*International Journal of Engineering Applied Sciences and Technology, 2025*
**Vol. 10, Issue 01, ISSN No. 2455-2143, Pages 104-108**
**Published Online May 2025 in IJEAST (http://www.ijeast.com)**

# DESIGN AND ANALYSIS OF A THERMAL MANAGEMENT SYSTEM FOR ELECTRIC VEHICLE CHARGING STATIONS

Mr.R.Manikandan
Assistant Professor
Department of Mechanical Engineering
Anjalai Ammal Mahalingam Engineering College, Anna University, Chennai

Balaji.S.G, Logeshwarr.C, Kishore.P, Sankaranarayanan.S
UG - Scholar
Department of Mechanical Engineering
Anjalai Ammal Mahalingam Engineering College, Anna University, Chennai

*Abstract:* **The rapid growth of electric vehicles (EVs) has led to an increased demand for efficient EV charging stations. However, the high-power electronics used in fast charging generate substantial heat, which can impact performance, efficiency, and longevity. This project focuses on designing and analyzing a thermal management system for EV charging stations to ensure optimal temperature control. The thermal management system is designed to dissipate heat from the charging equipment effectively, maintaining components within safe operational limits. Various cooling techniques, including air, liquid, and PCM, are explored, with simulations conducted to evaluate their effectiveness. Using software like Solid Works for design and Ansys for thermal analysis, the project investigates heat flow, identifies critical hot spots, and proposes improvements to cooling strategies. The outcome of this project will provide insights into developing a robust, scalable, and energy-efficient thermal management solution, contributing to the safety, performance, and longevity of EV charging stations. This system will also help mitigate risks associated with overheating, thereby improving the overall reliability and user experience of EV charging networks.**

*Keywords:* **charging station,** Phase change material thermal storage EV, **Battery swapping station thermal analysis**

## I. INTRODUCTION

Transportation system is one of the major sources of gasoline use and contributes vastly to the annual gas emission. Transportation system was increased rapidly over the century and the rarity of natural resources besides the emission problem guides the developers to expand the alternative technology. Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) are considered to be sustainable and environmentally-friendly transportation options in the midst of rising oil prices and global climate changes due to greenhouse gas emission. It was believed that the new generation vehicle could reduce the dependency on natural resources and could limit the greenhouse gas emission. The development of electric and hybrid electric vehicle required few step to develop. Such as, the development of the high power density, high energy density cell for the battery system, the thermal management system modeling, and development of the charging infrastructure for the deployment of the vehicles. The major work has been done on the development of the cells. However, due to the high temperature limitations of the currently available cells, a high efficient thermal management system is necessary. Therefore, the development of dynamic and precise thermal model deserves a significant attention.

## II. PROBLEM STATEMENT

Fast charging generates significant heat, which can lead to thermal degradation of batteries. The challenge lies in maintaining battery temperature within a safe range specifically, reducing peak temperatures from 338k to an expected 313k.Lithium-ion batteries experience rapid heat buildup, which can lead to thermal stress, reduced cycle life. Overheating of Charging Component High-power charging generates substantial heat, which can lead to thermal stress, reduced efficiency, and equipment failure. Energy Loss & Reduced Efficiency Poor thermal management can cause energy dissipation, reducing the overall efficiency of charging stations. Component Degradation & Reduced Lifespan Continuous exposure to high temperatures can degrade power electronics, batteries, and connectors, increasing maintenance costs. Safety Risks Inadequate cooling can lead to fire hazards, system malfunctions, and overheating of charging cables, compromising user safety.

## III. OBJECTIVE OF THE PROJECT

To reduce the operational battery temperature range from an existing high of 338k down to a safer limit of 313k , enhancing thermal stability during repeated fast charging cycles. To conduct thermal simulations using ANSYS to evaluate the effectiveness of the PCM-enhanced system (**hybrid graphene PCM and conventional praffin PCM**) and under various charging conditions, validating thermal performance and material behavior. Compare and Analyze the impact of with and without PCM-based thermal management on battery life, reliability, and overall system safety during real-world usage scenarios. Regulate and reduce battery surface temperatures during high-rate charging to prevent overheating and extend battery life. Evaluate and compare the thermal performance of conventional cooling (without PCM) versus PCM-based passive cooling using computational simulations. Analyze fluid flow, temperature distribution, and thermal stress within the battery enclosure using ANSYS Workbench. Demonstrate the effectiveness of graphene-enhanced PCM in improving thermal conductivity and stabilizing system temperature under transient conditions. Provide a cost-effective, energy-efficient, and scalable thermal solution suitable for real-world deployment in battery swapping stations.

## IV. LITERATURE REVIEW

1. Literature Review

Jackie D. Renteria **[1**thermal properties of graphene, few-layer graphene and graphenenanoribbons, and discuss practical applications of graphene in thermal management and energy storage. The first part of the review describes the state-of-the-art in the graphene thermal field focusing on recently reported experimental and theoretical data for heat conduction in graphene and graphenenanoribbons.

Ya Liu**[2],** graphene assembled film integrated heat sink and water cooling technology was used to build an experimental set-up of a thermal management system to demonstrate the possibility to achieve efficient cooling of the propulsion battery in electric vehicles

Hy Zhang**[3],**A hybrid thermal management system (TMS) using phase change material (PCM) and bottom liquid cooling techniques for a large-sized power battery module was experimentally investigated. The system consisted of 106 test batteries in 18650 format, connected with a heat spreading plate, adjacent thermal columns and a cold plate populated with mini-channels installed beneath the module for liquid cooling to form the interconnected thermal structure.

Nikhil S. **[4**phase change materials (PCM) that are capable of efficient battery cooling. In this work, a composite PCM is prepared by mixing $Fe_3O_4$ nanoparticles (1 wt.%) in paraffin, and the effects of these nanoparticles on the enthalpy and melting point of PCM are studied. It is found that the $Fe_3O_4$ nanoparticle additives reduce the onset of melting from 61.46°C to 57.03°C

TitinTrisnadewi[5], The high working temperature in the battery can cause a thermal runaway, decrease in battery capacity, and reduce the discharge cycle. Therefore, a thermal management system is needed to maintain the temperature of the battery when operated on high-performance electric vehicles, required a reliable thermal management system with light weight, compact size, and able to increase the efficiency of battery performance

Jimmy Forsman**[6],**The performance of the proposed algorithm is assessed over a road with a hilly terrain, where two charging possibilities are considered along the driving route. According to the results, trip time including driving and charging times, is reduced by 44%, compared to a case without battery active heating/cooling.

Young-Jun Kim [7], we designed a high-energy density electrode using artificial graphite (AG) with a graphene-coated Si/C active material (Gr@Si/C). The Gr@Si/C composite synthesized via iterative coating processes not only ensures the electronic conductivity of adjacent silicon particles but also provides a buffering capability against volumetric expansion during repeated charge/discharge cycles at high loading and increased electrode density.

2. Outcome of the Literature Review

- The outcomes from both analyses are subjected to **post-processing and result interpretation** to identify performance bottlenecks and areas of concern. Based on these insights, **optimization and design modifications** are performed to improve structural durability and thermal protection, leading to a more robust and reliable design suitable for demanding industrial environments.

The integration of PCM with graphene reduced the maximum battery surface temperature from 312 K (without PCM) to 309 K (with PCM) during a simulated 30-minute charging cycle, demonstrating the effectiveness of latent heat storage.

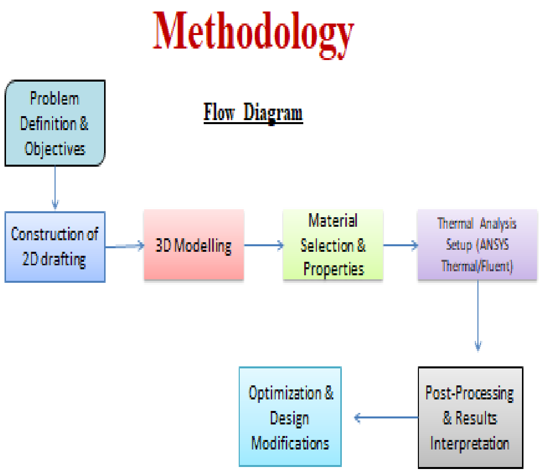
The system with PCM showed a **21% slower temperature rise rate**, indicating superior thermal buffering and protection against overheating, especially during peak thermal loads.

## V. METHODOLOGY

The methodology adopted in this project involves a systematic approach to design, simulate, and analyze the thermal behavior of an EV battery swapping station using a composite PCM-based cooling system. The study combines **CAD modeling, material selection, thermal-fluid**

International Journal of Engineering Applied Sciences and Technology, 2025
Vol. 10, Issue 01, ISSN No. 2455-2143, Pages 104-108
Published Online May 2025 in IJEAST (http://www.ijeast.com)

**simulation, analysis** using ANSYS Workbench.
Following this, the **geometry and model preparation** phase involves developing a 3D CAD model of the PCM block. In the **material selection and property assignment** stage, appropriate materials are chosen based on mechanical strength, thermal conductivity, and environmental suitability to ensure optimal performance in industrial applications.




The next step is **meshing**, where the geometry is discretized into finite elements to facilitate accurate simulation. After meshing, the simulation bifurcates into two paths: **thermal analysis** and **structural analysis**. Thermal analysis is conducted using CFD **Thermal/Fluent** to evaluate the temperature distribution and heat flow across the robot's components when exposed to high-temperature materials. Simultaneously.

## MATERIAL SELECTION

A critical aspect of this project involved selecting an optimal **composite Phase Change Material (PCM)** capable of both storing latent heat and conducting thermal energy efficiently. After evaluating multiple options, a mixture of **10% graphene and 90% paraffin wax** was selected as the primary thermal energy storage and transfer medium.

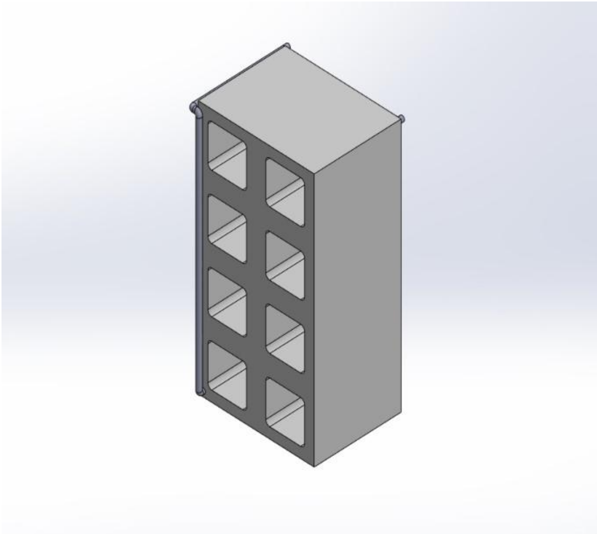


Figure 1. Model ofPcm block

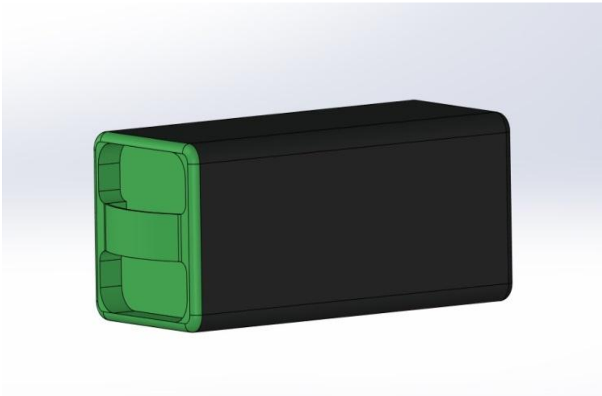
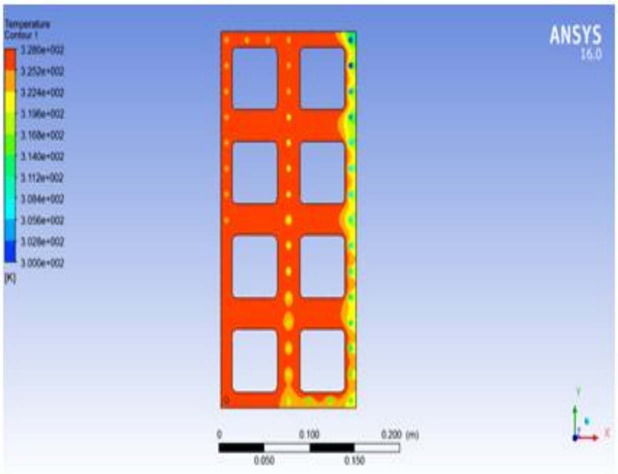


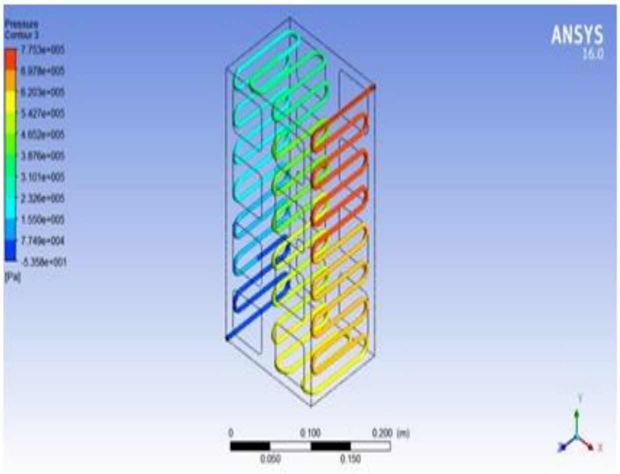
Figure.2 Model of battery

- High latent heat of fusion (~200–220 kJ/kg), allowing it to store large amounts of energy during melting**.** Chemical stability, non-toxicity, and wide commercial availability. Melting range (~50–60°C), ideal for battery systems that need to be kept below ~60°C.
- To overcome paraffin's low thermal conductivity, **graphene nanoparticles** were selected as an additive.
- Graphene offers **Extremely high thermal conductivity** (>5000 W/m·K),**Large surface area**, which enhances heat exchange,

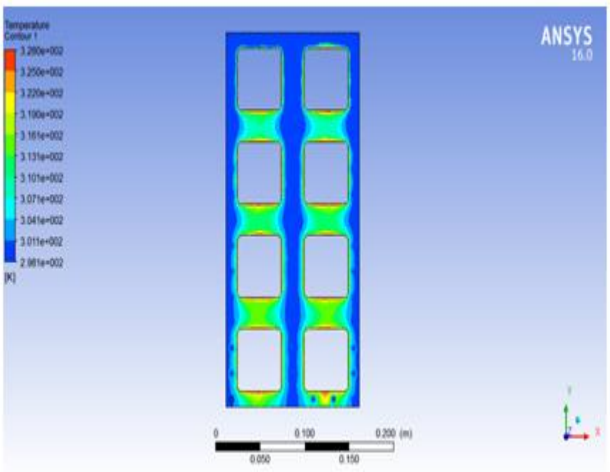
**International Journal of Engineering Applied Sciences and Technology, 2025**
**Vol. 10, Issue 01, ISSN No. 2455-2143, Pages 104-108**
**Published Online May 2025 in IJEAST (http://www.ijeast.com)**




RESULTS OF FLOW WITHOUT PCM




PRESSURE DISTRIBUTION OF FLOWING FLUID




RESULTS OF FLOW WITH PCM

## VI. RESULT A DISCUSSION:

**Without PCM:** The maximum temperature reached **312 K**, indicating a relatively fast and uneven heat accumulation near the battery surfaces. **With PCM:** The maximum temperature was significantly reduced to **309 K**, due to the latent heat absorption capacity of the PCM. A 30-minute transient analysis showed that the **rate of temperature increase was 21% slower** in the PCM-integrated model. **Without PCM:** Reached 312 K at 30 minutes. **With PCM:** Peaked at 309 K, remaining within the optimal battery operating range. From the very beginning of the project, keys of designs were identified through information gathering and literature reviewing. Earlier conceptual designs were carried out through brainstorming method. During the design progresses, active cooling concepts were referred. The most goals - achieved designs were then chosen and proceed for drawing using SOLIDWORKS. For achieving thermal management PCM is used as an intermediate material which helps to carry heat form battery to the atmosphere through coolant flowing inside the tube. The system with and without PCM is analyzed using ANSY

RESULT

| Parameter | Without PCM (Air + Water) | With PCM (Paraffin Wax and Grephene + Water) |
|---|---|---|
| Temperature Coolant (K)(Inlet) | 298 | 298 |
| Temperature Coolant (K)(Outlet) | 304 | 328 |
| Temperature Battery Maximum (K) | 330 | 330 |
| Temperature Battery Minimum (K) | 325 | 319 |
| Velocity (m/s)(Inlet) | 8.73E-2 | 1.41E-4 |
| Velocity (m/s)(Outlet) | 5.14 | 65.2 |
| Pressure (pa)(Inlet) | 0 | 0 |
| Pressure (pa)(Outlet) | 1.41E5 | 6.1E2 |

## VII. CONCLUSION:

For achieving thermal management PCM is used as an intermediate material which helps to carry heat form battery to the atmosphere through coolant flowing inside the tube. The system with and without PCM is analyzed using ANSYS CFD. The exit temperatures from both results were compared and validated. With the increase of fluid flow area, the cooling performance improves gradually. After exceeding a certain flow speed cannot improve system cooling performance obviously. Boundary distance (Distance between heat wall and flow tube) has great effect on the cooling performance. The cooling performance of system rises gradually with the decrease of boundary distance; especially when the spacing is small, the effect of boundary distance on the system consistency is more prominent. In terms of the arrangement of battery pack, staggered design is better than aligned design in cooling performance

## VIII. REFERENCES:

[1]. Bang, J. H., Kim, H. S., Lee, D. H., and Min, K., "Study on Operating Characteristics of Fuel Cell Powered Electric Vehicle with Different Air Feeding Systems," Journal of Mechanical Science and Technology, Vol. 22, No. 8, pp. 1602–1611, 2008.

[2]. Pesaran, A. A., "Battery Thermal Models for Hybrid Vehicle Simulations," Journal of Power Sources, Vol. 110, No. 2, pp. 377–382, 2002.

[3]. Sato, N. and Yagi, K., "Thermal Behavior Analysis of Nickel Metal Hydride Batteries for Electric Vehicles," JSAE Review, Vol. 21, No. 2, pp. 205–211, 2000.

[4]. Wei, X. Z., Zou, G. N., and Sun, Z. C., "Modelling and Parameter Estimation of Li-Ion Battery in a Fuel Cell Vehicle," Chinese Journal of Power Sources, Vol. 28, No. 10, pp. 605–608, 2004.

[5]. Belt, J. R., Ho, C. D., Miller, T. J., Habib, M. A., and Duong, T. Q., "The Effect of Temperature on Capacity and Power in Cycled Lithium Ion Batteries," Journal of Power Sources, Vol. 142, No. 1, pp. 354–360, 2005.

[6]. Sabbah, R., Kizilel, R., Selman, J., and Al-Hallaj, S., "Active (Air- Cooled) vs. Passive (Phase Change Material) Thermal Management of High Power Lithium-Ion Packs: Limitation of Temperature Rise and Uniformity of Temperature Distribution," Journal of Power Sources, Vol. 182, No. 2, pp. 630–638, 2008.

[7]. Mills, A. and Al-Hallaj, S., "Simulation of Passive Thermal Management System for Lithium-Ion Battery Packs," Journal of Power Sources, Vol. 141, No. 2, pp. 307–315, 2005.