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ACTIVE BATTERY PACK COOLING SYSTEM USING PELTIER MODULE

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Abstract - *Our project is Active Battery Pack Cooling System using Peltier Module. It is Electric Vehicles battery pack cooling system which tends to maintain a constant temperature inside a battery pack system. In this project we are going to increase the lifecycle of batteries and increase the quality of the batteries in Electric Vehicles. Nowadays electric vehicle plays a major role in automotive industry. Electric Vehicles use power to charge their batteries as opposed to utilizing non-renewable energy sources like petroleum or diesel. Electric vehicles are more productive, and that joined with the power cost implies that charging an electric vehicle is less expensive than filling petroleum or diesel for your movement prerequisites. But in Electric Vehicles, batteries are getting busted due to sudden increase of temperature. For this problem statement we made a solution. When the temperature inside a battery pack is suddenly increases, it gets explode. So we need to maintain a constant temperature inside the battery pack system. For that, we add a module called Peltier module(Thermoelectric) to the battery pack system. This module works on the principle of both cooling and heating process. It also works like a coolant. When it is summer season, we need to cool a battery, if it is winter season, we need to heat a battery to certain temperature. That is what we use the Peltier module. This system will work only on 12v DC. So it is very helpful to increase our battery's lifecycle. This module will work on more type of batteries like lithium-ion batteries and lithium- potassium ion batteries.*

Keywords: *Active cooling, battery pack, Peltier module, Electric vehicle, thermoelectric, coolant, temperature, lithium Ferro phosphate.*

1. INTRODUCTION

An active battery pack cooling system using Peltier modules is a high-tech way to control and maintain battery pack temperature in various applications, including renewable energy storage systems, electric vehicles (EVs), and portable electronics. This novel method actively transfers heat away from the battery pack 0using the thermoelectric effect made possible by Peltier modules. This ensures ideal operating conditions and prolongs the life of the batteries. Among the myriad challenges faced by battery systems, one critical aspect is the effective management of temperature, a factor that profoundly influences performance, longevity, and safety. However, the best performance from these battery packs depends on maintaining exact temperature settings; high temperatures can damage performance, hasten depreciation, and even be dangerous, which emphasizes how important thermal management is. The evolution of cooling systems even though they are widely used, traditional passive cooling techniques frequently fail to dynamically adjust to the changing demands and environmental circumstances that batteries encounter. Active cooling systems are a result of the search for a more intelligent and responsive solution. They are made to actively control temperature and mitigate the negative consequences of heat build-up. Peltier modules, also known as thermoelectric coolers, are semiconductor devices that exploit the Peltier effect to create a heat transfer mechanism. A temperature difference is produced when heat is absorbed on one side of the module and released on the other when an electric current passes through it. Peltier modules are perfect for applications involving thermal management since they actively cool or heat surfaces using this concept. The active battery pack cooling system integrates Peltier modules into its design to actively control the temperature of the battery pack. This is important since battery cell performance and lifetime are directly impacted by temperature. High temperatures have the potential to quicken chemical processes inside the cells, which could result in decreased capacity, quicker deterioration, and safety issues. There are numerous benefits of integrating

Peltier modules into active cooling systems. These include increasing battery cell longevity, boosting general performance, and boosting safety a crucial factor in applications like electric automobiles. The system's adaptability to different battery chemistries, dynamic reactivity, and reasonably small size all add to its appeal to a wide range of sectors.

2. LITERATURE SURVEY

Angelo Maiorino (2023) explores the development of efficient Electric Vehicles (EVs) and the importance of thermal management systems for Lithium-ion batteries. He compares academic studies with the automotive industry's thermal engineering state of art. He analyzes nine EV models and their development, focusing on the quality and quantity of data available on manufacturers' official sites and specialist journals. The review concludes by examining future perspectives on thermal management of battery packs.

Gang Zhao and Xiaolin Wang (2022) found that liquid-cooling battery thermal management systems (BTMS) are an efficient thermal management solution for electric vehicles (EVs). They reviewed recent research on design improvement and optimization, focusing on coolant channel, heat transfer jacket, cold plate, and liquid cooling- based hybrid system improvements. They found that cooling channel, refrigerant cooling, and liquid-PCM hybrid cooling improvements were most effective.

Seham Shahid (2022) explores the thermal runaway process in lithium-ion batteries, a potential energy source for electric vehicles. The paper reviews key aspects of thermal runaway, including initiation mechanisms, propagation, and gas characterization. It discusses the development of mathematical and numerical models to predict thermal runaway, effective battery thermal management systems, and mitigation strategies to minimize damage during thermal runaway.

Zhi Xu's (2022) study investigates the impact of inlet position and air velocity on the cooling performance of battery packs in electric vehicles. The mechanism of the influences of inlet position and inlet air velocity on the cooling performance of the battery pack is revealed. The results show that the maximum temperature decreases by 4.17 K at 30 mm inlet position, and by 8.5-18.5 K with increasing inlet air velocity. The study provides valuable guidelines for improving battery pack cooling design.

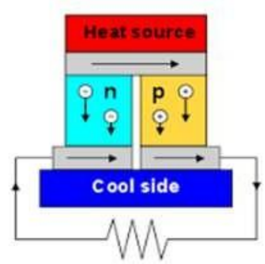
3. OBJECTIVE AND METHODOLOGY

The objectives our project is to maintain optimal battery temperature, to improve battery performance, to enhance battery safety and to optimize energy consumption and Cost-effective solution.

Our product is unique without any external coolant and we are reducing the battery temperature using novel idea. This prototype uses Peltier module TEC1-12706. As we know it works based on see-beck effect. Once rated temperature is set prescribed in the manufacturer datasheet controller, it compares the actual temperature of battery pack using NTC 10K resistance. Totally we are using 2 NTC to take the average temperature variation of the pack. The set point for our battery pack was 30degree Celsius when temperature goes beyond this value, controller triggers the fan and Peltier. The supply to the Peltier was fed in one direction so that hot side will be hot and cold side will be cold. And the speed of the fan will be minimum which can be seen in the DSO. When the temperature increased, the PWM will be increased to cool down the pack. This will be happen for the temperature drop but the current direction for the Peltier will be reversed. The overall circuit is controlled by PIC16f877A controller.

WORKING PRINCIPLE:

See-beck effect **-** A phenomenon known as the See-beck effect occurs when two distinct semiconductors or electrical conductors have different temperatures, which causes a voltage differential between the two materials.



4. CONTRIBUTION

The contribution for the successful completion of an active battery pack cooling system utilizing Peltier modules has been divided into three parts.

One focused on selecting efficient Peltier modules to maximize cooling capacity. To choose the ideal Peltier module configurations based on cooling capacity, power consumption, and cost constraints.

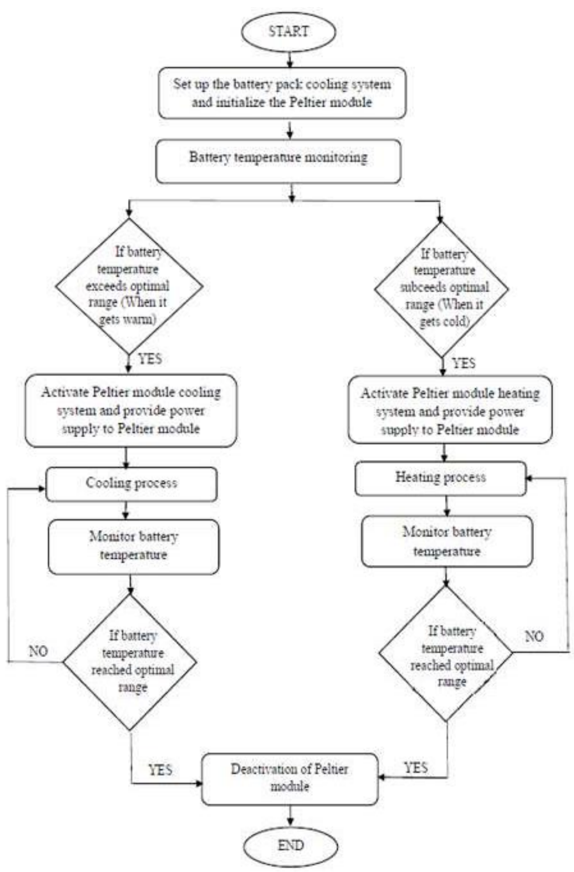
Second concentrated on developing the control system to manage power delivery and ensure safe operation. And also to integrate battery protection. Implement over-current, over-voltage and thermal runaway protection circuits to safeguard the battery and other components.

Third tackled system design and modeling, optimizing the physical layout for efficient heat transfer and integrating all the components. Designed a circuit in Proteus software.

Developed a robust and lightweight enclosure that accommodates the battery pack.

Through our combined efforts, we developed a working prototype of the cooling system that demonstrates the ability to maintain optimal battery temperature using Peltier modules. We demonstrated the effectiveness of this cooling approach in maintaining optimal battery temperature, potentially extending battery life and enhancing device performance.

5. FLOW DIAGRAM



EXPLANATION OF FLOW DIAGRAM:

- Start
- Initialization:
  a. Assemble the parts of the battery pack cooling system.
  b. Set up the control circuits and Peltier module.
- Battery Temperature Monitoring:
  a. To continuously check the battery temperature, use temperature sensors.
- Control System Activation:
  a. Determine whether the battery temperature exceeds or subceeds the optimal range.
  b. If yes, start the Peltier module cooling system and Peltier module heating system.
- Power Supply to Peltier Module:
  a. If exceeds, supply power to the Peltier module for cooling.
  b. If subceeds, supply power to the Peltier module for heating.
  c. Ensure that the correct voltage and current levels are maintained.
- Cooling process:
  a. The Peltier module absorbs heat from the battery side.
  b. And heat is transferred to the other side of the module.
  c. Peltier module cools the whole battery pack to a certain temperature.
  d. The integrated exhaust fan spreads the cool air inside the pack.
- Heating process:
  a. The Peltier module absorbs cool air from the battery side
  b. And cool air is transferred to the other side of the module.
  c. Peltier module warms the whole battery pack to a certain temperature.
  d. The integrated exhaust fan spreads the warm air inside the pack.
- Temperature Feedback:
  a. During the cooling or heating process, continuously check the battery's temperature.
  b. Use feedback loops to precisely control the Peltier module's power.

- Optimal temperature reached?
  a. Verify if the battery temperature has reached the optimal range.
  b. If it has, move on to Peltier module deactivation step.
  c. If not, continue the cooling or heating process again.
- Peltier Module Deactivation:
  a. Turn off the Peltier module's power source.
  b. Stop the cooling process [When the temperature gets low, the fan gets off (e.g. from 40 C to 30 C)].
  c. Stop the heating process [When the temperature gets high, the fan gets off (e.g. from 20 C to 30 C)].
- End.

6. PROCEDURE

Our product is a hardware application. It has some hardware components inside the battery pack system such as

1. Peltier modules,
2. Heat sinks,
3. Fan,
4. Power supply,
5. Temperature sensors,
6. Microcontroller,
7. Battery pack enclosure,
8. 16 X 2 LCD display.

Some software tools are used to design the prototype. They are

1. Solid works
2. Proteus
3. Mikropic.

6.1 SYSTEM DESIGN AND COMPONENT SELECTION:

- **Define target battery type and operational conditions:** Indicate the predicted temperature range, capacity, and battery chemistry (Lithium Ferro phosphate).
- **Choose Peltier modules:** Select modules with the right amount of cooling power in relation to the size of your battery and the desired temperature differential. Think about things like physical size and electricity use.
- **Design cooling assembly:** For the best possible heat transfer from the battery, decide where to put the Peltier modules and how many of them. To disperse heat from the hot side of the Peltier modules, think about utilizing heat sinks.
- **Choose a control system:** To control temperature monitoring, Peltier module power regulation, and fan control, select a microcontroller or specialized controller board.
- **Choose a sensor:** To keep an eye on the temperature of the battery, Peltier module, and maybe the surrounding air, choose precise temperature sensors. Think about using voltage and current sensors for monitoring performance of the system.

6.2 SYSTEM ASSEMBLY AND INTEGRATION:

- **Prepare the battery pack:** Make that the Peltier modules and temperature sensors can be attached to the battery pack. For safety, think about electrical insulation.
- **Mount Peltier modules**: To guarantee proper thermal contact, firmly affix the Peltier modules to the battery pack using thermally conductive paste or adhesive pads.
- **Attach heat sinks:** To help heat disperse into the surrounding area, install heat sinks on the hot side of the Peltier modules.
- **Wire the system:** As specified by the selected controller, connect the Peltier modules, sensors, and any fans to the control system.
- **Program the control system:** Write software that will allow the controller to:
  a. Read temperature data from sensors continuously.
  b. Determine how much the current temperature deviates from the desired temperature.
  c. Peltier modules should be turned on when the differential reaches a certain point.
  d. Adapt the power of the Peltier module (e.g., pulse width modulation) according to the temperature differential.
  e. Track the health of the system (voltage, current) and the Peltier module's performance.
  f. Adapt fan speed to cooling requirements.

g. Install safety features such as alarm triggers and overheated cut-off mechanisms.

6.3 CONTROL SYSTEM PROGRAMMING:

- Install the selected control algorithm on the MCU. Setting the control settings, communication protocols with the sensors and other components, and the set point temperature are all part of this process.
- Evaluate and improve the control mechanism. Verify its functionality and tweak the settings for best results.

6.4 TESTING AND OPTIMIZATION:

- **Initial power-up and system check:** Make sure that all of the sensors, Peltier modules, and control system are operating as intended.
- **Testing at baseline:** Take a regulated temperature reading of the battery without using any active cooling.
- **Testing with active cooling:** Simulating various battery loads and operating circumstances, such as charging, discharging, and fluctuating outside temperatures.
- **Gathering and analyzing data:** Data points such as battery temperature, Peltier module performance, power usage, and system health should be tracked and recorded.
- **Performance evaluation:** Examine the gathered information to determine how well the cooling system keeps the battery temperatures within the intended range.
- Test the system as a whole in a range of operational scenarios. To evaluate its cooling capacity, efficiency, and stability, simulate various temperature and load scenarios.
- Examine the test data and note any possible areas that need improvement. Enhance the system by modifying the control parameters, choosing the right components, or even looking into different cooling techniques.
- **Optimization:** To maximize performance and minimize energy consumption, fine-tune the control system logic or modify the Peltier module configuration in light of test findings.

7. RESULT AND DISCUSSION

Our project active battery pack cooling system using Peltier module is successfully developed and tested. The system demonstrated the ability to keep the battery temperature within the desired target range under various operating conditions.

We designed the prototype in proteus software and is shown below.

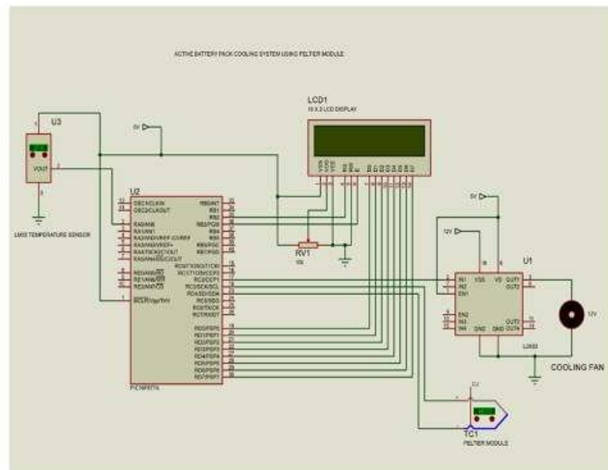


Figure 1 - Design of prototype in Proteus software

The images of our project active battery pack cooling system using Peltier module is shown below.

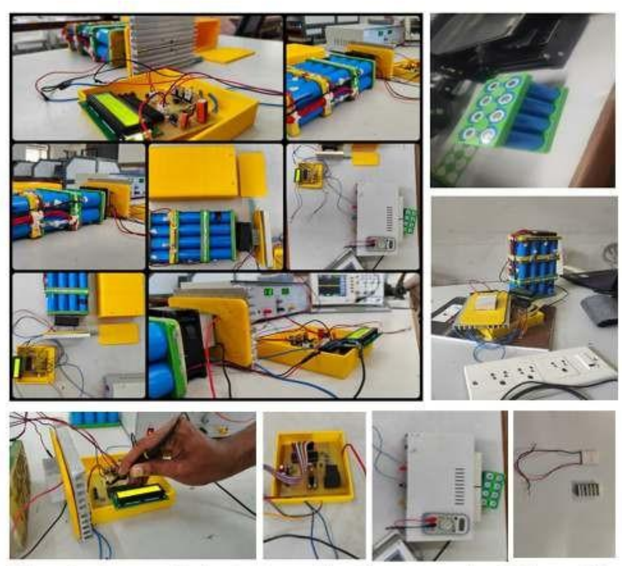


Figure 2 – Images of Active battery pack cooling system using Peltier module

- **Enhanced Battery Life:** The system can considerably increase the battery's lifespan by maintaining it at optimal temperatures. More charge cycles are possible due to reduced battery degradation at lower temperatures.
- **Improved Battery Performance**: When batteries are used within optimal temperature ranges, they function better. Consistent power output and avoidance of performance drops due to overheating are guaranteed by the cooling system.
- **Enhanced System Reliability:** Safety risks and system failures can result from overheating. By reducing these hazards, active cooling can help creating a battery system that is more dependable.

The image of active battery pack cooling system maintained at an optimal temperature range and 3D printing is shown below.

Figure 3 – System maintained at optimal range

Figure 4 – 3D printing

8. CONCLUSION

Our project has been successfully developed, tested and evaluated an active battery pack cooling system using Peltier module. Using Peltier modules, this study effectively built and assessed an active battery pack cooling system. our project investigated the feasibility of using Peltier modules for active battery pack cooling. The outcomes show how this strategy may be used to enhance battery safety and performance. Depending on the particular needs, Peltier module-based cooling may be a good option for a variety of applications by weighing the trade-offs between cost, power consumption, and efficiency. The battery pack's temperature was lowered to the appropriate level while taking energy consumption and system viability into account. The battery pack's temperature has been successfully managed within the intended range by the integration of Peltier modules, sophisticated control algorithms, and carefully chosen components. This has resulted in improved performance and longevity. All things considered, our research offered insightful information about the possibility of utilizing Peltier modules for battery pack cooling, advancing the creation of more effective and environmentally friendly battery systems.

9. SUGGESTIONS FOR FUTURE WORK

To further improve the active cooling of the battery pack, there are some suggestions which includes to investigate other cooling techniques (such as heat pipes) for particular situations where a larger cooling capacity or efficiency may be necessary. Look into using more sophisticated Peltier modules that utilize less power or have higher efficiency. Provide a user interface that allows you to keep an eye on system performance and modify cooling settings in real time. Create control strategies that adapt to the environment and battery usage patterns to optimize cooling. Investigate more recent Peltier modules with a greater coefficient of performance as technology develops. This increases the system's overall efficiency by enabling more cooling with fewer power usage.

REFERENCES

[1] Maiorino, A., Cilenti, C., Petruzziello, F. & Aprea, C. (2023). A review on thermal management of battery packs for electric vehicles. Applied Thermal Engineering, Volume 238,122035.

[2] Zhao, G., Wang, X., Negnevitsky, M. & Chengjiang. (2023). An up-to-date review on the design improvement and optimization of the liquid-cooling battery thermal management system for electric vehicles. Applied Thermal Engineering, 219, Part B, 119626.

[3] Zhao, G., Wang, X., Negnevitsky, M. & Zhang, H. (2021). A review of air-cooling battery thermal management systems for electric and hybrid electric vehicles. Journal of Power Sources, 501, 230001.

[4] Shahid, S. & Chaab, M.A. (2022). A review of thermal runaway prevention and mitigation strategies for lithium- ion batteries. Energy Conversion and Management: X, 6,100310.

[5] Ogura, K. & Kolhe, M.L. (2017). Battery technologies for electric vehicles. Electric Vehicles: Prospects and Challenges, Elsevier Inc, pp. 139-167.

[6] Ali, H.M. (2023). Thermal management systems for batteries in electric vehicles: A recent review. Energy Reports., 9,5545-5564.

[7] Shen, X., Cai, T., He, C., Yang, Y. & Chen, M. (2023). Thermal analysis of modified Z-shaped air-cooled battery thermal management system for electric vehicles. Journal of Energy Storage,58.

[8] Xu, Z., Yu, G., Zhang, T. & Wang, R. (2022). Cooling performance of battery pack as affected by inlet position and inlet air velocity in electric vehicle. Case Studies in Thermal Engineering., 39.

[9] Guo, J. & Jiang, F. (2021). A novel electric vehicle thermal management system based on cooling and heating of batteries by refrigerant. Energy Conversion and Management., 237.

[10] Bernagozzi, M., Georgoulas, A., Miche, N. & Marengo, M. (2023). Heat pipes in battery thermal management systems for electric vehicles: A critical review. Applied Thermal Engineering., 219.

[11] Behi, H., Karimi, D., Behi, M., Jaguemont, J., Ghanbarpour, M., Behnia, M., Berecibar, M. & Mierlo, J.V. (2023). Thermal management analysis using heat pipe in the high current discharging of lithium-ion battery in electric vehicles. Journal of Energy Storage., 32.

[12] Wu, W., Wang, S., Wu, W., Chen, K., Hong, S. & Lai, Y. (2019). A critical review of battery thermal performance and liquid based battery thermal management. Energy Conversion and Management,182,262-281.

[13] Siddique, A.R.M, Mahmud, S. & Heyst, B.V. (2018). A comprehensive review on a passive (phase change materials) and an active (thermoelectric cooler) battery thermal management system and their limitations. Journal of Power Sources, 401, 224-237.

[14] Zhang, T., Gao, C., Gao, Q., Wang, G., Liu, M., Guo, Y., Xiao, C. & Yan, Y.Y. (2015). Status and development of electric vehicle integrated thermal management from BTM to HVAC. Applied Thermal Engineering, 88,398-409.

[15] Hamed, M.M., Tayeb, A.E., Moukhtar, I., Dein, A.Z.E. & Abdelhameed, E.H. (2022). A review on recent key technologies of lithium-ion battery thermal management: External cooling systems. Results in Engineering., 16.