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Effective Heat Dissipation in Li-ion Battery: A Thermoelectric Approach

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Abstract

Thermoelectric Li-ion battery temperature management systems (BTMS) are decisive for maintaining optimal operating conditions of Li-ion batteries. The paper primarily focuses on designing, implementing, and evaluating the thermoelectric BTMS, taking into account factors like power consumption, temperature control accuracy, and system efficiency. The proposed BTMS utilizes the thermoelectric effect to regulate the temperature of Li-ion batteries using Peltier modules actively. By controlling the electrical current applied to the Peltier modules, the system can transfer heat either into or out of the battery, allowing for cooling or heating as needed. The BTMS has successfully reduced the battery temperature from 41.7°C to 36.2°C in 210 seconds. Experimental results validate the effectiveness of this approach in maintaining stable battery temperatures across varying operating conditions. With the proposed BTMS, the temperature was controlled more effectively, keeping the battery within an optimal temperature range (15°C to 35°C), ensuring better performance and longevity. It also reconnoitres potential optimization techniques for improving the overall performance of the thermoelectric BTMS. The output contributes to sustainability by improving battery efficiency and lifespan through a refrigerant-free, solid-state thermal management system, thus supporting global objectives for carbon neutrality and net zero.

Keywords

Battery temperature management systems, Electric vehicles, Lithium-ion batteries, Peltier module, Thermoelectric

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1. Introduction

The rapid adoption of lithium-ion (Li-ion) battery systems across several sectors, including electric vehicles, portable electronics, and renewable energy storage, has highlighted the critical importance of efficient thermal management. As the energy density and operational demands of these batteries increase, so does the challenge of maintaining safe and stable temperatures during charging and discharging cycles. Inadequate heat dissipation can lead to a significant reduction in battery lifespan, thermal runaway, capacity degradation, and pose both performance and safety risks.

Traditional cooling methods, like air and liquid cooling, are often complex, bulky, or inefficient when subjected to dynamic thermal loads [1]. In contrast, thermoelectric technologies offer a promising alternative by enabling solid-state heat transfer without the need for moving parts or refrigerants. Based on the Peltier effect, thermoelectric modules can absorb and remove excess heat directly from battery cells, offering compact and responsive thermal control. These systems are particularly attractive for applications where size, noise, and energy efficiency are critical considerations.

The 21st century has become the era of innovative technology, and modern life is almost unimaginable without the comfort and luxury provided by advanced technology. With the rise of automated and intelligent systems, innovation has become an integral part of people's lives. One of the most significant challenges modern society faces is the issue of global warming and the depletion of fossil fuels. As a result, there has been a growing demand for electric vehicles (EVs). With the advancement and commercialization of EVs and hybrid EVs, the transportation sector has undergone significant transformation over the past two decades [2].

While electric vehicles (EVs) have been around since the 1890s, various battery technologies have been developed over time, including lead-acid, nickel-cadmium, silver-zinc, and nickel-metal-hydride [3]. However, these technologies have certain disadvantages, such as rapid capacity degradation and low power density. In 1985, Japanese chemist Akira Yoshino invented the Lithium-ion (Li-ion) battery, which led to significant developments in electric vehicle (EV) battery technology [4]. Lithium-ion batteries are relatively compact and lightweight compared to older technologies and have significantly better energy and power density. They can also hold a charge for an extended period and have long life and durability [2,5,6]. EVs with rechargeable Lithium-Ion batteries offer a promising choice for the development of clean energy vehicles [7]. It offers benefits such as increased discharge duration and the ability to provide fast-response services. The demand for lithium-ion batteries has been skyrocketing in various industries, including electric vehicles, connected devices, and automation [8-10]. Temperature behavior is an important consideration for batteries [11]. However, the use of Li-ion batteries also brought some thermal issues, which have a significant impact on battery capacity. To solve this problem, a battery temperature management system is necessary.

The growing demand for high-performance lithium-ion (Li-ion) battery systems in electric mobility, consumer electronics, and renewable energy storage has prompted significant research into effective thermal management strategies [12]. Maintaining optimal battery temperature is essential for ensuring safety, maximizing efficiency, and extending the service life of Li-ion cells. In this perspective, battery thermal management systems (BTMS) have become a critical component of modern battery design.

Conventional BTMS technologies primarily rely on passive or active cooling methods using air and liquid. While these approaches are effective to a certain extent, they often involve bulky components, slower response times, or complex maintenance requirements, particularly in compact or high-energy applications. These limitations have encouraged exploration into alternative thermal management solutions, with thermoelectric systems emerging as a promising direction.

Battery thermal management (BTM) is a critical feature of electric vehicles and other applications. Several studies have focused on understanding and improving the thermal characteristics of batteries [13]. Katoch and Eswaramoorthy [10] conducted a detailed review of BTM in electric vehicles, exploring the battery's chemical composition and behavior under different conditions. Energy storage plays a crucial role in the adoption of electric cars, providing a constant and high-quality electricity supply. Ma et al. [14] emphasized the importance of energy storage systems in facilitating this adoption. Olabi et al. [15] discussed the latest advancements in BTM, particularly in ensuring battery safety. They highlighted the use of heat transfer intensifying methods to enhance battery safety and performance under normal and abnormal operating conditions. Liu et al. [16] provided a comprehensive summary of recent progress in BTMS. They discussed various strategies, including air, liquid, heat pipe, boiling, and solid-liquid phase change-based approaches. O'Connor et al. [17] investigated the temperature behavior of various battery types, including photovoltaic, lead-acid, and Li-ion batteries, under different temperature conditions. Schmidt et al. [18] explored research strategies for energy storage, including alternative technologies and improvements in lithium-ion battery performance. Wang et al. [19] investigated heating strategies for Li-ion batteries operated at sub-zero temperatures. Bandhauer et al. [20] conducted a review of thermal issues in Li-ion batteries, emphasizing the importance of thermal management for their safe and efficient operation. Chen et al. [21] examined the effects of several phase change material thermal management approaches on the cooling performance of Li-ion batteries. Feng et al. [22] provided a detailed review of the thermal runaway mechanism of Li-ion batteries in EVs. Vashisht et al. [23] presented a 2D electrothermal model to assess the thermal, and voltage behavior of a Li-ion cell. Baveja et al. [24] developed a specific thermal prediction model to design BTMS for electric vehicles.

Luo et al. [25] modeled a hybrid system combining TECs, CPCM, and liquid cooling, identifying an optimal configuration (12% expanded graphite, 3 A TEC current, 0.05 m/s coolant flow) that minimized battery peak temperature and energy consumption under extreme conditions, while also enabling preheating at low temperatures. Alghassab [26] demonstrated an integrated approach using TEC modules and PCM within a water reservoir. Their system achieved temperature reductions of 9–14% compared to natural convection across varying load scenarios, underscoring its compactness and suitability for applications such as electric vehicles (EVs). Khan et al. [27] delivered a comprehensive review of thermoelectric cooling in Li-ion BTMS. They highlighted that system performance depends critically on TEC geometry, operational current, and thermal coupling to the battery—insights essential for improving TEC BTMS designs. Bozorg and Torres [28] explored liquid-cooled channels enhanced by PCM-embedded metallic foam within prismatic battery modules. Their numerical results indicated that dual-PCM arrangements provided a temperature reduction of 1.3–2.7°C and improved uniformity under high discharge loads. Liu et al. [29] advanced a compact hybrid BTMS with microchannel liquid cooling, PCM/aluminum foam, and nanofluid pulsed flow. Experimental validation revealed a 3.44°C reduction in maximum temperature at 1C discharge with only 5 % additional pumping energy, resulting in a 6–15 % extension in battery cycle life.

Recent studies emphasize the necessity of employing multiple battery thermal management (BTM) approaches to effectively regulate battery temperatures [30], though quantitative comparisons between systems remain challenging due to variations in battery types, capacities, charge and discharge rates, and external conditions. The charge and discharge rate of lithium-ion batteries significantly influences the speed at which energy is stored or released, directly impacting thermal behavior. To address these complexities, standardized evaluations under controlled conditions are essential for understanding BTMS thermal characteristics. Current advancements in BTM focus on enhancing the thermal conductivity of phase change materials (PCMs), achieving flame retardancy in organic PCMs, and ensuring thermal stability in inorganic PCMs. Air-based systems have adopted symmetrical configurations with uneven cell spacing and tapered cooling ducts to reduce temperature variations and flow rate imbalances. Among emerging solutions, thermoelectric-based systems show considerable promise in improving temperature regulation, particularly when integrated with innovations in control systems, materials science, and system-level design. Building on these developments, the present study investigates the integration of thermoelectric cooling modules into Li-ion battery systems, evaluating their effectiveness in dissipating heat under various operational conditions, improving temperature uniformity, and optimizing cooling efficiency. The proposed modified BTMS aims to enhance performance by focusing on temperature control accuracy, energy efficiency, and real-world applicability, ultimately contributing to the creation of safer, more durable, and more reliable energy storage solutions.

2. Battery Temperature Management System (BTMS)

An electric vehicle incorporates a battery temperature management system (BTMS), which plays a critical role in providing vital information and functionalities [31], including:

1. Thermal Protection: Ensuring the battery operates within a safe temperature range.
2. Over- and Under-Voltage Protection: Safeguarding the battery against excessively high or low voltage conditions.
3. Over-Current Protection: Preventing excessive current flow that can damage the battery.
4. Prolonging Battery Life: Implementing strategies to extend the battery's overall lifespan.
5. Cell Balancing: Ensuring uniform charge distribution among battery cells to optimize performance.
6. The State of Charge (SoC) and State of Health (SoH) Calculation: Accurately estimating the battery's current charge level and overall health status.
7. Communication with Battery Components: Facilitating communication between the BMS and various battery components for monitoring and control purposes.
8. Data Acquisition and Analysis: Gathering and analyzing data to evaluate battery performance and health.

The temperature of the battery has a significant impact on its performance, lifespan, and safety [32]. Hence, a BTMS is crucial for all battery modules. The primary objective of a BTMS is to maintain the battery system within the optimal temperature range and ensure uniform temperature distribution across the battery modules. In addition to temperature, other factors influencing battery selection include weight, size, reliability, and cost considerations.

The technical specifications of the battery cell used for this work are:

The cylindrical Cell is designated as 18650; its dimensions are 18 mm in diameter and 65 mm in length, and it is designated as 0, given its cylindrical shape.
Nominal voltage: Operating 3.6V, Upper cutoff: 4.2V, and lower cutoff: 2.5V.
Nominal capacity: 3000mAh
Anode: Graphite or Silicon-graphite composites.
Cathode: Lithium Cobalt Oxide ($LiCoO_2$)
Electrolyte material: Liquid organic solvent containing a lithium salt.

The selection of parameters for an effective battery cooling system involves several aspects, such as:

1. Operating Conditions: Considerations include the load on the battery, current rate, and voltage requirements.

2. Environmental Conditions: Assessing factors such as ambient temperature, humidity, and exposure to external heat sources.

3. Battery Cells: Evaluating the chemistry of the battery cells (e.g., Lithium-ion), cell geometry (cylindrical or rectangular), cyclic or non-cyclic reactions, properties of cell materials, cell packing, and thermal interface design.

4. Cooling Medium: Determining the mode of cooling, whether it is forced convective (active cooling) or natural draft cooling (passive cooling). Computational fluid dynamics (CFD) simulations can aid in determining the cooling rate and optimizing the thermal design of the cooling circuit.

5. Thermal Interface and Battery Pack Fitting: Ensuring the proper use of thermal interface materials and the correct fitting of battery packs to enhance heat dissipation.

3. Methodology

By carefully considering the above parameters, an optimal battery cooling system is proposed Figure 1, which contributes to improved performance, extended battery life, and reduced risks associated with excessive heat. Since the battery temperature in the experiment was close to the nominal temperature and below the maximum allowable temperature, the tab temperature was not considered.

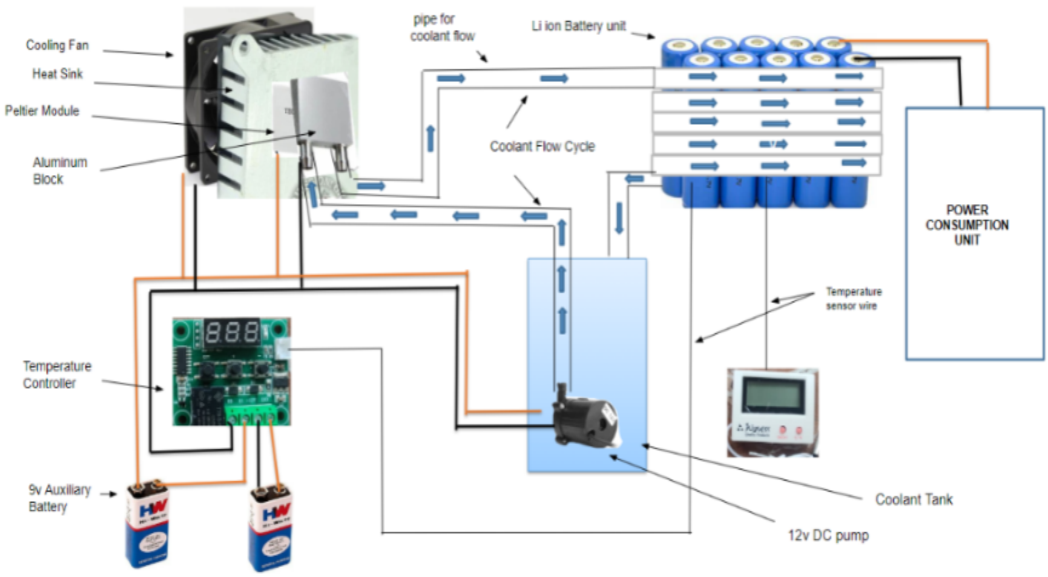

Figure 1. Diagram of the system's component assembly.

This technique maintains the cells at 25°C by continuously monitoring the cell temperature with the aid of a thermostat and providing or extracting heat as needed. The standard dimensions of lithium-ion battery packs do not require change, as the enclosure fits around the cells and the liquid flows in the gaps between the cells. Changing the polarity of the Peltier module changes the hot and cold sides. The proposed system can be used in both high-temperature regions, such as deserts, and cold-temperature regions, like the Himalayas. The thermostat monitors the cell temperature every 0.5 seconds. Combining this with the thermostat's high accuracy makes the system very fast and highly responsive. Peltier modules come with standard dimensions. Additionally, this modular system enables the technique to be applied to all types of EVs. The components used in the technique are comparatively cheaper than those in other techniques, which makes this a unique value proposition.

3.1 Design and Assembly

According to the proposed diagram, as shown in Figure 1, the model is illustrated in Figure 2. The plastic case contains the 12V adapter, secondary battery, and wired connections. The cooling block unit consists of a fan, heat sink, Peltier module, and aluminium cooling block. The Li-ion battery is connected to the four lights, which drain the Li-ion battery's power, and is controlled by a switch for on/off operation. The Thermostat has a sensor placed near the Li-ion battery, which monitors cell temperature every half-second.

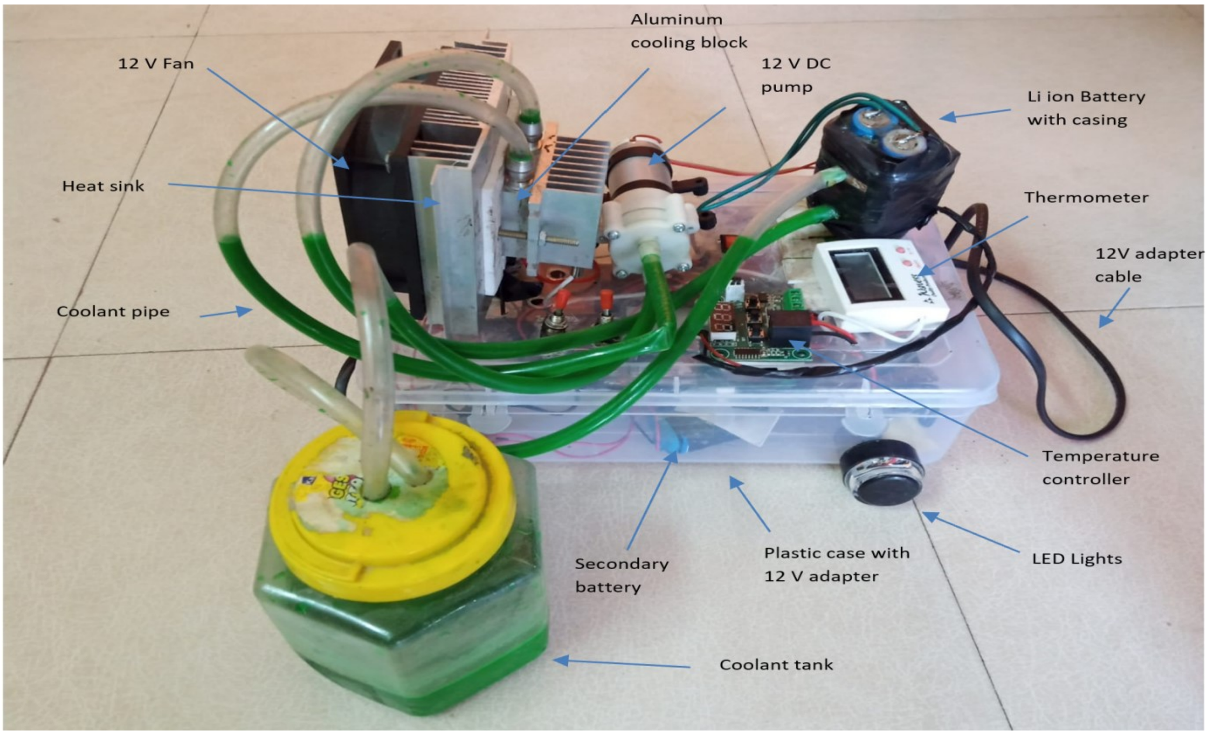

Figure 2. Proposed model of battery temperature management systems (BTMS).

The thermometer is connected to the Peltier module to monitor its cooling effect. The 12 V DC pump is attached to the 12 V adapter, which has a heat pipe connected to the coolant tank. After the coolant tank, the heat pipe traverses through the aluminium cooling block. Tested each component for its appropriate working.

4. Results & Discussion

4.1 Observation and Calculation

To investigate the impact of different charging and discharging conditions on battery temperature, experiments were conducted. The objective was to understand the temperature variations and the maximum temperatures reached by the battery under different load and discharge conditions. The results are summarized below, and a graph illustrating the heat added to the battery under room temperature conditions is presented.

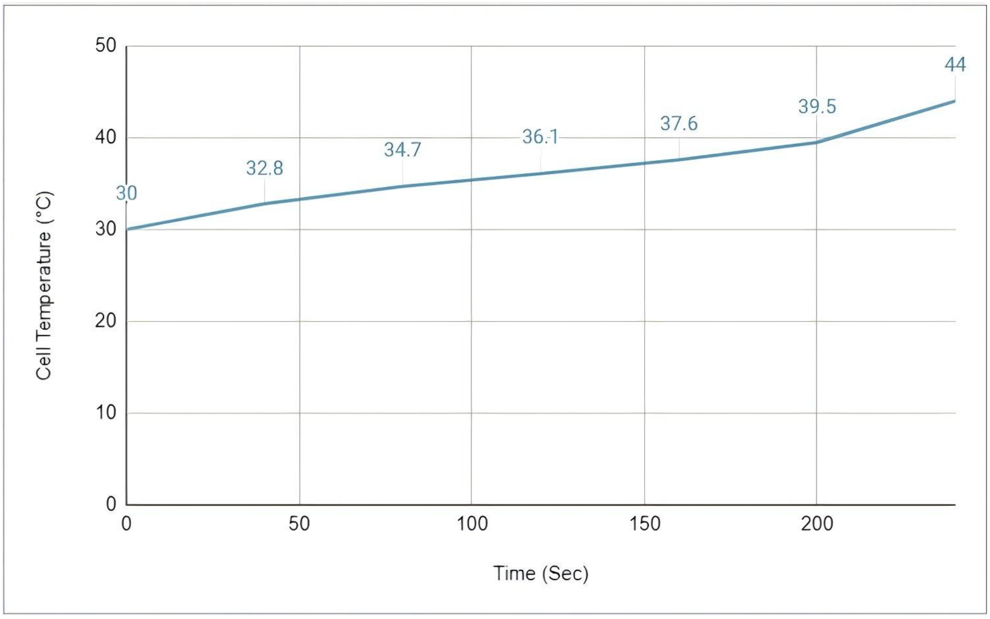

Figure 3. Graph for cell temperature during a load condition.

The graph presented in Figure 3 illustrates the performance and behavior of a Li-ion battery under load conditions, as experiments were conducted at a room temperature of 29°C. The discharge rate for all the experiments was set at 1C. It is essential to note that the BTMS remained inactive during these experiments, with a focus on the surface temperature rise of the battery.

At initial Condition (0 sec), the cell starts at a baseline temperature of 30°C, which is within the optimal operating range for Li-ion batteries. As the battery operates under load, it generates heat due to internal resistance and the electrochemical activity that occurs within it. After 40 seconds, the temperature rises to 32.8°C, indicating the start of a steady thermal response to the load. By 80 to 120 seconds, the temperature continues to increase gradually, reaching 36.1°C. This is slightly above the optimal range (typically 15°C–35°C), suggesting the system is experiencing mild thermal stress. At 160 seconds, the cell temperature reaches 37.6°C, showing that without sufficient cooling, the battery could eventually exceed safe temperature limits, which may affect performance and safety.

As shown in the graph, the battery temperature increases rapidly as the cell temperature reaches 39.5°C. The maximum surface temperature recorded for the battery was approximately 44 °C, occurring between 200 and 245 seconds. This graph provides valuable insights into the thermal behavior of the Li-ion battery under load conditions, showcasing the temperature increase over time. The results underscore the importance of effective BTMS in preventing thermal rise beyond safe limits, as the battery temperature increased from 30.0 °C to 44.0 °C, exceeding the optimal range (15°C–35°C). This supports findings by Bandhauer et al. [20], who linked poor thermal control to accelerated degradation and thermal runaway, and Liu et al. [16], who showed that advanced systems like liquid cooling and PCM improve stability. The proposed thermoelectric-assisted system offers enhanced temperature regulation, making it suitable for high-demand applications like electric vehicles.

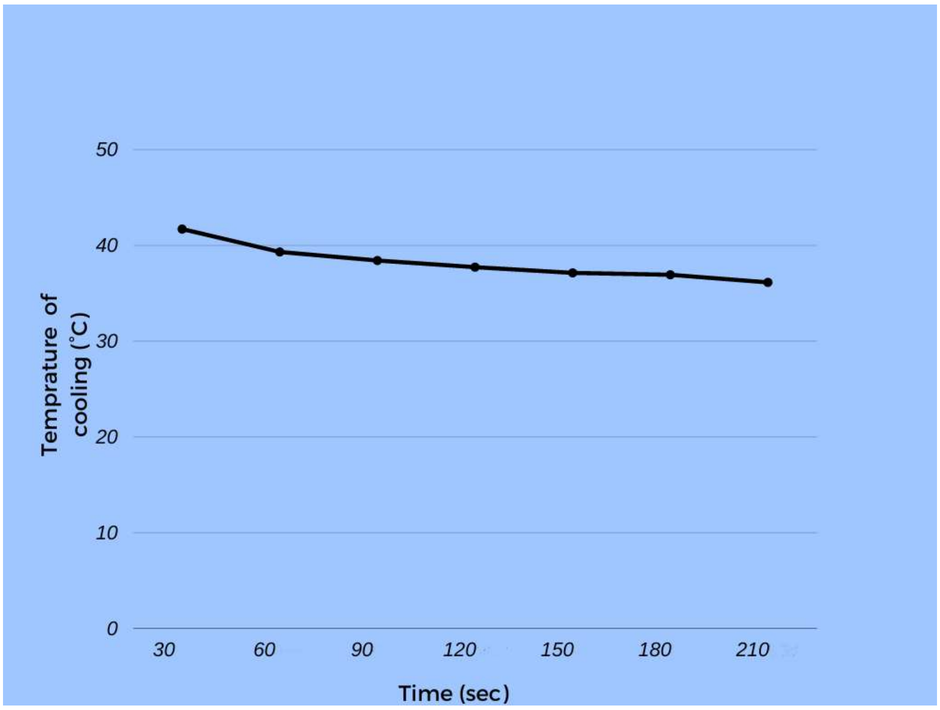

Figure 4. Variation of temperature when using coolant (Auto cool F002 H24).

The above graph Figure 4 is plotted after implementing the use of BTMS using Bosh Auto coolant F002 H24. The BTMS is on when the battery surface temperature reaches 37°C. The rise in Battery surface temperature is detected by the Temperature sensor, which continuously monitors the battery temperature.

At the initial condition (0 sec), the system starts at a high temperature of 41.7°C, likely due to prior operation under load without cooling. Within the first 30 seconds, the temperature drops by nearly 1.8°C, indicating a rapid initial response from the coolant. Between 30 and 120 seconds, the temperature gradually reduces from 39.9°C to 37.6°C, showing a steady cooling effect. Between 120 and 210 seconds, the rate of cooling slows slightly as the system approaches thermal equilibrium, eventually reaching a temperature of 36.2°C. The coolant Auto Cool F002 H24 effectively reduces the temperature from 41.7°C to 36.2°C in 210 seconds, demonstrating good cooling performance. The temperature decline is consistent and smooth, indicating the coolant's thermal stability and effectiveness in absorbing heat. While the final temperature is still slightly above the ideal range (15°C–35°C for optimal Li-ion performance), it shows that active cooling significantly enhances thermal regulation compared to no cooling. This result supports the need for integrating cooling strategies, such as thermoelectric BTMS or hybrid solutions, for even better performance. Pesaran et al. [31] showed that the optimal temperature range for lithium-ion battery performance (LIB) is 15°C to 35°C, and our system has successfully maintained the optimum temperature of the battery.

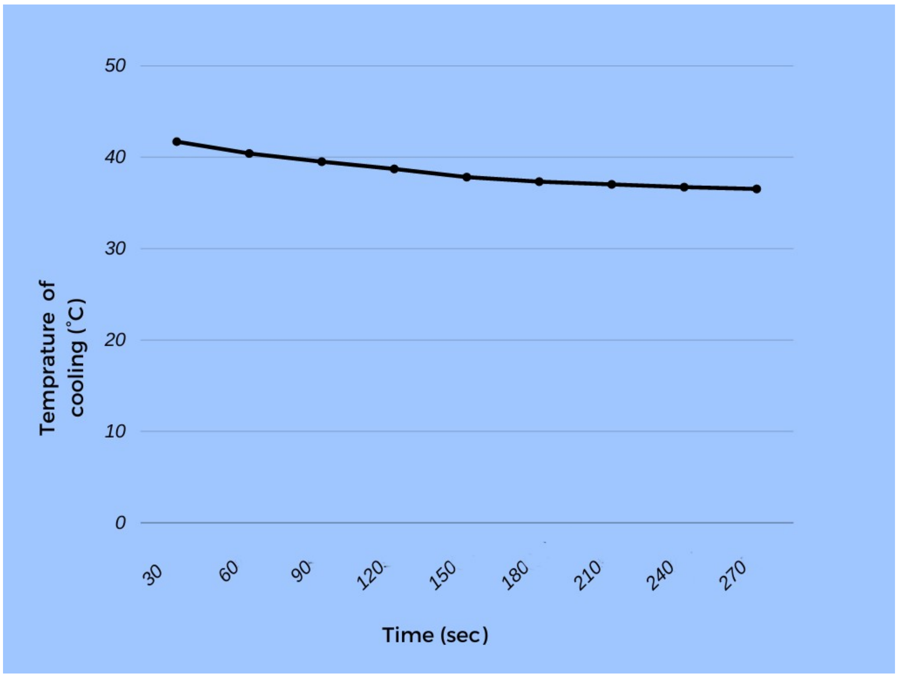

Figure 5. Variation of temperature when using water as a coolant.

The graph depicted in Figure 5 represents the observed increase in battery temperature over time. Initially (around 30 sec), the system starts cooling at 40.4°C, indicating that heat buildup occurred before the coolant was applied. The temperature gradually decreases at each interval, showing a steady cooling trend. From 40.4°C at 30 sec to 36.0°C at 270 sec, the system experiences a total drop of 4.4°C over 240 seconds. The cooling rate is steady but slower compared to some commercial coolants, such as Auto Cool F002 H24. Water provided steady and reliable cooling, lowering the battery temperature from 40.4 °C to 36.0 °C over 240 seconds. However, it did not reach the optimal Li-ion range (15°C–35°C) due to its moderate thermal conductivity, lack of additives, and limitations such as fixed flow rate, ambient testing conditions, and non-pressurized circulation. The absence of hybrid enhancements like phase change materials (PCM) or thermoelectric modules further constrained performance. These factors highlight the need for advanced or hybrid cooling strategies in high-demand industrial applications [25,26]. This graph illustrates the performance and behavior of a Li-ion battery under the influence of the BTMS. Specifically, the graph examines the effect of the "Peak coolant" on the battery's thermal properties. Upon comparing this graph with Figure 4, it becomes evident that the presence of the BTMS has a dominant effect on the battery's behavior. The heat extraction process is more efficient in this graph Figure 5 compared to the previous graph. This suggests that the use of an improved coolant plays a crucial role in the system's ability to extract heat from the battery rapidly.

Water, as a natural and readily available coolant, provides stable and gradual cooling of the battery system. While it is effective in reducing temperature, it may not be the most efficient option for rapid heat dissipation. These results suggest that water-based cooling can be beneficial in situations with moderate thermal loads. Still, they may require enhancement (e.g., with additives or combined with thermoelectric systems) for high-performance applications, such as electric vehicles or heavy-duty storage systems.

4.2 Comparative Analysis

Table 1. Comparison of temperature variation in Li-ion Battery systems under different cooling methods.

Criteria	No Coolant (Load)	Auto Cool F002 H24	Water as Coolant
Initial Temperature	30.0 °C (no prior load)	41.7 °C (after heating)	40.4 °C (after heating)
Trend	Steady increase in temperature	Steady decrease in temperature	Gradual decrease in temperature
Final Temperature	37.6 °C (at 160 sec)	36.2 °C (at 210 sec)	36.0 °C (at 270 sec)
Net Temperature Change	**+7.6 °C** (rise)	**–5.5 °C**	**–4.4 °C**
Cooling Duration	N/A (heating only)	210 seconds	240–270 seconds
Cooling Rate	N/A	~0.026 °C/sec	~0.016 °C/sec
Efficiency	Low (heat accumulates)	High (fast cooling response)	Moderate (stable but slower cooling)
Approach to Optimal Temp (≤35 °C)	Exceeded after 120 sec	Near-optimal (just above 35°C)	Near-optimal (slightly slower approach)
Stability & Slope	Rising trend (uncontrolled)	Smooth downward trend	Smooth, slightly less steep trend
Suitability	Unsafe for long-term operation	Ideal for high-performance systems	Acceptable for moderate applications

The comparative analysis of the three cooling methods, no coolant, Auto Cool F002 H24, and water, reveals significant differences in thermal behavior and effectiveness (Table 1). Without any cooling, the cell temperature rises steadily from 30.0 °C to 37.6 °C within 160 seconds under load, indicating an uncontrolled increase that can lead to overheating and reduced battery safety. In contrast, the use of Auto Cool F002 H24 exhibits the most efficient cooling performance, reducing the temperature from 41.7°C to 36.2°C in just 210 seconds. This demonstrates a rapid and effective thermal response, making it suitable for high-demand applications such as electric vehicles. Water, although slightly slower, also exhibits consistent cooling performance, lowering the temperature from 40.4°C to 36.0°C over 270 seconds. Although not as fast as Auto Cool, water remains a reliable and cost-effective option, especially for systems with moderate thermal loads. Overall, Auto Cool F002 H24 offers the best cooling efficiency, followed by water. In contrast, the absence of a cooling system leads to thermal buildup, posing a risk to battery performance and longevity.

The observed data emphasizes the significance of effective thermal management systems, particularly the use of advanced coolants, in maintaining the battery's temperature within safe operating limits. Efficient heat extraction is vital for preventing excessive temperature rise and ensuring the optimal performance and safety of the Li-ion battery.

5. Conclusion

The efficient development of a Thermoelectric-based BTMS holds significant importance in ensuring the sustainable growth of electric vehicles. The proposed solution shows promise in improving battery performance and safety. From the outcomes of this research, it can be concluded that:

1. This solution addresses the drawbacks of current BTMS by performing well in both low- and high-temperature regions, thereby enhancing convective heat transfer and making it more efficient than air-based systems.
2. The system is compact, requiring less space and consuming minimal power.
3. The proposed system keeps the battery within an optimal temperature range (15°C to 35°C), ensuring better performance and longevity.
4. It can be seamlessly integrated into standard battery packs without altering their dimensions.
5. Additionally, this solution offers a cost-effective alternative compared to existing options.

The proposed thermoelectric BTMS highlights the sustainable potential by offering a compact, energy-efficient, and easily integrable solution that minimizes environmental impact. The system's scalability, cost-effectiveness, and potential for future enhancement through material and control innovations further strengthen its role in advancing eco-friendly energy storage solutions.

Thermoelectric cooling is ideal for diverse applications, including EVs, portable electronics, renewable energy storage, robotics, aerospace, and data centers, offering compact, reliable, and efficient thermal management to enhance performance and safety.

Thermoelectric cooling faces industrial limitations such as reduced efficiency under high thermal loads, increased costs and power consumption at scale, moderate material performance, integration complexity, environmental sensitivity, and maintenance challenges in demanding conditions.

This thermoelectric Li-ion BTMS can be leveraged to its full potential, enhancing battery performance, prolonging lifespan, and improving safety in various industries and applications. Future work can focus on enhancing thermoelectric materials, integrating intelligent control algorithms, and developing hybrid cooling systems for better efficiency. The solution can be scaled for larger battery systems and integrated with battery management systems for enhanced safety and performance. Long-term testing and economic analysis will help in real-world adoption.

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Data Availability Statement

The data is available in the manuscript.

Author Contributions

Umeer Fulari: Conceptualization, methodology, investigation, data analysis, validation, formal analysis, resources, writing-original draft;

Umesh Kadam: Conceptualization, methodology, investigation, formal analysis, writing-original draft, writing-review, and editing;

Shubham Kalaskar: Conceptualization, methodology, investigation, writing-original draft, and editing;

Nandkishor Gitte: Conceptualization, methodology, investigation, data analysis;

Dr. Himadri Majumder: Conceptualization, writing-original draft, writing-review, and editing;

Conflict of Interest

The authors declare that they have no conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Abbreviations

Symbol	Description
	Nomenclature
$\vec{v}$ (v)	Velocity field of the fluid
ρ (rho)	Fluid density
P (P)	Pressure
μ (mu)	Dynamic viscosity
$\vec{f}$ (f)	External forces
cp (cp)	Specific heat capacity at constant pressure
T (T)	Temperature
	Greek Symbols
ρ (rho)	Fluid density
μ (mu)	Dynamic viscosity
∂ (partial)	The partial derivative symbol is used for differentiation
k (k)	Thermal conductivity
	Subscripts
p	Constant pressure
t	Time
	Superscripts
-	Denotes differentiation (e.g., $\partial\vec{v}/\partial t$)
	Acronyms
Li-ion	Lithium-ion (commonly referring to lithium-ion batteries)
CFD	Computational Fluid Dynamics
EVs	Electric vehicles
BTM	Battery temperature management
BTMS	Battery temperature management systems
PCM	Phase change materials
SoC	The State of Charge
LIB	Lithium-ion battery
SoH	State of Health
OCV	Open circuit voltage
HEV	Hybrid Electric Vehicle

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