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Arduino-Based Active Cooling System for Lithium-Ion Battery Packs using Peltier Module

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ABSTRACT

The Active Battery Pack Cooling System employing a Peltier Module is the name of our project, which was created especially for electric cars (EVs). The objective is to maintain a constant temperature inside the battery pack, which enhances the batteries' lifespan and performance.

Compared to conventional cars that run on fuel or diesel, electric vehicles are proving to be more economical and ecologically benign as they gain popularity in the automotive sector. But a big problem with EVs is that their batteries can overheat, especially when they're used a lot or in hot weather. This abrupt increase in temperature has the potential to harm the batteries or perhaps cause hazardous events like explosions.

We have created a system that makes use of a Peltier module, sometimes referred to as a thermoelectric module, in order to address this issue. Depending on the situation, this device can both heat and cool the batteries, softly warming them in cold weather and chilling them in hot weather. It serves as the battery pack's intelligent temperature controller.

The system is straightforward to integrate into EVs and is energy-efficient because it only requires 12 volts of DC power to operate. It works with both lithium-ion and lithium-potassium ion batteries, among other battery types. Our solution increases overall vehicle reliability, prolongs battery life, and improves safety by assisting batteries in maintaining a steady and safe temperature.

Keyboards: Thermal Runaway, Heat Dissipation, Temperature Control, Energy Efficiency, Microcontroller-Based Cooling, Active Cooling System, Lithium-Ion Battery Packs, Peltier Module, Battery Thermal Management System (BTMS), Thermoelectric Cooling, Electric Vehicles (EVs), Real-Time Monitoring, and Hybrid Cooling System.

I. INTRODUCTION

Our project offers a clever, dependable, and effective method of controlling battery temperatures in a range of applications by introducing an Arduino-based Active Cooling System for lithium-ion battery packs utilising Peltier Modules. Keeping batteries at the proper temperature is essential for longevity, performance, and safety in a variety of applications, including electric vehicles (EVs), renewable energy storage, and portable electronics.[1]

Temperature has an impact on batteries. They become less effective, deteriorate more quickly, and may even be dangerous when they become overheated. Their performance deteriorates and they might not produce enough power when they get too cold. Because they react slowly and are unable to adjust to sudden changes in temperature or ambient circumstances, traditional passive cooling techniques—such as heat sinks or air vents—frequently fail. [2]

This is the role of our active cooling system. Small solid-state devices called Peltier modules, which transfer heat from one side of the module to the other when electricity passes through them, are the foundation of our concept. They are perfect for maintaining batteries within their ideal temperature range because of their dual use, whether it's a chilly winter morning or a scorching summer day. [3].

Our approach can react to temperature changes in real time by combining Peltier modules with a temperature monitoring and control system. This prolongs the battery's life, improves safety, and guarantees consistent performance under various circumstances in addition to preventing overheating or overcooling. [4]

Additionally, the system is small, adaptable, and energy-efficient, which makes it appropriate for use in off-grid solar power storage systems as well as high-performance EV battery packs. Our idea provides an innovative approach to more intelligent thermal management in light of the growing electrification and energy storage technologies. [5]

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II. FLOW CHART

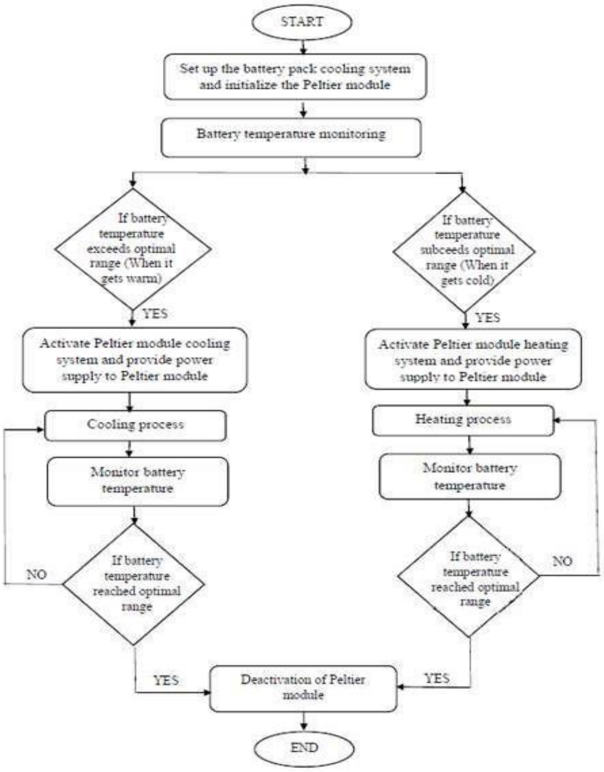

Fig. flow chart

a. Get started
b. The procedure starts. Setting up: The first step is to assemble the battery pack cooling system. The Peltier module, which has dual heating and cooling capabilities, and the control circuits are configured and linked.
c. Monitoring Battery Temperature: To make sure the battery remains within a safe and effective range, temperature sensors are utilised to continuously check the battery's temperature.
d. Turning on the Control System: The system determines if the battery's temperature is within the ideal range or is too high or low. The system turns on the Peltier module to either warm or cool the battery if the temperature deviates from that range.
e. Peltier Module Powering: The Peltier module receives power to cool the battery if it becomes too hot. Power is provided for heating if the battery is too cold. In both situations, the system makes sure the current and voltage are at the proper levels for effective and safe operation.
f. Cooling Process: The Peltier module takes over to absorb the battery's heat when it becomes excessively hot. This heat is transferred from the battery to the opposite side of the module. Consequently, the battery pack reaches a safe temperature.
   By uniformly distributing the cool air throughout the battery pack, an exhaust fan aids. [6]
g. Heating Process:
   The Peltier module absorbs the cold from the battery side if the battery becomes too cold.
   On the other side of the module, this cold is shunted. This assists the Peltier module in achieving the proper battery pack temperature. Once more, the exhaust fan aids in the battery pack's internal distribution of heated air. [7]
h. Feedback on Temperature: The system continuously checks the battery's temperature during the heating and cooling procedures. To ensure that the temperature stays precisely where it needs to be, a feedback loop modifies the power supplied to the Peltier module.
i. Do We Have the Ideal Temperature?
   The device continuously checks to see if the battery temperature has returned to the ideal range. In the event that the temperature remains excessively high or low, the process of cooling or heating proceeds.
j. Disconnecting the Peltier Module :
   The power to the Peltier module is cut off when the battery reaches the proper temperature. Additionally, when the temperature falls to the lower limit (for instance, from 40°C to 30°C), the cooling fan turns off [8]. As the temperature reaches a safe level (for instance, from 20°C to 30°C) while heating, the fan also turns off.

k. End
After the system has finished its task, it idles until the battery requires another temperature adjustment.

Components:
The components of our product are hardware applications. The battery pack system contains a few hardware parts, including:

1. Modules for Peltier
2. Sinks for heat
3. A fan
4. The power source
5. Sensors of temperature
6. A microcontroller
7. Enclosure of battery pack
8. LCD display, 16 x 2.

III. SYSTEM SELECTION: DESIGN AND COMPONENT

- Describe the type and conditions of the battery: First, we identify the battery type (in this case, Lithium Iron Phosphate, or LiFePO4) and ascertain the capacity,

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temperature range, and other essential features required for safe and effective operation. [9]

- Pick the Correct Peltier Modules: We pick Peltier modules according to the amount of cooling power they can deliver. The battery's dimensions and the desired temperature differential will determine this. We also take into account things like the modules' actual dimensions and electrical consumption.
- Design the Cooling System: We choose the optimal location for the Peltier modules to transfer heat in order to keep the battery cold. We also decide how many modules are required. Heat sinks are used to assist cool the Peltier modules' hot side.
- Select the Control System: To operate the system, we select a microcontroller or specialised controller board. This will regulate fan control, temperature monitoring, and power adjustments for the Peltier modules.
- Pick Temperature Sensors: To keep an eye on the battery's, Peltier modules', and perhaps the ambient air's temperature, precise temperature sensors are selected. To monitor the system's performance, we might additionally employ voltage and current sensors. [10]

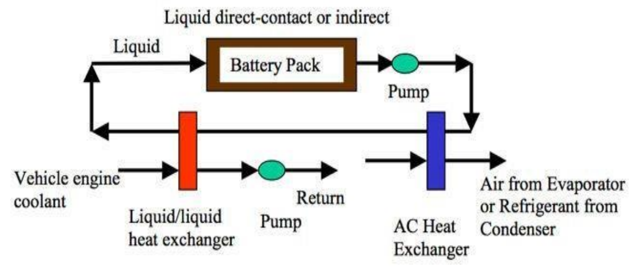
IV. PROPOSED METHODOLOGY

- Maintaining the battery at a safe and ideal temperature is our project's primary objective. This enhances battery performance, boosts safety, conserves energy, and provides an affordable solution.
  Our technology is special because it actively cools the battery using Peltier modules (TEC1-12706), a clever and straightforward concept that eliminates the need for external coolant. [11]
- This is how it operates: The Peltier module generates a temperature differential when powered, making one side hot and the other cool. This phenomenon is known as the Seebeck effect.
- For the battery pack, we have specified a target temperature of 30°C.
- The battery's temperature is tracked by two NTC 10K temperature sensors, which are utilised to compute the average.
- The system, which is managed by a PIC16f877A microcontroller, activates the Peltier module and cooling fan when the battery temperature surpasses 30°C.
- The Peltier's current direction is reversed when the battery cools down again, which aids in effectively balancing the temperature. • The fan speed increases as the temperature rises, using PWM (Pulse Width Modulation) to adjust cooling intensity.
  This idea is both inventive and useful for electric vehicle batteries since it offers a small and effective cooling system without depending on conventional liquid coolants. [12]

V. BATTERY MANAGEMENT SYSTEM (BMS)

An integral component of electric vehicles is the Battery Management System (BMS). Its primary responsibility is to oversee and maintain the battery's safety and health. In order to avoid overheating, damage, or even safety risks, it keeps the battery from overcharging or overdischarging. In order to ensure that all battery cells function as a unit, the BMS also:

- Balances the charge across each cell.
- Keeps an eye on current, voltage, and temperature to prevent dangerous circumstances.
- Contributes to a longer battery life.
- Increases the vehicle's range and performance through effective energy management.
- Notifies the user if there is a battery issue. [13]

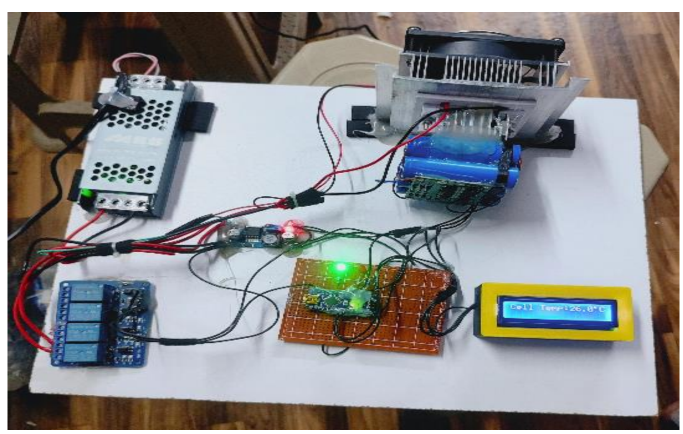


F. Active Cooling and Heating – Liquid Circulation

Fig. Block Diagram

VI. RESULTS

Peltier modules in the Active Battery Cooling System have the potential to enhance the cooling of electric vehicle (EV) batteries. It improves performance and safety by assisting in maintaining batteries at a safe temperature. This method provides a strong basis for improved EV thermal management. It might, however, play a role in the future of EVs with additional advancements, such as making it more economical, energy-efficient, and compatible with other EV models.



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VII. CONLUSION

The necessary research has been finished, and the project's validation has been demonstrated, in preparation for the first step of project presentation. Therefore, the project's goal, "Arduino-Based Active Cooling System for Lithium-Ion Battery Packs Using Peltier Module," can be effectively accomplished. Using a Peltier module, our research successfully constructed, tested, and assessed an active battery pack cooling system. This study successfully constructed and evaluated an active battery pack cooling system using Peltier modules. The viability of employing Peltier modules for active battery pack cooling was examined in our project.

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