A Review on Thermal Management of Electric Vehicle

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Abstract*- On the present automobile market, there are several levels of hybrid electric vehicle and pure electric vehicle blending. In electric vehicles, different sizes, types, and numbers of battery cells are used depending on the blending level. Unlike traditional fuels, battery cells have more stringent requirements for the operating environment. They are extremely temperature sensitive. A Battery Thermal Management System (BTMS) is typically integrated with battery cells to maintain an appropriate thermal operating environment. As a result, understanding the right operating needs of batteries, as well as what types of management systems can adequately and efficiently meet these criteria, is critical. Efficient temperature management systems contribute significantly to battery health and extend the overall lifespan. Moreover, as the capacity and charge/discharge rate increase, battery security issues need more attention. The performance and durability of a battery pack in an electric vehicle can be maximized with this cornerstone. Subsequently, various BTMS has been developed to meet the demand for higher power, faster charge rates, and improved driving performance. This study will improve battery performance by lowering BTMS energy consumption and increasing the electric range of EVs.*

Keywords- Electric Vehicles, BTMS, HEV, PHEV, FCEV

I. INTRODUCTION

The paper explains Firstly; brief background is given referring to electrified vehicle Types and subsystems. Then, the thermal management requirements are discussed and its basic architectures are presented. Then, a detailed EV types along with their functionality. Then it explains EV subsystems in detail. Finally, it explains the complete BATTERY THERMAL MANAGEMENT SYSTEMS (BTMS) along with its all components.

II. EV TYPES

EVs can run entirely on electricity or with an internal combustion engine. The most basic type of electric vehicle uses simply batteries as its energy source, however there are others that use different energy sources. These are known as hybrid electric vehicles (HEVs). Technical Committee 69 (Electric Road Cars) of the International Electrotechnical Commission proposed that vehicles with two or more types of energy sources, storage, or converters can be classified as HEVs as long as at least one of them provides electrical energy [4]. This specification allows for a wide range of HEV pairings, including ICE and battery, battery and flywheel, battery and capacitor, battery and fuel cell, and so on. As a result, both the general public and specialists began referring to automobiles as –

(1) Battery Electric Vehicle (BEV)
(2) Hybrid Electric Vehicle (HEV)
(3) Plug-in Hybrid Electric Vehicle (PHEV)
(4) Fuel Cell Electric Vehicle (FCEV)

Battery Electric Vehicle (BEV)

BEVs are electric vehicles that rely only on batteries to power the drive train. BEVs must rely only on the energy stored in their battery packs, hence their range is directly proportional to their battery capacity. They can typically travel 100–250 kilometres on a single charge [5], although the top-tier models can travel up to 500 kilometres. These ranges are influenced by factors like as driving style, vehicle combinations, road conditions, climate, battery type, and age. When the battery pack is exhausted, charging it takes a long time compared to refuelling a standard ICE car. It can take up to 36 hours to fully recharge the batteries; there are, however, significantly less time-consuming options.

Hybrid Electric Vehicle (HEV)

HEVs are powered by both an internal combustion engine and an electric motor. These two can be combined in a variety of ways, which will be explored later. When the power demand is low, a HEV utilises the electric propulsion system. It has a significant advantage in low-speed environments such as cities; it also reduces fuel consumption because the engine remains completely off during idling periods, such as traffic jams. This feature also cuts down on greenhouse gas emissions. The HEV switches to the ICE when more speed is required. The two drive trains can also collaborate to boost performance. In turbocharged cars like the Acura NSX, hybrid power systems are often used to lessen or eliminate turbo lag.

It also improves performance by filling in the gaps between gear shifts and boosting speed as needed. The ICE can charge the batteries, and HEVs can use regenerative braking to recover energy. As a result, HEVs are largely ICE-powered vehicles that incorporate an electric drivetrain to boost mileage or performance.

A. Plug-In Hybrid Electric Vehicle (PHEV)

The PHEV concept arose in order to extend the range of HEVs that can run entirely on electricity [9–14]. It, like a HEV, has both an ICE and an electrical power train, but the distinction is that the PHEV uses electric propulsion as the primary driving force, necessitating a larger battery capacity than HEVs. PHEVs start in 'all electric' mode, run on electricity, and call on the ICE for a boost or to charge up the battery pack when the batteries are low on charge.

B. Fuel Cell Electric Vehicle (FCEV)

FCEVs are also known as fuel cell vehicles (FCV). Fuel cells, which produce energy through chemical processes, are at the heart of such vehicles, hence the name. Because hydrogen is the preferred fuel for this reaction, hydrogen fuel cell cars are sometimes referred to as "hydrogen fuel cell vehicles." FCVs transport hydrogen in special high-pressure tanks, and oxygen, which it obtains from air taken in from the atmosphere, is another ingredient in the power-generating process. The fuel cells generate electricity, which powers an electric motor that drives the wheels. Excess energy is stored in battery or supercapacitor storage systems [2,3,16–18]. Batteries are used in commercially marketed FCVs such the Toyota Mirai and Honda Clarity. Water is discharged out of the car through the tailpipes as a consequence of the power generation process in FCVs.

III. EV SUBSYSTEMS

The electric motor, power converter, controller, transmission, and driving wheels make up the propulsion subsystem. Auxiliary power supply, temperature control system, and power steering unit make up the auxiliary subsystem. Figure 1 illustrates these subsystems.

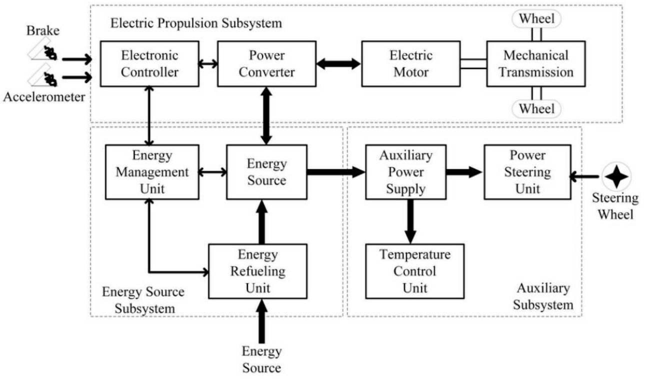


Figure 1: EV subsystems

The arrows show how the things in question flow. Regenerative operations such as regenerative braking can provide a backward flow of power. To store the energy returned by regenerative actions, the energy source must be receptive. The majority of electric vehicle batteries, as well as capacitors and flywheels (CFs), are compatible with energy regeneration processes.

IV. BATTERY THERMAL MANAGEMENT SYSTEMS (BTMS)

To ensure the proper operation of the battery pack, the BTMS should have four fundamental functions:

1. Cooling

Battery cells will not only generate energy but also heat due to inefficiency. When the battery pack temperature reaches the optimum temperature, or even before, this heat should be removed. As a result, BTMS requires a cooling feature.

2. Heating

Battery pack temperature is likely to fall below the lower temperature limit in cold areas. As a result, a heating function, such as a PTC heater, is necessary to help the battery pack in quickly reaching the right temperature range.

3. Insulation

The temperature difference between the inside and outside of the battery pack is substantially bigger in extreme cold or hot weather than it is in mild weather. As a result, the battery temperature will drop (cold) or rise (hot) faster than it should. To avoid this, adequate insulation can reduce the rate at which the battery temperature drops or rises, especially while the car is parked outside.

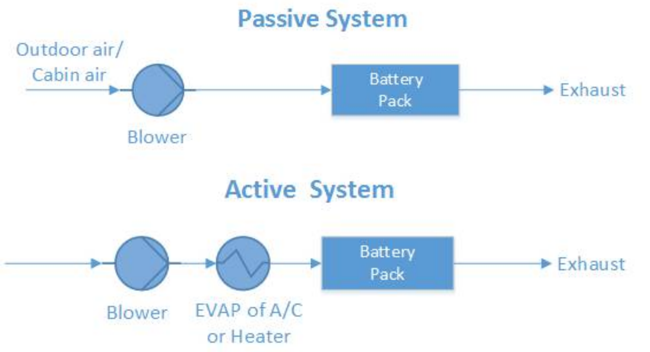
4. Ventilation

To exhaust the harmful gases within the battery pack, ventilation is essential. This function is integrated with cooling and heating functions in some systems, such as air systems. Different heating and cooling systems will be discussed in detail in the following sections, as well as their ability and simplicity of ventilation.

V. TECHNOLOGIES OF BTMS

A. Air Cooling and Heating

The thermal medium in air systems is air. The intake air might come directly from the atmosphere or the cabin, and it could also be conditioned air from an air conditioner's heater or evaporator. The former is referred to as a passive air system, whereas the latter is referred to as an active air system. Active systems might provide extra cooling or heating capacity. A passive system can provide hundreds of watts of cooling or heating power, while an active system is restricted to 1 kW of power.



Figurer 2: Forced air systems (passive and active)

The forced air system with heat recovery is presented below.

B. Liquid Cooling and Heating

There are two types of liquids commonly used in heat management systems. One is dielectric liquid (direct-contact liquid), such as mineral oil, which can directly contact the battery cells. The other is a conducting liquid (indirect-contact liquid), such as a mixture of ethylene glycol and water, that can only contact the battery cells indirectly. Different layouts are made depending on the different liquids. The standard configuration for direct-contact liquid is to submerge modules in mineral oil. A jacket around the battery module, individual tubing around each module, mounting the battery modules on cooling/heating plates, or integrating the battery module with cooling/heating fins and plates are all conceivable layouts for indirect-contact liquid. (Pesaran, 2001) Indirect contact systems are favoured over direct contact systems in order to achieve better isolation between the battery module and the environment, and hence better safety performance.

Liquid systems can be classified as passive or active depending on the type of heat-sink used for cooling. A radiator serves as the heat sink for cooling in a passive liquid system. This mechanism is incapable of producing heat. The schematic diagram of a passive liquid system is shown in Figure 3.3. The pump circulates the heat transfer fluid in a closed system. The circulating fluid collects heat from the battery pack and transfers it to a radiator for release. The cooling power is highly dependent on the temperature difference between the ambient air and the battery. Fans behind the radiator can help with cooling, but if the ambient air temperature is higher than the battery temperature or the difference is too tiny, the passive liquid system will fail.

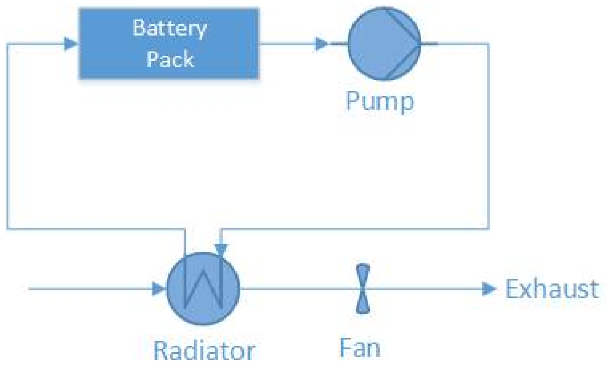


Figure 3: Passive liquid cooling system.

C. Direct Refrigerant Cooling and Heating

A direct refrigerant system (DRS) employs refrigerant directly as a heat transfer fluid circulating through the battery pack, similar to active liquid systems. Figure 4 shows the systematic layout.

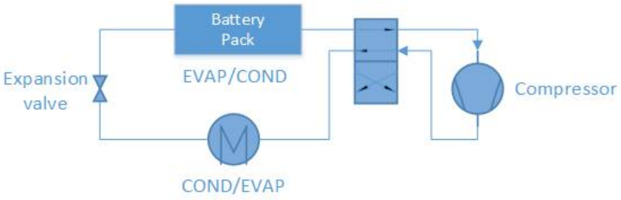


Figure 4. Direct refrigerant cooling system

D. Phase Changing Materials

PCM absorbs heat during melting and stores it as latent heat until the latent heat reaches its maximum. The temperature is held at melting point for a length of time before gradually increasing. As a result, PCM is employed in battery temperature management systems as a conductor and buffer. The functioning mechanism of PCM on battery cells is depicted in Figure 3.6. A PCM is also used in conjunction with an air or liquid cooling system to control battery temperature.

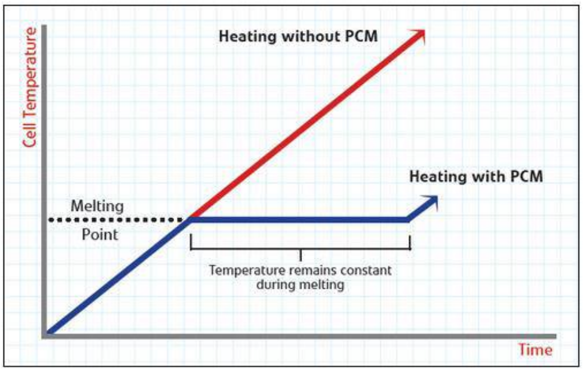


Figure 5: The working mechanism of PCM on battery cells

E. Heat Pipe

A heat pipe, in addition to thermo-electric modules, is another technique to improve passive air systems. Figure 3.8 depicts the structure of a heat pipe. The heat pipe's flat copper envelope was partially vacuumed. Sintered copper powder forms the capillary structure. The operating fluid of the heat pipe is water. Due to the low pressure inside the evaporator, water on the evaporator side absorbs heat and becomes vapour at temperatures below 100°C. The heat is dissipated by the water on the condenser, which then becomes liquid again. This loop keeps repeating itself.

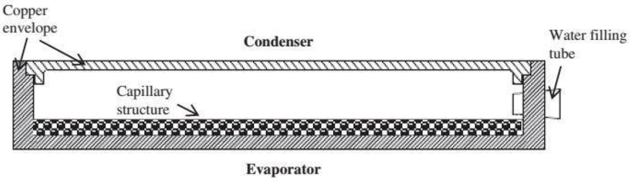


Figure 6: Structure of the heat pipe

A heat pipe cooling system is schematically depicted in the diagram below. A battery serves as a heat source beneath the heat pipe (on the evaporating side). The heat pipe has cooling fins that act as heat sinks (on the condensing side). According to the results of an experiment (Tran, 2014), a heat pipe cooling system can lower thermal resistance by 30% when compared to natural convection without one.

Under low air velocity convection, a 20 percent reduction in heat resistance is attainable. A heat pipe is more reliable than a thermo-electric system because there are no moving parts and no energy consumption. Due to its set structural architecture, a heat pipe, on the other hand, is unable to heat the battery.

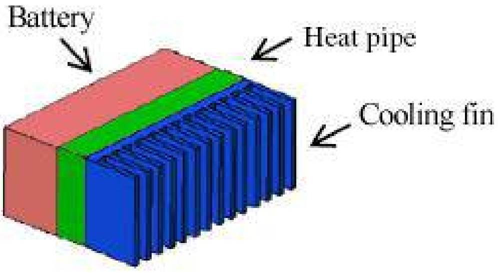


Figure 7: Scheme of heat pipe cooling system.

F. Thermoelectric cooling

Thermoelectric coolers (TEC) are based on the conversion of voltage to the temperature difference. This Peltier – Seebeck effect together with Thompson effect belongs to the thermoelectric effect. The thermoelectric effect refers to all of the transformation processes from heat to electricity, and vice versa. When the current is passed through the thermoelectric device one side becomes cold which absorbs the heat and other side becomes hot which dissipates the heat to the environment. An efficient heat dissipation equipment such as heat sink is needed to dissipate the heat from the hotter side. The stability of the device depends upon how effectively the temperatures of both sides are maintained. The main advantages of thermoelectric coolers are relatively quiet, stable, and reliable. Furthermore, the temperature can be easily controlled by varying the voltage supply.

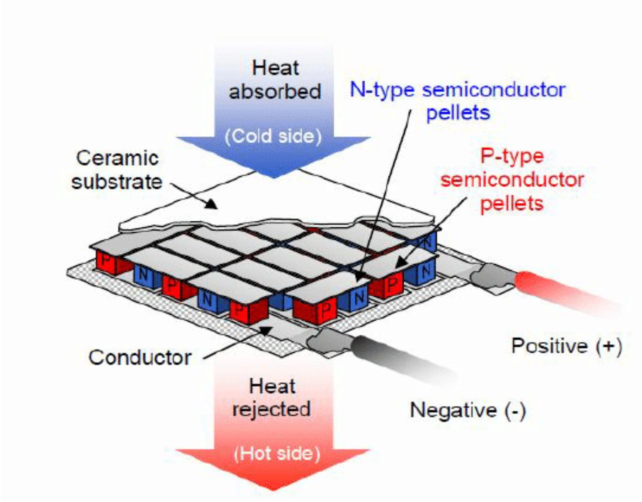


Figure 8: Structure of a thermoelectric cooler

G. PTC Heater

By leveraging their own voltage-current or current-time properties, PTC thermistors can be used in a variety of self-heating applications. One of the applications is as a PTC heater, which is a self-regulating heater. The temperature of a PTC heater can be kept constant by automatically altering the resistance, as shown in Figure 8.

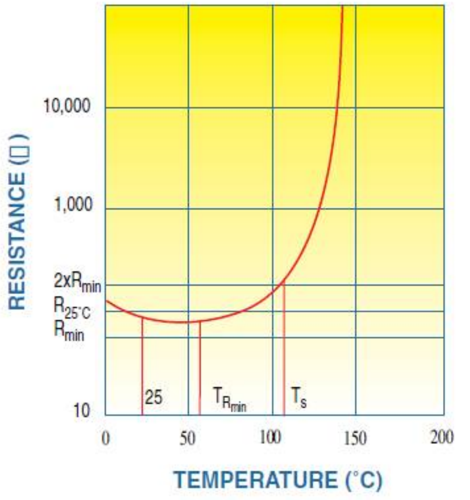


Figure 9: Resistance versus Temperature for a PTC

VI. CONCLUSION

The main issue in the electric vehicles is of the heat that is generated in various components like motor, controller and the batteries. Hence the need of an efficient thermal management system is at the top priority. This paper completely explains the details of EV types, EV Subsystem, Battery Thermal Management Systems (BTMS) and the technologies of BTMS.

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