor battery parameters and maintain safe operating limits. The voltage sensor measures the battery voltage to prevent overcharging and deep discharge conditions. The current sensor tracks charging and discharging currents to avoid overload and short-circuit faults. Additionally, a temperature sensor monitors battery temperature to detect overheating and ensure thermal safety. A microcontroller-based control unit processes the data collected from these sensors and makes intelligent decisions for power management and protection. When abnormal conditions such as overvoltage, undervoltage, overcurrent, or excessive temperature are detected, the system automatically activates protective mechanisms. These include disconnecting the load, stopping the charging process, or limiting current flow to prevent battery damage. The developed prototype is cost-effective, compact, and suitable for electric two-wheelers and small EV applications. By integrating voltage, current, and temperature sensing within the BMS framework, the system significantly improves battery safety, operational, and lifespan. This project contributes to enhancing EV reliability while promoting sustainable and energy-efficient transportation solutions.

Keywords*—,Battery Management System (BMS), Lithium-ion Battery, Voltage Sensor, , Temperature Sensor, Battery Protection Real-time Monitoring, Arduino Nano, Thing Speak , SolidWorks.*

INTRODUCTION

The rapid growth of electric vehicles (EVs) has increased the demand for efficient, reliable, and intelligent battery management systems. Since the battery is the heart of an electric vehicle, ensuring continuous power supply, safety, and optimal performance is essential. An Electric Vehicle Battery Backup System is designed to enhance energy reliability, monitor battery health, and provide controlled power distribution to various vehicle components such as the BLDC hub motor, lights, horn, and display systems. In this system, a Lithium-Ion battery serves as the primary energy source due to its high energy density, lightweight nature, and long lifecycle. The battery is managed by a Battery Management System (BMS), which monitors voltage, current, and temperature to prevent overcharging, deep discharging, and thermal runaway conditions. The controller acts as the central processing unit of the vehicle. It receives inputs from sensors such as temperature, current, and voltage sensors, as well as user inputs like the ON/OFF key and accelerator. Based on these inputs, the controller regulates power flow to the BLDC hub motor and auxiliary loads such as lights and horn. The battery indicator display provides real time information about battery status, ensuring user awareness and operational safety. The backup feature of the system ensures that in case of voltage fluctuations, overload conditions, or partial battery failure, the system can maintain controlled operation, thereby improving vehicle reliability and safety. This intelligent monitoring and control approach enhances battery lifespan, improves efficiency, and reduces the risk of unexpected power loss. Overall, the Electric Vehicle Battery Backup System integrates power electronics, sensing technologies, and embedded control to deliver a safe, efficient, and sustainable transportation solution.

EXISTING SYSTEM

The conventional Electric Vehicle (EV) system operates using a single main battery pack that supplies power to the controller, which in turn drives the BLDC hub motor. The system includes a Battery Management System (BMS), voltage sensor, current sensor, temperature sensor, accelerator input, and output components such as lights, horn, brake indicator, and battery display.

The battery indicator display shows the State of Charge (SOC) to the user. When the battery level becomes critically low, the system either limits motor speed or shuts down completely to prevent deep discharge. There is no secondary battery or emergency backup mechanism in most conventional EV designs.

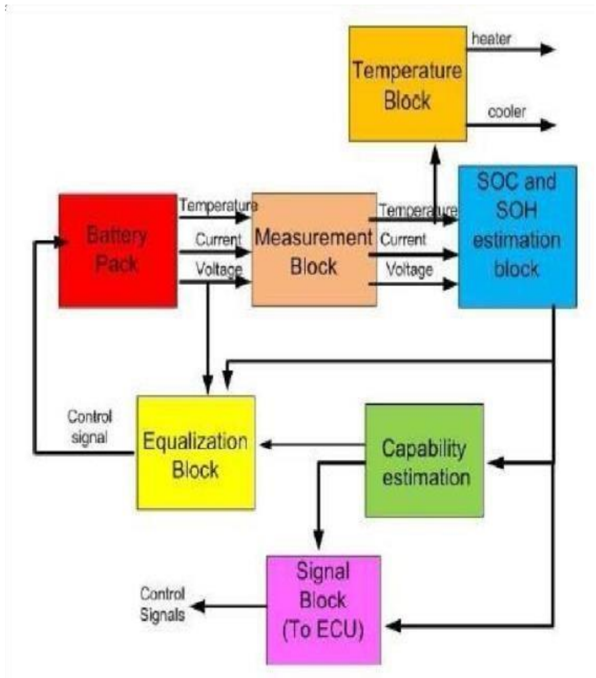

Fig.1 Block diagram of Battery Management System

PROPOSED SYSTEM

The proposed Electric Vehicle Battery Backup System introduces an intelligent dual-battery architecture to ensure uninterrupted and safe vehicle operation. In addition to the primary high-capacity battery pack, a secondary auxiliary backup battery is integrated into the system. Under normal operating conditions, the main battery supplies power to the controller, which drives the BLDC hub motor based on accelerator input. The Battery Management System (BMS) continuously monitors key parameters such as voltage, current, temperature, State of Charge (SOC), and State of Health (SOH) to ensure safe and efficient performance. When the main battery voltage drops below a predefined threshold or a fault condition such as overheating or overcurrent is detected, the controller automatically activates an intelligent switching mechanism.

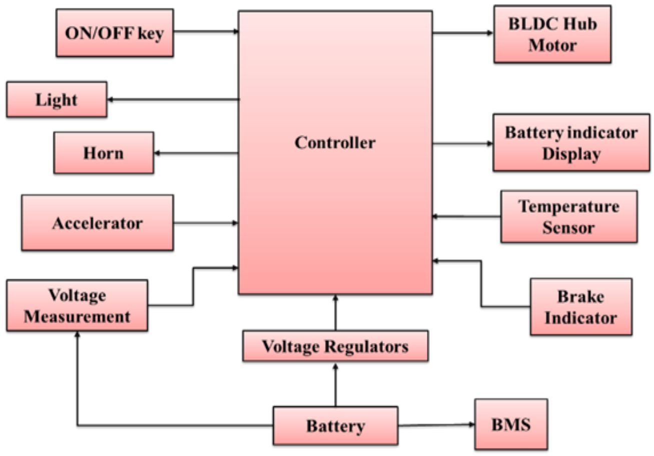

Fig.2 Block diagram of Proposed system

This mechanism seamlessly transfers the load from the primary battery to the auxiliary backup battery without interrupting vehicle operation. Upon activation of the backup system, the vehicle enters an emergency operating mode in which the motor runs at a limited speed to conserve energy while maintaining essential functions such as lights, horn, brake indicator, and battery display. The proposed system enhances safety by preventing sudden shutdowns and allowing the rider to travel a limited distance to the nearest charging station.

By leveraging AI and real-time analytics, this system revolutionizes EV battery safety, optimizing performance, extending battery lifespan, and preventing catastrophic failures. Its predictive and proactive approach enhances user safety and supports the broader adoption of electric vehicles by addressing critical battery reliability concerns. allowing the rider to travel a limited distance to the nearest charging station.

METHODOLOGY

1. System Design and Architecture

The overall system architecture is designed based on a central controller that manages power flow between the Lithium-Ion battery, BLDC hub motor, and auxiliary loads. A Battery Management System (BMS) is integrated to ensure battery protection and monitoring. The block diagram includes sensors (temperature, voltage, and current), user inputs (ON/OFF key, accelerator), and output devices (motor, lights, horn, display).

2. Battery and BMS Integration

A Lithium-Ion battery is used as the primary energy source due to its high energy density and efficiency. The BMS continuously monitors:

- ➢ Battery voltage
- ➢ Charging/discharging current
- ➢ Temperature
- ➢ State of Charge (SOC)

The BMS protects the battery from overcharging, deep discharge, overheating, and short circuits.

3. Sensor Implementation

Different sensors are integrated to ensure safe operation:

- Voltage Sensor: Monitors battery voltage levels.
- Current Sensor: Measures motor and load current consumption.
- Temperature Sensor: Detects battery and controller temperature to prevent thermal issues.

Sensor data is continuously fed to the controller for real-time decision-making.

4. Controller Programming and Control Strategy

The controller acts as the main processing unit. It:

- Receives input from accelerator and ON/OFF switch.
- Processes sensor data.
- Regulates power supply to the BLDC hub motor.
- Controls auxiliary loads (lights, horn, brake indicator).
- Activates protection mechanisms during abnormal conditions.

A control algorithm is implemented t o ensure efficient power distribution and automatic cutoff during faults.

5. Motor Drive Operation

The BLDC hub motor is controlled based on accelerator input. The controller adjusts motor speed using PWM (Pulse Width Modulation) techniques to ensure smooth acceleration and energy efficiency.

6. Battery Backup Mechanism

The system is designed to maintain stable output during:

- ➢ Voltage drops
- ➢ Overcurrent conditions
- ➢ Temperature rise

If abnormal parameters are detected, the controller limits motor speed or disconnects the load to protect the battery and system components.

7. Display and User Interface

A battery indicator display provides real-time information about:

- ➢ Battery level
- ➢ Fault conditions
- ➢ System status

This improves user awareness and operational safety.

8. System Process

The Electric Vehicle (EV) Battery Backup System operates by coordinating the battery pack, BMS, controller, sensors, and BLDC hub motor to ensure safe and efficient vehicle operation.

The overall system process is explained below:

Step 1: Power Initialization

➢ When the ON/OFF key is turned ON, the battery supplies power to the system.

➢ The Voltage Regulators step down the battery voltage to required levels (5V/12V) for controller and sensors.

➢ The controller initializes and checks system status.

Step 2: Battery Monitoring (BMS Operation)

➢ The Battery Management System (BMS) continuously monitors:

- ➢ Battery voltage
- ➢ Charging/discharging current
- ➢ Temperature
- ➢ State of Charge (SOC)

➢ If any abnormal condition (overvoltage, undervoltage, overcurrent, overheating) is detected, the BMS disconnects the battery to protect the system.

Step 3: Voltage Measurement & Display

➢ Voltage measurement circuit sends real-time battery voltage to the controller.

➢ The controller updates the Battery Indicator Display to show battery level and warning alerts.

Step 4: Acceleration & Motor Control

➢ When the rider presses the accelerator, a signal is sent to the controller.

➢ The controller regulates power to the BLDC Hub Motor using PWM signals.

Step 5: Temperature Monitoring

➢ The Temperature Sensor continuously measures battery/motor temperature.

➢ If temperature exceeds safe limits, the controller reduces motor power.

Step 6: Auxiliary Controls

- ➢ The controller manages:
- ➢ Light system
- ➢ Horn
- ➢ Brake Indicator (activated during braking)

Step 7: Backup & Protection Mode

➢ During sudden load or power fluctuation, the battery backup system ensures continuous supply.

➢ If the main battery voltage drops below threshold, the controller limits speed to extend battery life.

9. Feasibility Study

1. Technical Feasibility

➢ Uses readily available components such as Lithium-ion battery, BMS, BLDC hub motor, voltage regulators, and sensors.

➢ Microcontroller-based control system is easy to program and integrate.

➢ Proven technologies ensure reliable and safe operation.

➢ System design is modular and scalable.

2. Economic Feasibility

➢ Components are cost-effective and widely available in the market.

➢ Low maintenance cost due to fewer mechanical parts.

➢ Energy-efficient system reduces operational cost.

➢ Suitable for student projects and commercial.

3. Operational Feasibility

- ➢ Simple ON/OFF key-based operation.
- ➢ Automatic battery monitoring and protection.
- ➢ User-friendly battery indicator display.
- ➢ Minimal human intervention required.

4. Environmental Feasibility

➢ Reduces carbon emissions compared to fuel vehicles.

➢ Promotes use of renewable charging sources (solar/grid hybrid).

➢ Low noise pollution.

System Design and Architecture

The overall system architecture is designed based on a central controller that manages power flow between the Lithium-Ion battery, BLDC hub motor, and auxiliary loads. A Battery Management System (BMS) is integrated to ensure battery protection and monitoring. The block diagram includes sensors (temperature, voltage, and current), user inputs (ON/OFF key, accelerator), and output devices (motor, lights, horn, display).

Motor Drive Operation

The BLDC hub motor is controlled based on accelerator input. The controller adjusts motor speed using PWM (Pulse Width Modulation) techniques to ensure smooth acceleration and energy efficiency.

Additionally, the system includes an automated safety response mechanism that can adjust charging rates, activate cooling systems, or isolate faulty cells when anomalies are detected. Its integration with IoT enables remote monitoring, allowing manufacturers and users to track battery health in real time. A motor control algorithm is a software-based, mathematical procedure.

System Process

The Electric Vehicle (EV) Battery Backup System operates by coordinating the battery pack, BMS, controller, sensors, and BLDC hub motor to ensure safe and efficient vehicle operation.

Arduino UNO

Arduino/Genuine Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, wors case scenario you can replace the chip for a few dollars and start over again.

Fig.3 Arduino UNO interface

Arduino Nano

The Arduino Nano is a small, powerful microcontroller that serves as the brain of the system. It collects data from multiple sensors, processes it, and sends it to the machine learning model. It also facilitates communication with external systems such as cloud platforms (Thing speak) and notification systems. (emails, voice alerts). Operates at 5V with a 16MHz clock speed, making it suitable for low-power applications.

Temperature Sensor

Used to monitor the temperature of the battery and surrounding environment. Prevents overheating issues by detecting sudden temperature rises. Helps in early detection of thermal runaway, which is a major cause of battery fires and explosions. Common choices include LM35 or DS18B20 sensors, which provide accurate readings in real time. A thermistor is a type of resistor whose resistance varies with temperature. The temperature response is also different; RTDs are useful over larger temperature range. while thermistors typically achieve a higher precision. A motor control algorithm is a software-based, mathematical procedure executed by a microcontroller or DSP to manage electric motor speed, torque,and position.

Fig.4 Temperature Sensor

LCD display

They are used in a wide range of applications including: computer monitors, television, instrument panels, aircraft cockpit displays, signage, etc. They are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones. LCDs have displaced cathode ray tube (CRT) displays in most applications.

Fig.5 Temperature Sensor

Voltage Sensor

Measures the voltage level of the battery to ensure it is operating within a safe range. Detects overvoltage or under voltage conditions, which could indicate battery failure. Helps in predicting battery health and preventing unexpected shutdowns. A typical sensor used is the voltage divider circuit or an INA219 sensor for precise measurements.

Fire Sensor

Monitors for flames or excessive heat near the battery area. Helps in detecting fire hazards early and triggers immediate alerts. Can be an IR-based flame sensor or a temperature threshold sensor.

Thing speak

Thing Speak is an opensource API “Internet of Things” application and API to store and retrieve data from things using HTTP over the Internet or via a Local Area Network. With location tracking applications, and a social network of things with status updates in addition to storing and retrieving numeric and alphanumeric data, the Thing Speak API allows for numeric data processing such as time scaling, averaging, median, summing, and rounding. Each Thing Speak Channel supports data entries of up to 8 data fields, latitude, longitude, elevation and status. The channel fields support JSON, XML, and CSV formats for integration into applications. The primary element of Thing Speak activity is the channel, which contains data fields, location fields, and a status field.

DESIGN VALIDATION/PROTOTYPE TESTING

- Verification of battery charging and discharging operation
- Testing of automatic switching between main battery and backup battery
- Validation of Battery Management System (BMS) functionality
- Measurement of output voltage and current stability
- Load testing under different operating conditions
- State of Charge (SoC) monitoring accuracy test
- Thermal performance testing during continuous operation.
- Overcharge and over-discharge protection testing
- Short-circuit and overcurrent protection validation
- Backup switching time measurement
- Energy efficiency calculation (input vs output power)
- Power loss analysis in DC-DC converter
- Real-time monitoring system testing
- Field testing under practical driving conditions
- Overall system reliability and safety validation

HARDWARE SPECIFICATION

A. *Lithium-Ion Battery Pack*

- 48V / 60V DC output
- 20Ah–30Ah capacity
- Rechargeable, high-Energy density
- Provides main power supply

B. *Battery Management System (BMS)*

- Overvoltage protection
- Undervoltage protection
- Overcurrent protection
- Short circuit protection
- Temperature monitoring

BLDC Hub Motor

- 250W–1000W power rating
- 48V operating voltage
- High efficiency (80–90%)
- Low maintenance

Motor Controller

- 48V input
- PWM speed control
- Regulates torque and speed
- Supports regenerative braking (optional)

Voltage Regulator (DC-DC Converter)

- Converts 48V to 12V / 5V
- Supplies power to controller and sensors
- High efficiency (>85%)

Microcontroller Unit (MCU)

- 5V operating voltage
- ADC for voltage sensing
- Controls system operations

Temperature Sensor

- Monitors battery/motor temperature
- Prevents overheating

Voltage Measurement Circuit

- Measures battery voltage
- Sends data to MCU

Accelerator (Throttle)

- Hall-effect type
- Controls motor speed

Display Unit

- LCD/LED display
- Shows battery level and warnings

RESULT AND DISCUSSION

Voltage Output

The voltage regulator maintained a constant and stable output supply to the controller and auxiliary components, ensuring uninterrupted operation.

Efficient Battery Monitoring

The Battery Management System (BMS) accurately monitored battery voltage, temperature, and current. Overcharge and deep discharge protection were successfully triggered during extreme test conditions.

Temperature Control Performance

The temperature sensor detected abnormal heat conditions, and the controller responded by limiting motor operation, preventing overheating.

Smooth Motor Operation

The BLDC hub motor showed smooth acceleration and deceleration based on accelerator input. Speed control was stable without sudden fluctuations.

Effective Backup Performance

The system provided reliable backup power during load variations, maintaining consistent performance without sudden power.

Real-Time Display Monitoring

The battery indicator display accurately reflected charge percentage and system status, allowing users to monitor battery health easily.

Discussion

The experimental results demonstrate that the proposed battery backup system enhances both safety and performance of the electric vehicle. The integration of BMS with voltage and temperature monitoring significantly reduces risks such as overheating, short circuits, and battery degradation.

The controller playsacritical role in coordinating inputs from the accelerator, brake indicator, and sensors to maintain stable vehicle operation. The use of a BLDC hub motor improves efficiency due to reduced mechanical losses and high torque capability.

shows good energy management and efficient power utilization. However, the performance may vary depending on battery capacity, load conditions, and environmental temperature. Future improvements may include advanced state-of-charge (SOC) estimation algorithms, regenerative braking integration,and IoT-based remote monitoring. Over all, the developed Electric Vehicle Battery Backup System demonstrates reliable performance, improved safety, and effective energy management, making it suitable for practical EV applications.

Fig.6 Real-Time Monitoring And Protection of Lithium -ion Batteries using microcontroller -Based BMS

CONCLUSION

The Electric Vehicle Battery Backup System is a reliable and efficient solution designed to enhance the performance, safety, and lifespan of electric vehicles. The developed system integrates key components such as the battery pack, BMS (Battery Management System), voltage regulators, controller, sensors, BLDC hub motor, and monitoring indicators to ensure smooth and safe operation.

The Battery Management System continuously monitors voltage, temperature, and current parameters to prevent overcharging, deep discharging, overheating, and short circuits. The controller effectively manages inputs from the accelerator, brake indicator, and temperature sensor to regulate motor speed and overall system performance. Voltage regulators provide stable power supply to sensitive electronic components, improving system reliability. The battery indicator display helps users monitor charge levels, ensuring timely recharging and preventing unexpected power.

Overall, the proposed system improves energy efficiency, enhances operational safety, and provides real-time monitoring for better control. It is cost-effective, scalable, and suitable for modern electric vehicles. The implementation of this battery backup system contributes to sustainable transportation by promoting efficient energy utilization and reducing dependency on fossil fuels.

FUNDING

The development of Electric Vehicle (EV) technologies, including battery management and energy storage systems, is supported by increasing investments from governments, research institutions, and private organizations. In India, several programs encourage research and innovation in EV subsystems such as battery management systems, power.

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