"Optimization of battery Cooling system for electric vehicle using Simulation"

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Abstract: The BTMS is a crucial component of an electric vehicle (4) that has a direct impact on its performance. This research provides a CFD model that improves the accuracy of data received from temperature analysis inside battery packs. Effective model design and development of a battery pack increases the life of the battery cells and the electric vehicle's energy efficiency in excellent specified road traffic circumstances. The thermal in the battery pack research methodology is based on an efficient co-simulation concept that includes steady-state CFD simulations (4) and a researched analysis model for the thermal behavior of a lithium-ion (Li-ion) cylindrical battery and is applied in the battery pack's forced air-cooling thermal management system and liquid cooling system. When comparing the two data, we may conclude that liquid coolant systems have higher heat conductivity and heat capacity than air, i.e., the capacity to store heat as energy in its bonds (6). As a result, battery performance is significantly improved, and SOC may be maintained for longer periods of time.

INTRODUCTION

The transportation sector primarily runs means of transportation powered with internal combustion engines using fuels like diesel, petrol etc, it accounts for 27 percent of the world economy's total energy usage. So, the greenhouse gas will affect the environment the gasses like Carbon-monoxide, nitrogen-oxides, hydrocarbons, volatile-organic compounds, and other pollutants are released into the environment when internal combustion engines are used. As a result, developing and using electric cars might be a viable option for lowering greenhouse gas emissions and pollution that depletes the ozone layer. (1). Many technologies for electric vehicles are now being developed, with the goal of increasing electric cars' and electric powertrains' total efficiency. Electric vehicles, therefore, requires in order to provide an alternative solution to internal combustion engine vehicles, a high developed and complicated structural system for controller, a large amount of power density of the energy source, the longer self-life of lithium-ion batteries, and greater efficiency for power electronic equipment with futuristic features are required. To give a long driving range and a high battery % efficiency, lithium-ion batteries with a high density and high energy are the most preferred power sources. Li-ion batteries, on the other hand, emit a large amount heat leads to quick state of charge at high power consumption, and the temperature increase, and consistency will impair their energy storage capacity and lifetime (1).

The necessity of keeping and optimizing the batteries to an optimal temperature range that is adequate has been demonstrated through studies and research. According to research, the working temperature range for lithium-ion batteries is 15 to 50 degrees Celsius (2), with a temperature rise of one degree reducing the battery's lifetime by two months. Also, to support battery balance and consistent charging during the cycle, the maximum temperature differential in a battery pack should be kept below 5 degrees Celsius. (1), so that the battery's life cycle may be extended by a comparable margin and the battery's performance can be expected to be uniform.

According to recent studies, a temperature rise in Li-ion cells induced by a larger state of SOC can reduce battery life by 66 percent to 97 percent. Based on the above statement, a correct design, modification, and construction of a battery thermal management system (BTMS) is essential for electric vehicles. With right technique, we can maintain ideal thermal operating conditions. According to recent studies, a temperature rise in Lithium cells induced by a higher rate of SOC can reduce battery life by 66 percent to 97 percent. A correct design, modification, and construction of a thermal management system for an electric vehicle's battery (BTMS) is necessary based on the above assertion; with the right approach, we can maintain perfect thermal operating conditions, with right technique, we can maintain ideal thermal operating conditions. As a result, the battery's BTMS is used to optimize a safe temperature range for the batteries. Various research on BTMS, including cooling techniques and battery thermal modelling design models, have been conducted. Thermal cooling systems include air cooling, liquid cooling, heat pipe cooling, and phase change material (PCB) cooling. Liquid cooling has a higher thermal conductivity coefficient and performs better in general. However, the extra payloads, such as liquid coolant, casing, and sealing devices to avoid liquid leakage, as well as the high costs of the liquid coolant circulation system, reduce its effectiveness.

Air-cooling is the most extensively utilized cooling systems in BTMS because it is inexpensive and easy to maintain, and it's frequently used in electric and hybrid vehicles. The use of a forced air-cooling system is common. Which flows cooled air into the battery cells. Reduce the cycle rate of the cell, lower the temperature, and this will function within the intended range. However, a greater cycle rate of the battery causes a significant increase in temperature, necessitating the circulation of a considerable volume of air towards the battery module in order to maintain or lower the rising temperature (1).

Methodology:

Step 1: Defining the parameter

Step 2: 3D modelling

Step 3: CFD Analysis

Step 4: Simulation

Step 5: Resultant Graph Comparison

Methodology of Study:

The procedures for determining the temperatures in the battery cell's core, as illustrated in Fig. 1, are as follows:

1. The amount of electric current drawn from the batteries during EV operation and the amount of temperature rise caused by the batteries, as calculated using simulation.

2. Computational Fluid Dynamics simulations to manage and maintain the coefficient of heat transfer values on the batteries within a specified range at various temperatures and airflow rates (2).

3. Complete the heat transfer maps gathered, create a mathematical model and assess the thermal performance (2).

Establishing Requirements:

The amount of heat produced by the Li-Ion cells and the battery pack is related to the battery demand, and hence the vehicle's operating mode. Thermal criteria imposed on the battery pack are specified by completing 22 kilometers on a racetrack without exceeding the 50°C restriction. The figures are based on the velocity profile of a Formula Student EV during a fast lap of Germany's Hockenheim ring circuit. The electric current required to be provided by the battery cells at each point of the event and the heat load that the battery's cooling system will have to bear may be calculated using the velocity profile of the accelerations and the parameters of the examined propulsion system. The following information is available about the building of the examined electric prototype powertrain.

Model requirements

- Battery pack: 4
- Battery subsystem
- Cold plate subsystem
- Cooling plate subsystem
- Heating -cooling unit subsystem
- Refrigerant subsystem
- Radiator sub system
- Pump controller
- Air stream
- Environment
- FTP-75 Drive cycle coolant

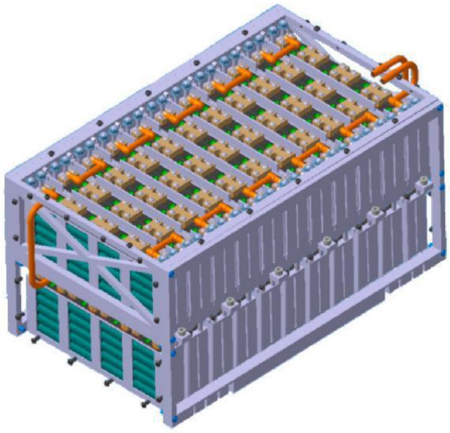

Fig 1: required packs model for analysis

Battery Heat Generation:

To begin, the electric current drawn from the battery cells must be calculated based on the motors' power requirements and the battery's level of charge. The vehicle's longitudinal resistance forces to achieve the necessary to calculate the velocity profile. The resistance force, aerodynamic drag-force, and acceleration-resistance force are estimated because of this. The rolling resistance force, aerodynamic drag-force, and acceleration resistance force are estimated because of this. Their sum produces the traction force necessary at the wheel, which is used to calculate the torque at the wheel and motor torque required for the desired performance The mechanical power produced by the motors may be computed at any time using the motor speed provided by the velocity profile. In addition to the power necessary for acceleration, the possibility for energy recovery via regenerative braking is considered. The needed electric power for each motor is computed using the efficiency map, which is then used to calculate the amount of electricity to be pulled from the battery based on state changes (2).

Power profiles are repeated 23 times throughout a single lap to create a power profile to reach 22 kilometres in 1960 seconds, while the value of the electric vehicle remains constant (1).

The current to be drawn from the battery is computed separately from the voltage at the battery's output based on its state of charge (SOC) (1).

State of Charge (SOC): State of charge refers with relation to the amount charged in a battery. The estimations of SOC can add to the performance of BMS and its dependability. Battery charge and discharge cycles involve release of complex substances like arsine in case of lead-acid batteries, Cadmium in case of Nickel-Cadmium batteries, Fluoride gas in case of Lithium-ion batteries, and their estimation is difficult to make. It is therefore difficult to appraise the SOC precisely under different operational conditions. There are a few sorts of LIBs in the market, for example, those containing LiFeO4, lithium polymers and LiCoO2 that involve high emission of power from the battery and possess complex topology of battery cells where SOC calculations require time.

Temperature monitoring: Thermistors are typically used to cover the battery's temperature. The temperature information from the thermistor is frequently read out of an ADC. Temperature detectors screen every cell of any energy storage system (ESS) like power banks or an assembling of cells in case of small batteries used in adaptable operations. Since the chemical composition used to develop a battery is unchangeable, also a battery with repeated current spike can result in the battery touch off. Temperature estimations are not only limited to optimize the temperature but also monitor the safe range of charge or to discharge. In in order to keep the cells' temperatures within the desired range, coolant is circulated around the surface of the battery packs.

Thermal management: Thermal management involves monitoring and regulating battery temperature to ensure that the battery is not harmed by high or low temperature. Unlike SOC and SOH that depend on more than one parameter for their estimation, temperature estimation solely depends on the dimension of individual cell temperature. Thermal management is done by controlling a fan or an electric warmer, as needed, which helps to keep the temperature of the battery under ideal conditions. A thermal management equipment estimates the battery temperature by thermal detectors and performs cooling or warming tasks and sends an extreme flag to the Control Unit about its variation.

SoC = SoC0 − 1 CAh Z t t0 I(t)dt (1) where SoC is the original state of charge (2).

CAh denotes battery capacity, while I denote uprooted current.

The voltage of the batteries is calculated using the data table and the temperature curve at particular temperature i.e. 45 C, based on their state of charge. Using the obtained current value, the temperature rise of each battery cell is calculated as follows:

Q = Irreversible Q + Reversible Q

= I 2 ·Rint − IT· dEOV dT (2)

When intrinsic resistance exists Rint is calculated from a chart based on the SOC (Rint = f (C-rate, SoC)) and, using Drake's experimental observations, T implies temperature and dEOV/dT represents the entropic coefficient. The battery's C-rate and SoC. Thus, Figure 4c depicts the average range of the heat created by the battery cells during the test on endurance (2).

s equals 1 W/cell CFD Simulations 2.3 On the surface of the battery cells, the heat transfer coefficient is determined using the fluent solver. The primary purpose of utilizing CFD simulations is to estimate SOC values for various occurrences of produced heat and air movement. These findings are then used to create heat transfer maps that discriminate thermal behavior under various settings. The justification for utilizing this approach, which involves doing brief simulations with a 1D model that incorporates the features generated from 3D CFD steady-state simulations, is the significant decrease in computing work required. The justification for utilizing this approach, which involves doing brief simulations using a 1D model that incorporates the features generated from 3D CFD simulations in steady state, is the significant decrease in computing work required. The goal of the first phase is to develop a reference CFD model that can be utilized for the other investigated scenarios. The mesh system is created at the interfaces between the fluid layer and the cell borders, as well as between the fluid layers. The following equation is used to compute the thickness of the first inflation layer for y+=1 (2).

Δy = Dh ·y +· √ 74·Re−13/14 D

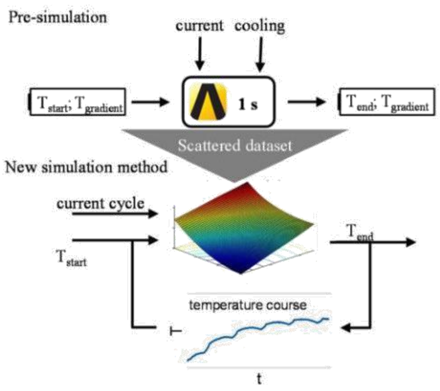

Fig 2: Process

The model is developed using Ansys work bench. The value of the cell is calculated and defined in the ANSYS work bench the properties are added according to the cell. Here the Li-ion cell is used for the study

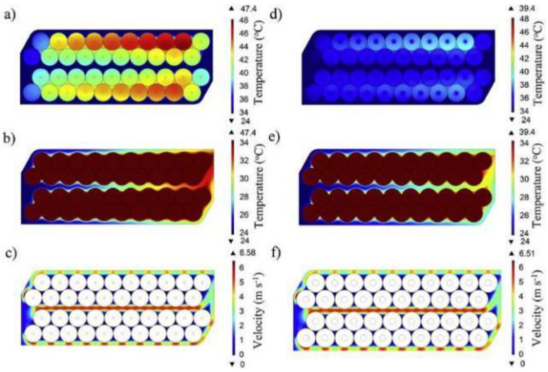

Fig3: single cell analysis

When the car is in acceleration mode, the battery is rapidly depleted at both ends, on the positive and negative sides of the electrode. As a result, the temperature within the battery rises, and the battery life is affected by how hot the battery is. We all know that the lithium-ion battery's optimum temperature is at or near 35 degrees Celsius.

Within this temperature range, the battery performance is excellent, and we may anticipate a long battery life. As a result, battery cooling is required to maintain this temperature.

Battery Cooling Systems (BCS) or BTMS

The primary goal of a thermal management, battery pack will be delivered via the system. With an acceptable mean and constant According to the battery provider, temperature distribution (or even minor variations) across the battery modules of the battery cell, it must also be accurate and accessible for routine maintenance. Setting up a proper thermal management system will help to properly dissipate heat from the battery pack, reducing excessive temperature increases, and improving charging and discharging stability and protection. LIBs have two forms of thermal management: cooling and heating. The heat management system for the battery module must be small, light, economical, easily packed, and suitable with the location of the car manufacturer in the vehicle. The BTMS may be dissolved into a few primary parts/sections using a hierarchical model's decomposition technique, as illustrated in Fig. 3, including the battery cell, air intake system, and battery module. Every sub-system is further divided into secondary sub-systems that are categorized into different domains, such as fluid dynamics, thermodynamics, and structure in the case of the battery module (3).

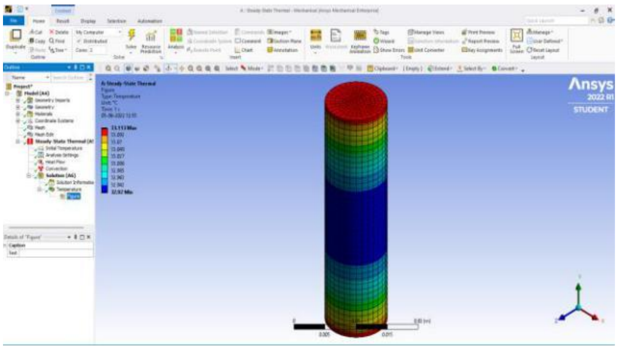

Fig4: Temperature variation analysis

The simulation has been completed. The temperature within the battery pack is determined by the fig 6 above. When water + Ethelyn glycol is employed as the solvent, liquid cooling is used to progressively lower the temperature within the battery pack. As a result, it's vital to keep the battery pack at the right temperature.

The MATLAB findings have been completed.

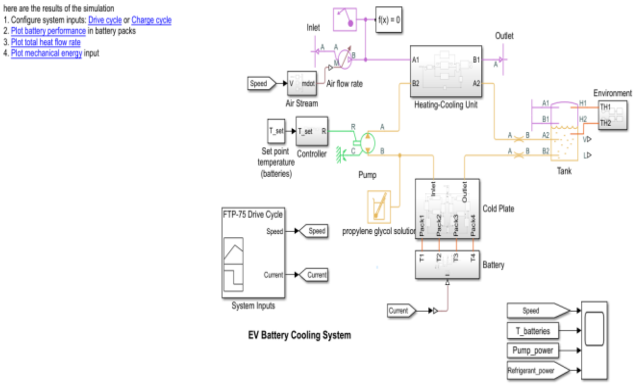
here are the results of the simulation
1. Configure system inputs: Drive cycle or Charge cycle
2. Plot battery performance in battery packs
3. Plot total heat flow rate
4. Plot mechanical energy input

Fig5: MATLAB model

This is the FTP-75 cycle which is also called the fast-charging cycle or the European standard cycle.

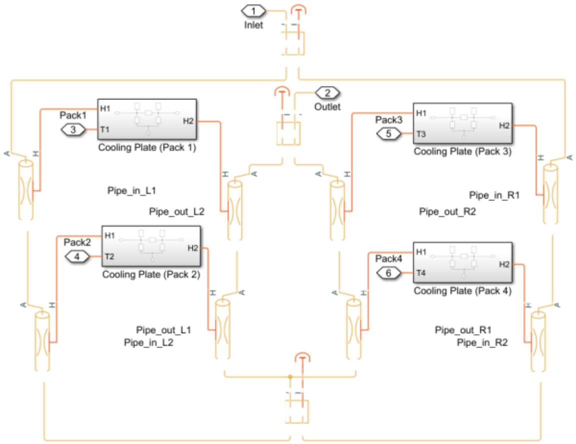

Fig6: Cold plates subsystem

Cold plate's function is that the coolant passes through inlet passes through all the hot pipes observe there heat and then it goes out through the outlet and this cycles repeats simultaneously.

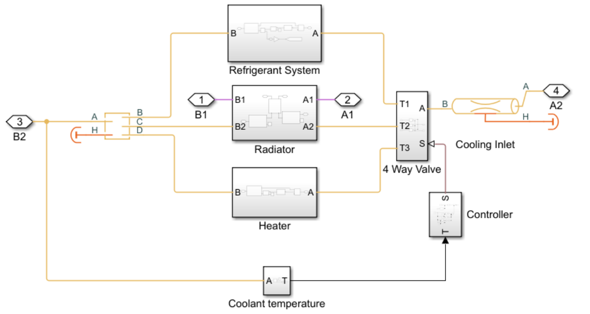

Fig7: Heating Cooling Unit subsystem

These heating cooling unit is used in some of weather conditions like rainy or in cold conditions the battery needs some minimum heat for its best performance at that time this heating cooling unit is used.

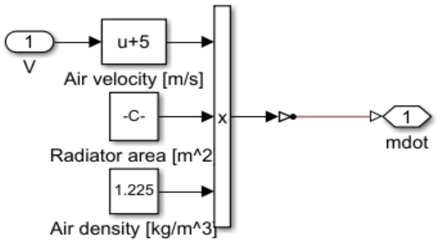

Fig8: Air Stream

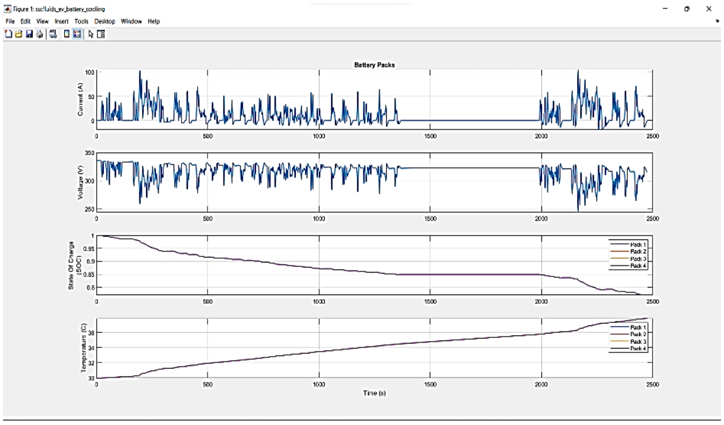

Fig9: Battery pack temperature graph

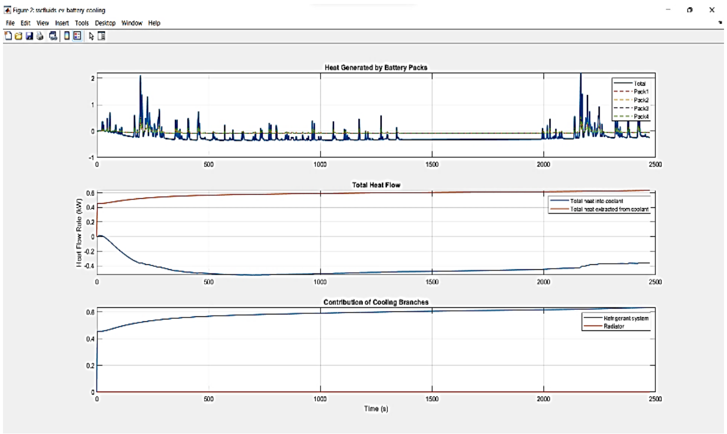

Fig10: Heat flow Graph

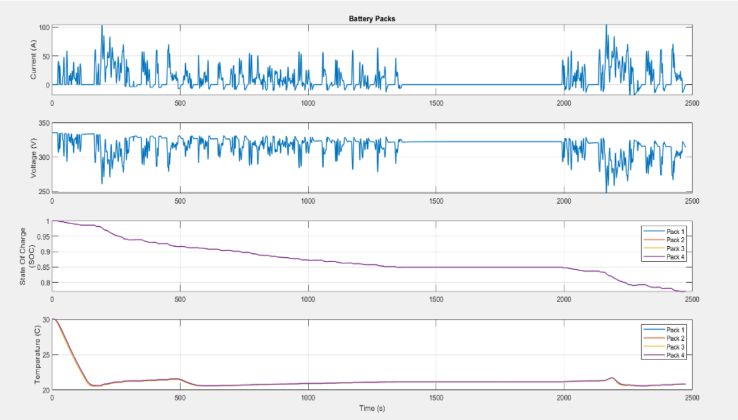

Fig11: Mechanical Power graph

The Coolant adopted here is propylene glycol + water mixture for best performance in the battery.

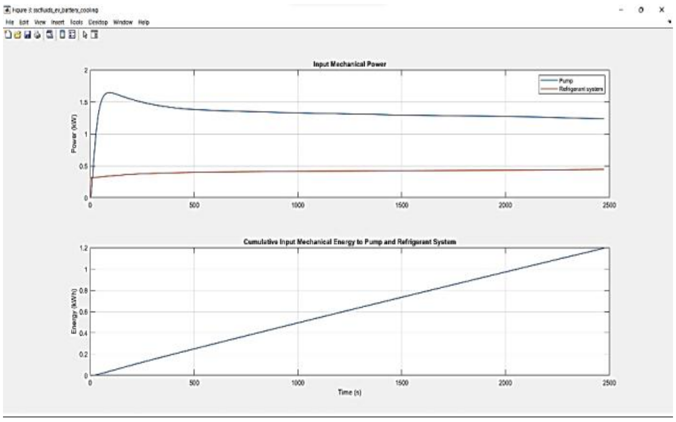

Fig12: Battery pack temperatures

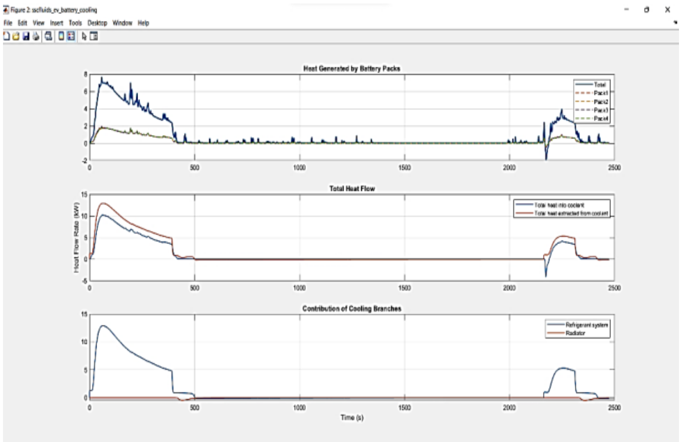

Fig13: Heat Flow graph

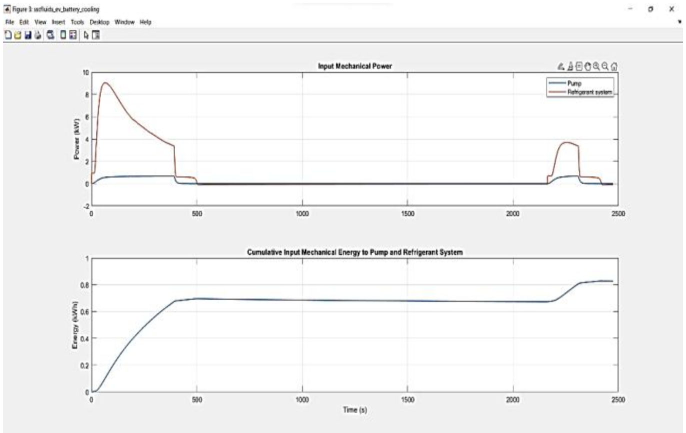

Fig14: Mechanical Power

Conclusion

The outcome of the MATLAB result is compared with analytical solution of the previous work. Here we can see that when we use coolant SAE-30 as the coolant the battery performance graph will increase in the normal acceleration so there, we can see temperature increase up to 35°C. We know that the optimal temperature of the Li-ion cell is around 35°C this when the LI-ion cell is maintained in optimal temperature. Were as in the ev vehicle there will be increase in acceleration, so the input required to the EV vehicle depends on the road conditions.so temperature in the battery increases when required input is more so in this model, we have use propylene glycol + water mixture as the coolant. We can see that the battery performance graph decreases gradually so here we can see that the battery coolant battery works properly, and we have optimized the battery temperature.

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