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Optimizing Electric Vehicle Battery Performance: Comprehensive Study of Battery Heating Challenges and Sustainable Battery Swapping System

[1] Ramya P, [2] Nagesh R, [3] Murugesh Dodakundi

[1]Assistant Professor, Department of Electrical and Electronics Engineering
Sri Venkateshwara College of Engineering, Bengaluru
[2]Assistant Professor, Department of Mechanical Engineering
Sri Venkateshwara College of Engineering, Bengaluru
[3]Assistant Professor, Department of Electrical and Electronics Engineering
Sri Venkateshwara College of Engineering, Bengaluru

Abstract: This paper conducts a comprehensive study on battery heating challenges in electric vehicles (EVs) and proposes a sustainable battery swapping system to optimize battery performance. With the increasing demand for EVs and the necessity for extended driving ranges, notable progress has been achieved in battery technologies. However, battery heating remains a crucial concern, particularly in cold weather conditions. This research thoroughly examines various factors contributing to battery heating, including battery size, chemistry, design, and ambient conditions. Diverse battery heating techniques, such as insulation and thermal management systems, are extensively analyzed. Underlining the significance of effective battery heating solutions, this study emphasizes the importance of maintaining an optimal battery temperature to enhance performance and prolong battery life. Additionally, the paper introduces a sustainable battery swapping system controlled by a Blynk app and Node MCU controller, facilitating seamless battery replacement and promoting the integration of renewable energy sources. This system ensures uninterrupted EV operation while providing users complete control and real-time monitoring capabilities via mobile devices, revolutionizing the EV charging paradigm.

Keywords: Battery heating challenges, Electric vehicles (EVs), Battery swapping system, Sustainable charging, Battery performance optimization.

1. Introduction:

The advancement of electric vehicles (EVs) has gained significant attention in recent years due to its potential to revolutionize transportation and contribute to a greener and more sustainable future. However, the widespread adoption of EVs faces various challenges, including battery heating issues and the need for efficient charging infrastructure. This paper aims to address these challenges by exploring battery heating challenges in EVs and proposing a sustainable battery swapping system for enhanced performance and optimal charging.

The development of battery technologies has enabled EVs to have extended driving ranges and higher energy densities [1]. However, battery heating poses a critical concern, particularly in cold weather conditions, as it significantly affects battery performance and lifespan. Factors such as battery size, chemistry, design, and ambient conditions play a crucial role in battery heating [2]. To optimize battery performance and ensure prolonged lifespan, it is essential to maintain a stable battery temperature within an optimal operating range [3].

In line with addressing battery heating challenges, this paper introduces a novel battery swapping system that offers a sustainable and efficient solution for EV charging. The concept of battery swapping has gained attention as an alternative to traditional charging methods, providing quick and seamless battery replacement [4]. This system utilizes a Blynk app and Node MCU controller, allowing users to conveniently switch between batteries and monitor the charging process in real-time [5].

To situate this research within the existing literature, several key studies have been conducted in related areas. A systematic review on dynamic wireless charging systems for electric transportation highlights the current state of research and development in this field [6]. It identifies potential benefits, such as reduced battery size and increased vehicle range, but also emphasizes the need for further optimization and practical implementation of these systems. This review serves as a foundation for understanding the advancements and challenges in charging infrastructure.

Additionally, user acceptance of light electric vehicles (LEVs) and novel charging infrastructure has been explored [7]. This literature review delves into various studies that investigate user behavior, preferences, and attitudes towards LEVs and charging infrastructure. It underscores the significance of a user-centric approach, customized infrastructure design, and effective communication strategies in improving user acceptance and promoting the adoption of EVs.

Furthermore, the implementation of battery swapping systems in EVs has been examined [8]. This study focuses on the design and implementation of such systems, along with the associated benefits and challenges. While battery swapping offers an alternative charging method, further research is necessary to optimize the system and ensure its feasibility and efficiency.

Moreover, a bi-level optimization approach for the operation management of electric vehicle battery swapping and charging systems has been proposed [9]. This approach aims to optimize the system's operation, maximizing benefits for both service providers and customers. The results demonstrate the effectiveness of this approach in reducing operational costs and increasing customer satisfaction. [10]

By incorporating insights from these relevant studies, this paper seeks to contribute to the existing knowledge by comprehensively addressing battery heating challenges in EVs and proposing an innovative battery swapping system that integrates renewable energy sources for sustainable and efficient charging. [11] The subsequent sections of this paper will delve into the development and analysis of battery heating issues, the description and implementation of the battery swapping system, and a combined analysis and discussion of the findings.

Overall, this research endeavours to enhance the performance of EVs by mitigating battery heating challenges and providing a sustainable charging solution through the utilization of a battery swapping system integrated with renewable energy sources. [12] By addressing these critical aspects, this paper aims to accelerate the adoption of EVs and contribute to a greener and more sustainable future.

2. Methods and Methodology:

To achieve the objectives of this study, a comprehensive research approach was employed, combining both quantitative and qualitative methods. The methodology involved several key steps, including literature review, data collection, and analysis.

The literature review served as the foundation for understanding the current state of research and development in battery heating challenges and battery swapping electric vehicle systems. Various academic databases, journals, and relevant publications were extensively reviewed to gather insights and identify gaps in the existing knowledge.

Data collection involved a combination of primary and secondary sources. Primary information was gathered using interviews and surveys conducted with experts in the field of electric vehicles, battery technologies, and renewable energy integration. These interviews provided valuable insights into the challenges and opportunities associated with battery heating and battery swapping systems. Surveys were distributed among electric vehicle owners and users to gather information about their experiences, preferences, and opinions regarding battery heating issues and charging methods.

Secondary data was collected from reliable sources such as research papers, technical reports, and industry publications. These sources provided additional information on battery technologies, thermal management systems, and existing battery swapping systems implemented in the market.

The collected data was analyzed using a combination of qualitative and quantitative methods. Qualitative analysis involved the categorization and interpretation of interview transcripts and survey responses, allowing for a deeper understanding of the factors influencing battery heating and user perspectives on battery swapping systems. Quantitative analysis involved the statistical analysis of survey data, including descriptive statistics and correlation analysis, to identify patterns and relationships between variables.

The findings from the analysis were then synthesized and presented in a coherent manner, providing insights into the challenges associated with battery heating and the benefits and feasibility of the proposed battery swapping system integrated with renewable energy sources.

The methodology employed in this study aimed to gather comprehensive and reliable data, combining both qualitative and quantitative approaches to ensure a robust analysis of battery heating challenges and the proposed battery swapping system. By adopting this research methodology, the study aimed to contribute valuable insights to the existing knowledge and offer practical recommendations for addressing battery heating issues in electric vehicles.

3. Requirements:

Hardware Requirements:

Laptop: A laptop computer is required for programming and configuring the hardware components of the battery swapping system.

Node MCU ESP8266: The Node MCU ESP8266 is a microcontroller board that acts as the main control unit for the system, facilitating communication between different hardware components.

Arduino UNO: The Arduino UNO microcontroller board is utilized for controlling and interfacing with various sensors and actuators in the system.

Voltage Sensor: A voltage sensor is employed to measure the battery voltage levels accurately during the swapping process.

Relays: Relays are used to control the switching of batteries and manage the power flow within the system.

IC 7805 Voltage Regulator: The IC 7805 voltage regulator ensures a stable and regulated power supply for the system components.

12V Batteries: The batteries serve as the power source for the electric vehicle and are interchangeable during the battery swapping process.

Solar Panel: A solar panel is integrated into the system to harness renewable energy and provide an eco-friendly charging option for the batteries.

Motor drive L298N: The motor drive L298N is employed to control the movement of the battery swapping mechanism, ensuring precise and reliable battery swapping operations.

Wheels: Wheels are attached to the battery swapping mechanism, enabling smooth movement and positioning within the charging station.

DHT11 Sensor: The DHT11 sensor is used to measure temperature and humidity levels within the charging station, allowing for effective thermal management.

I2C Display: An I2C display is incorporated to provide a user-friendly interface for monitoring battery status and displaying relevant information during the swapping process.

Software Requirements:

Arduino IDE: The Arduino Integrated Development Environment (IDE) is utilized for programming and uploading the code to the Arduino UNO and Node MCU ESP8266.

Blynk IoT platform: The Blynk IoT platform is employed in order to advance the mobile application or user interface that permits people to interact with the battery swapping system, monitor battery status, and initiate swapping operations.

The hardware aforementioned components are integrated within the proposed architecture of the battery swapping system. The Node MCU ESP8266 acts as the control unit, which gets information from sensors, controlling relays and actuators, and conversing with the Blynk IoT platform via Wi-Fi. The Arduino UNO facilitates sensor integration, voltage regulation, and actuator control, ensuring precise operation of the battery swapping mechanism and efficient energy management.

The software components, including the Arduino IDE and Blynk IoT platform, play a crucial role in programming and configuring the hardware components, as well as providing a user-friendly interface for monitoring and controlling the system.

By utilizing the specified hardware and software requirements, the implementation and architecture of the battery swapping system can be effectively realized, enabling seamless battery swapping operations, incorporating renewable energy sources, and enhanced user experience.

4. Implementation and Architecture:

The architecture of the Battery Swapping system in Electric Vehicles comprises two controllers, namely Arduino and Node MCU, along with various interconnected components that facilitate seamless battery swapping and monitoring. This section provides an overview of the system's architecture, including the controllers, sensors, relays, motors, motor driver, lithium-ion batteries, and additional features for voltage and temperature monitoring.

The system utilizes two controllers, Arduino and Node MCU, to manage and coordinate the operation of different components. Arduino is responsible for handling voltage sensing and relay control, while Node MCU controls the motor driver for vehicle movement and additional relay functions.

Voltage sensors are connected to the Arduino controller to sense the voltage levels of the batteries. These sensors provide accurate voltage readings and send signals to the controller for further processing and display to the user. The Arduino controller is powered by 5V and connects the sensors to its analog pins, enabling voltage measurement.

Relays play a crucial role in the battery swapping process. Two relays are connected to Arduino's digital pins D5 and D7, allowing control over the swapping mechanism. Additionally, two relays are connected to Node MCU's digital pin D8 and analog pin A0. These relays are used in parallel with the lithium-ion batteries, enabling the system to swap the circuit from the first battery to the second battery while putting the first battery in charging mode.

To facilitate vehicle movement, four motors are incorporated into the system. These motors are connected to a motor driver, which controls their rotation direction and movement. The motor driver is linked to Node MCU's digital pins D1, D2, D3, and D4, providing precise control over motor operation for smooth and reliable vehicle motion during the swapping process.

The system also includes additional features for voltage and temperature monitoring. Voltage divider circuits, connected to the sensors, allow for accurate voltage measurements. This information is displayed to the user, providing real-time feedback on the battery voltage levels. Furthermore, a DHT11 temperature and humidity sensor is utilized to monitor the temperature of the batteries. If the temperature exceeds a predetermined threshold, the system displays the temperature in degrees, serving as an early warning system to prevent potential damage or failure of the batteries.

To enhance the user interface and information display, an I2C display is integrated into the system. This display provides convenient monitoring of the voltage levels of both batteries and the temperature of the batteries, allowing users to stay informed about the battery health and take necessary actions if needed.

Overall, the architecture of the Battery Swapping system in Electric Vehicles encompasses the coordination of Arduino and Node MCU controllers, voltage sensors, relays, motors, motor driver, lithium-ion batteries, and additional monitoring features. This interconnected system ensures smooth battery swapping operations, efficient power management, and effective monitoring of battery parameters for a reliable and user-friendly experience.

BLYNK Interfacing

In the implementation of the Battery Swapping system, the Blynk IoT platform plays a crucial role in providing a user-friendly interface and enabling wireless control of the system. The Blynk platform consists of the Blynk app and the Blynk cloud server, which facilitate communication between the user's smartphone and the ESP8266 Wi-Fi module.

The Blynk app serves as the graphical user interface (GUI) through which the user can control the motors and relays of the system. It communicates with the ESP8266 Wi-Fi module by connecting to the Blynk cloud server using the Blynk library. This allows for seamless and secure data exchange between the user's smartphone and the Battery Swapping system.

The ESP8266 Wi-Fi module is connected to the motors and relays of the system. It acts as a bridge between the Blynk app and the physical components of the system. By establishing a Wi-Fi connection, the ESP8266 module receives commands from the Blynk app and translates them into motor and relay control signals. This enables the user to remotely control the direction, speed, and on/off state of the motors and relays through the Blynk app.

The motor driver module is responsible for controlling the direction and speed of the motors. It receives the control signals from the ESP8266 module and adjusts the motor parameters accordingly. During the battery swapping procedure, this enables exact control over the electric vehicle's movement.

Additionally, the relays are used to switch electrical circuits within the system. They can be turned on or off based on the user's commands through the Blynk app. This functionality enables the seamless connection and disconnection of batteries during the swapping process, ensuring a smooth transition between power sources.

The implementation code includes several functions that handle the control of motors and relays based on the user's inputs through the Blynk app. The BLYNK_WRITE() functions are responsible for reading the state of the Blynk app buttons and triggering the corresponding actions. For example, BLYNK_WRITE(V0) controls the direction and speed of the first motor, while BLYNK_WRITE(V3) controls the on/off state of the first relay.

The setup() function initializes the pins for the motor drivers and relays and establishes the connection with the Blynk cloud server. The loop() function continuously reads data from the serial port and updates the state of the motors and relays accordingly. It also ensures that the Blynk app reflects the current status of the system.

Overall, the Blynk IoT interfacing plays a crucial role in providing a user-friendly control interface for the Battery Swapping system. It enables wireless communication between the user's smartphone and the system, allowing for remote control of motor movements and relay operations during the battery swapping process.

5. Results and Discussion:

The simulation results for the Battery Swapping system include waveforms of voltage1, voltage2, temperature, and humidity. Additionally, the performance of a 12V solar panel using a rectifier circuit is evaluated in terms of voltage and current.

The waveform of voltage1 and voltage2 provides insights into the charging and discharging behavior of the two batteries in the system. It allows for the observation of voltage fluctuations and patterns over time, which can indicate the effectiveness of the battery swapping process and the stability of the power supply.

The waveform of voltage1, voltage2, temperature, and humidity showcases the correlation between battery voltage and environmental conditions. By monitoring the temperature and humidity levels, it becomes possible to assess the impact of these factors on battery performance. High temperatures, for example, can lead to increased battery degradation, while humidity levels can affect the efficiency of battery operation.

Moreover, the waveform of voltage1 and voltage2 individually offers a detailed analysis of each battery's behavior, enabling a closer examination of their charging and discharging patterns. This information can be valuable for optimizing battery usage, identifying any irregularities, and ensuring the overall stability of the system.

In addition to the simulation results, the maximum power output of a 12V solar panel with a rectifier circuit is determined. The calculated maximum power output of 41.65 watts indicates the panel's capability to generate energy efficiently. However, it is important to consider external factors such as temperature, shading, and the orientation of the panel to accurately assess its real-world performance.

These results demonstrate the effectiveness of the system for switching batteries in maintaining stable voltage levels during operation. The waveform analysis provides insights into the charging and discharging behaviour of the batteries, facilitating proper management and optimization of the system. Furthermore, the evaluation of the solar panel's power output highlights its potential for efficient energy generation.

Noteworthy is the fact that these results are based on simulations and calculations. Further experimentation and real-world testing would be necessary to validate and refine the performance of the system for switching batteries and the solar panel under varying conditions.

Overall, the simulation results and analysis provide valuable information for understanding the behaviour of the system for switching batteries and assessing the performance of the solar panel. This knowledge can guide future optimizations and improvements, ensuring reliable and efficient operation of the system in real-world scenarios.

6. Conclusions:

The study presents a Battery Changing the electric system vehicles that incorporate renewable energy integration via a solar panel. The developed system facilitates seamless battery swapping and ensures uninterrupted power supply for electric vehicles. Leveraging the Blynk IoT platform, users have enhanced control and interactive capabilities. The inclusion of a solar panel promotes sustainability and reduces dependence on conventional power sources.

The conducted waveform analysis offers valuable insights into battery performance characteristics. The findings showcase the Battery Swapping system's potential in addressing challenges related to range anxiety and limited charging infrastructure. However, further real-world testing and in-depth research are imperative to validate and optimize the system's functionality.

The integration of a Change of Batteries with renewable energy sources presents a promising solution for achieving efficient and environmentally friendly transportation. By leveraging renewable energy and implementing seamless battery swapping mechanisms, the system contributes to the advancement of sustainable electric vehicle technologies.

References:

[1] Schelte, N., Severengiz, S., Finke, S., Stommel, J. (2023). Analysis on User Acceptance for Light Electric Vehicles and Novel Charging Infrastructure. Bochum University of Applied Sciences, Sustainable Technologies Laboratory Bochum, Germany.

[2] Li, B., Xie, K., Zhong, W., Huang, X., Wu, Y., Xie, S. (2023). Operation Management of Electric Vehicle Battery Swapping and Charging Systems. IEEE.

[3] Liang, Y., Ding, Z., Zhao, T., Lee, W.-J. (2023). Real-Time Operation Management for Battery Swapping Charging System via Multi-Agent Deep Reinforcement Learning.

[4] Pradhan, R., Saxena, S. (2022). Battery Swapping System in Electric Vehicles.

[5] Yang, H., Qin, W., Zhou, Y. (2022). User-Based Battery Swapping Strategy in an Electric Bike Sharing System. Department of Industrial Engineering & Management, Shanghai Jiao Tong University, Shanghai, China.

[6] Shanmugam, Y., R, N., Vishnuram, P., Bajaj, M., Aboras, K. M., Thakur, P., Kitmo (2022). A Systematic Review of Dynamic Wireless Charging System for Electric Transportation.

[7] Zeng, M., Pan, Y., Zhang, D., Lu, Z., Li, Y. (2019). Data-Driven Location Selection for Battery Swapping Stations.

[8] Thakur, C. P., Namrata, K. (2022). Designing of Battery Thermal Management System for Electric Vehicle. In Proceedings of the 2022 Second International Conference on Power.

[9] Rushadiawan, I. P., Arifwardana, J. F., Tjahjana, D. D. D. P. (2022). Analysis of Li-Ion Battery Pack Performance Air Cooling Battery Compartment on a Swappable Battery of Electric Motorcycle. In Proceedings of the 2022 7th International Conference on Electric Vehicle Technology.

[10] Williams, N. P., O'Shaughnessy, S. M. (2020). Immersion Cooling of Lithium-ion Batteries for Electric Vehicles. In Proceedings of the 2020 8th International Workshop on Thermal Investigation of ICs and Systems.

[11] Tirkey, S. M. P., Pandey, R. K., Kumar, S. (2022). A Detailed Review on Battery Cooling Systems for Electric Vehicles. In Proceedings of the 2022 1st IEEE International Conference on Industrial Electronic Development & Application.