

Design and Simulation of a Smart Battery Management System (BMS) in EV

R.Gohila 

Associate Professor, Department of Electrical and Electronics Engineering
Sengunthar Engineering College (Autonomous), Tiruchengode, India

tgohila.eee@scteng.co.in

<https://orcid.org/0009-0001-5609-7855>

Deepu Kumar, Hariharan S, Imnavuvelraj M

UG Student, Department of Electrical and Electronics Engineering
Sengunthar Engineering College (Autonomous), Tiruchengode, India

deepukumareee2026@scteng.co.in, 995261harigmail.com, immanimman678@gmail.com



Publication History

Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10101

Research Article | Open Access | Double-Blind Peer-Reviewed | Article ID: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10101

Received: 22, February 2026, Revised: 01, March 2026, Accepted: 16, March 2026, Published Online: 25, March 2026.

<https://www.ijirae.com/volumes/Vol13/iss-03/22.AEMR26.MRAE10101.pdf>

Article Citation: Gohila, Deepu, Hariharan, Imnavuvelraj (2026), Design and Simulation of a Smart Battery Management System (BMS) in EV, IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 203-206 **Doi:** <https://doi.org/10.26562/ijirae.2026.v1303.22>

BibTeX Key: Gohila@2026Design

IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, <https://doi.org/10.26562/ijirae.2026.v1303.22> The journal's official abbreviation is IJIRAE. **Orcid:** <https://orcid.org/0009-0004-9398-7488>

About the License: Copyright © 2026 copyright by the authors. This article is an open access and license under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Abstract: This paper presents the Design and Simulation of a Smart Battery Management System (BMS) for an Electric Vehicle (EV). The proposed system ensures safe, efficient, and reliable charging using renewable energy sources such as solar power. The ESP 32 microcontroller monitors key battery parameters like voltage, current, and temperature, while the switching and balancing unit maintains equal charge among cells. An IoT-based platform enables real-time monitoring through a mobile application, enhancing system control and safety. Simulation tools are used to analyze the performance and efficiency of the BMS under various operating conditions. The system aims to reduce grid dependency, improve battery life, and promote sustainable energy use. Overall, this project demonstrates an intelligent, eco-friendly solution for next-generation EV charging infrastructure.

Keywords: Battery Management System (BMS), Off-Grid EV Charging, ESP32 Microcontroller, Temperature Monitoring, Cell Balancing, Smart Charging System.

INTRODUCTION

The global shift towards sustainable energy solutions has spurred the growth of electric vehicles (EVs) and renewable energy technologies. One of the critical challenges in this transition is the effective integration of off-grid energy systems that can independently power EV charging stations without relying on the conventional electricity grid. In such systems, a Battery Management System (BMS) plays a pivotal role in ensuring the efficient and safe operation of the energy storage solutions, which typically involve batteries sourced from solar or wind power. This paper focuses on the design and simulation of a Battery Management System (BMS) specifically tailored for use in an off-grid EV charging station. The primary objective is to create a robust system that optimizes the charge and discharge cycles of the battery bank, maintains the health of the battery, and enhances the overall efficiency of the energy system. The paper involves integrating several components, including solar power generation, energy storage, DC-DC converters, and a communication protocol between the system's components, all controlled by a sophisticated BMS. In addition to ensuring battery safety (temperature, voltage, and current monitoring), the BMS will be designed to manage the overall energy flow, ensuring the EV charging station operates efficiently even in remote, off-grid locations where traditional power infrastructure is unavailable. Simulations of this system will help validate its performance under various operating conditions and assess.

EXISTING SYSTEM

Existing Systems for an intelligent battery monitoring and management system based on the ESP32. In this system, Pack-1 (battery pack) acts as the main energy storage unit that provides DC power to the entire system and the connected load. To ensure safe and efficient operation of the battery, several sensors are used. The temperature sensor continuously measures the battery temperature to prevent overheating, which can damage the battery or reduce its life. The voltage sensor monitors the battery voltage level to detect conditions such as over-voltage or under-voltage. The current sensor measures the charging or discharging current flowing from the battery to the load. All these sensor signals are sent to the ESP32 microcontroller, which acts as the central processing unit of the system. The controller reads the sensor data, analyzes the battery condition, and decides whether the battery is operating within safe limits.

Based on this analysis, the ESP32 controls the switching/balancing unit, which performs two important tasks: switching the battery connection to the load and balancing the voltage of individual battery cells to maintain uniform charge distribution. Proper balancing improves battery efficiency, safety, and lifespan. The processed information, such as voltage, current, temperature, and system status, is displayed on the LCD display, allowing users to easily monitor the battery's condition in real time. A power supply unit is used to provide the required regulated voltage to operate the ESP32 controller and other electronic components in the circuit. Finally, the managed and protected power from the battery pack is delivered to the load, ensuring reliable and safe energy utilization. This overall system improves battery performance, enhances safety, and enables smart monitoring and control of power distribution.

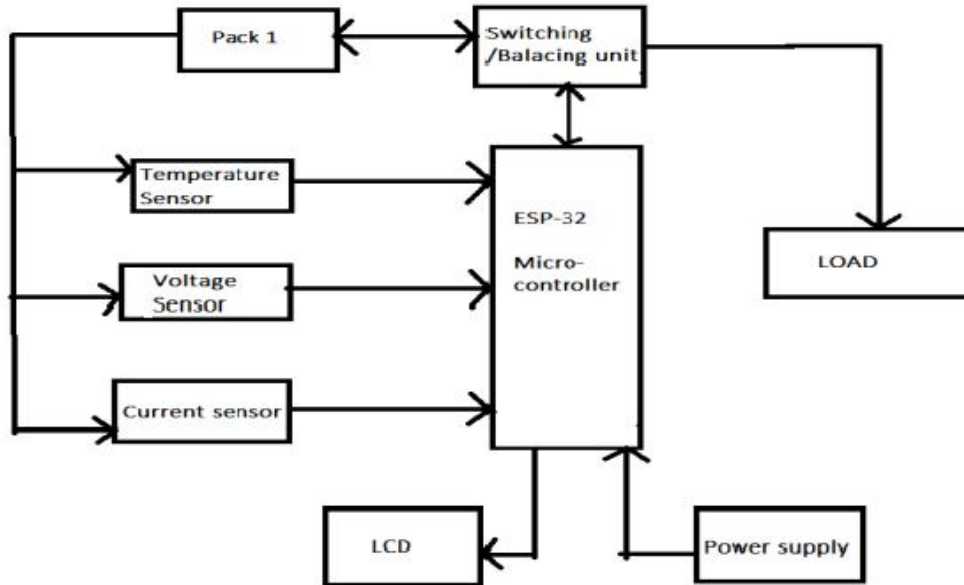


Figure1 - Block diagram for Existing system

PROBLEM IDENTIFICATION

Battery Overcharging and Over-discharging

In EV battery systems, improper charging or deep discharging can damage battery cells and significantly reduce their lifespan. Without an intelligent monitoring system, maintaining safe voltage limits for each cell becomes difficult.

Temperature Rise in Battery Pack

During charging and discharging, batteries generate heat. Excessive temperature can lead to performance degradation, safety hazards, or even thermal runaway. Hence, continuous temperature monitoring is required to ensure safe operation.

Uneven Cell Voltage in Battery Packs

An EV battery pack consists of many cells connected in series or parallel. Over time, these cells may develop different voltage levels due to internal resistance variations. Without a balancing mechanism, some cells may overcharge or discharge faster than others.

PROPOSED SYSTEM

The proposed system the battery pack supplies power to the load. To ensure safe operation, three sensors are used: a voltage sensor, current sensor, and temperature sensor. These sensors continuously measure the battery's condition and send the data to the ESP32 microcontroller.

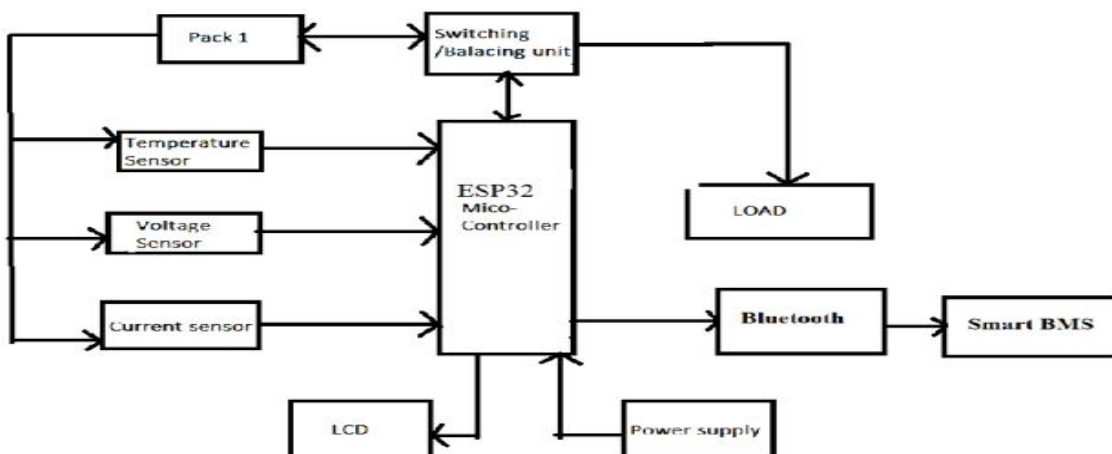


Figure 2- Block diagram for proposed system

The ESP32 processes this information and decides whether the battery is in a safe state. If any cell has higher voltage than others, the switching/balancing unit balances the cells by discharging the extra energy, keeping all cells equal. This helps increase battery life and performance. If the battery reaches unsafe levels (overcharge, over-discharge, or overheating), the ESP32 can disconnect the battery from the load to prevent damage. The system also has an LCD screen to display real-time battery status like voltage, current, temperature, and state of charge. A Bluetooth module is connected to the ESP32, allowing the data to be viewed wirelessly on a smart phone app. This forms the Smart BMS (Battery Management System). The power supply ensures ESP32 and sensors receive stable low-voltage power.

SIMULATION AND RESULT

In the simulation environment, a model of a battery pack was developed, comprising multiple cells connected in series to simulate an electric vehicle (EV) battery system. Voltage sensors were utilized to monitor the battery pack's voltage levels, while a current sensor tracked both the charging and discharging currents. Additionally, a temperature sensor was incorporated to measure the heat generated during the battery's operation. The simulation verifies that the proposed Smart BMS system effectively monitors battery parameters, safeguards against unsafe operating conditions, and ensures balanced cell voltages. This enhances battery safety, reliability, and efficiency in electric vehicle applications. Furthermore, the system facilitates real-time monitoring and intelligent control, making it well-suited for contemporary EV battery management systems.

MATLAB SIMULATION

The Smart Battery Management System (BMS) for electric vehicles was designed and simulated using MATLAB and Simulink to analyze and monitor important battery parameters such as voltage, current, and temperature. In the simulation model, a lithium-ion battery pack representing multiple cells connected in series was created to study the charging and discharging behavior of the EV battery. Voltage and current measurement blocks were used to continuously monitor the electrical parameters of the battery, while a temperature monitoring block was included to observe the thermal condition of the battery pack during operation. The measured signals were sent to the controller unit, where predefined limits were set to detect abnormal conditions such as over-voltage, under-voltage, over-current, and high temperature. When any parameter exceeded the safe limit, the controller activated the switching and protection mechanism to disconnect the load and protect the battery pack.

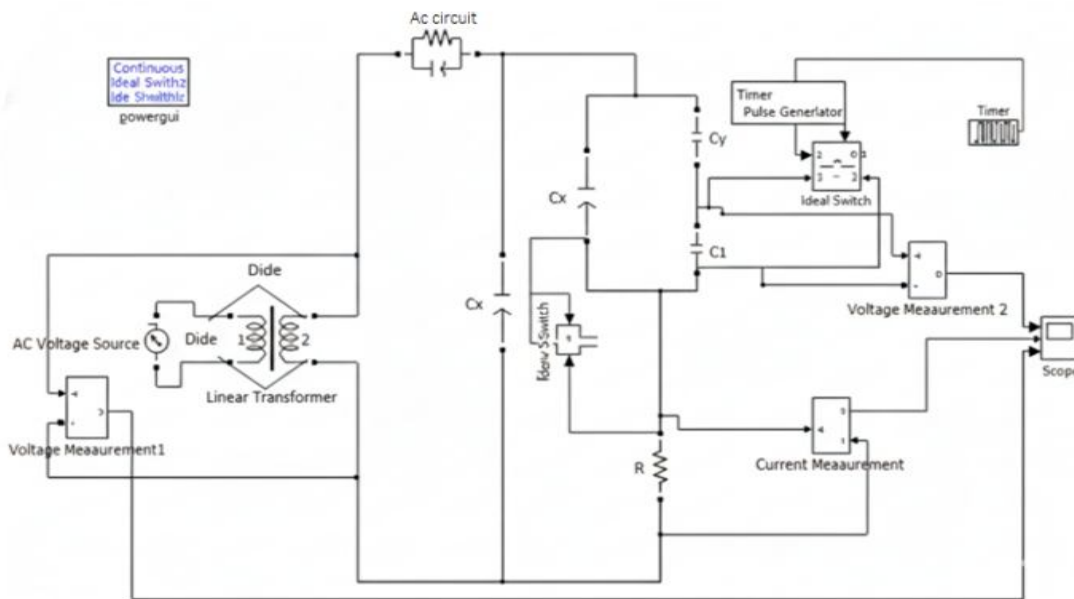


Figure4 - Simulink model

RESULT

The simulation results of the Smart Battery Management System (BMS) designed using MATLAB and Simulink show that the system effectively monitors and controls important battery parameters such as voltage, current, and temperature. The BMS successfully detected abnormal conditions like over-voltage, under-voltage, over-current, and excessive temperature during battery operation and activated the protection mechanism to disconnect the load when necessary. The simulation also demonstrated proper cell balancing, ensuring that all battery cells maintained nearly equal voltage levels, which helps improve battery efficiency and lifespan. Overall, the results confirm that the proposed Smart BMS enhances battery.

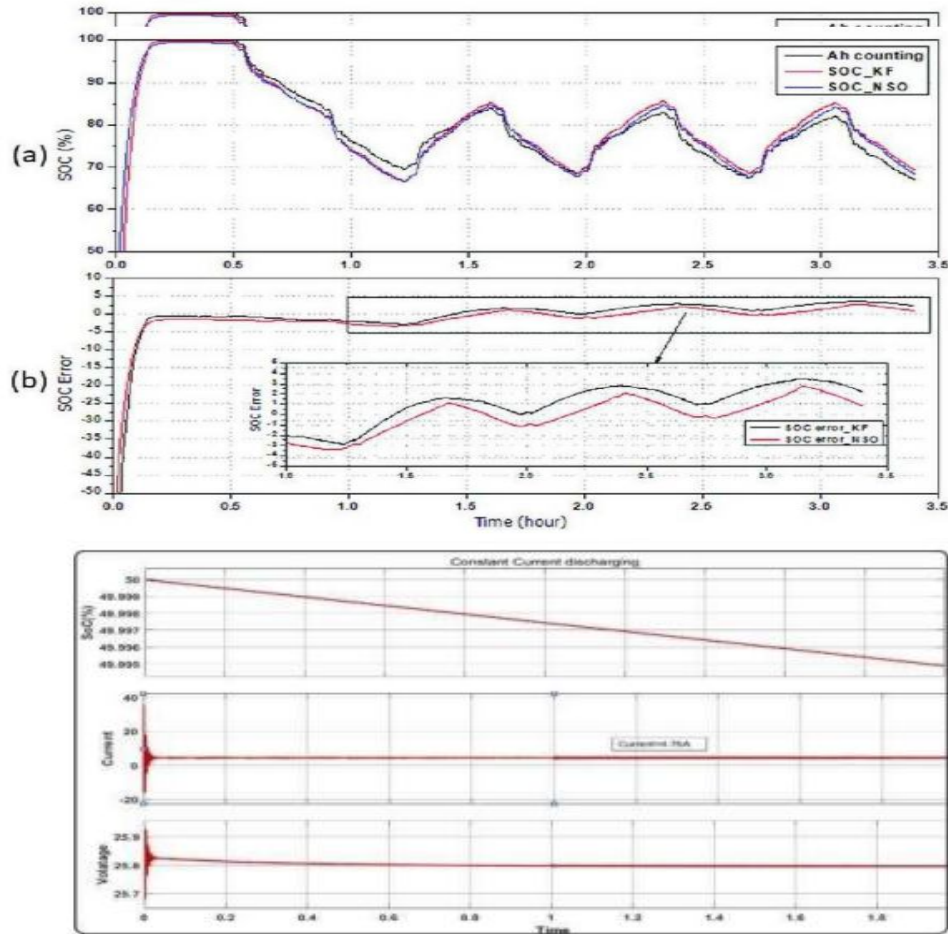


Figure 5 - Simulation result

CONCLUSION

The paper, "The Design and Simulation of the Battery Management System (BMS) for an Off-Grid EV Charging Station," emphasizes the critical role of advanced monitoring and control strategies to ensure the safe, efficient, and reliable operation of batteries in electric vehicle (EV) charging systems. By integrating key components like State of Charge (SoC) estimation, State of Health (SoH) estimation, thermal management, and fault detection, the BMS effectively addresses the most pressing challenges related to battery performance, lifespan, and safety. The SoC estimation method, utilizing Coulomb Counting, provides a precise measure of the battery's remaining capacity, enabling optimal energy management and improving charging efficiency. Meanwhile, SoH estimation simulates the battery's degradation over multiple discharge cycles, offering valuable insights into its long-term health, which helps users monitor wear and plan for timely maintenance or replacements.

REFERENCES

1. M.A.Hannan et al., "Smart battery management system for electric vehicles: A comprehensive review," *IEEE Access*, vol. 9, pp. 60061–60076, 2021.
2. H.Xiong et al., "State-of-health estimation of lithium-ion batteries using LSTM neural network," *IEEE Access*, 2021
3. Z.Chen, K.Liu, et al., "Machine learning-based battery aging assessment," *IEEE Transactions on Transportation Electrification*, 2022.
4. A.Moulietal., "Real-time SOC estimation using adaptive UKF in EV BMS," *IEEE Transactions on Industrial Electronics*, 2020.
5. P.Yang and K.Li, "SOH prediction using hybrid CNN-GRU model," *IEEE Access*, 2022. DOI: 10.1109/ACCESS.2022.3157445
6. J.Lietal., "Cloud-connected smart BMS for EV fleet monitoring," *IEEE Internet of Things Journal*, 2023.
7. N. Watrinetal., "Battery cell balancing strategies for EV BMS," *IEEE Access*, 2020. DOI: 10.1109/ACCESS.2020.2975180
8. Y.Tan et al., "Transfer learning-based SOH estimation for lithium-ion batteries," *IEEE Transactions on Industrial Informatics*, 2022. DOI: 10.1109/TII.2022.3163335
9. X.Hu, M.Xu et al., "Unified battery thermal and electrical modeling for BMS," *IEEE Transactions on Vehicular Technology*, 2021. <https://doi.org/10.1109/TVT.2021.3058753>
10. R.Teodorescu et al., "Fast charging-aware smart BMS architecture for EVs," *IEEE Transactions on Power Electronics*, 2021.