

A Review of Thermal Management Technologies for New Energy Vehicles

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Abstract. As new energy vehicles develop toward higher energy density, higher power output, ultra-fast charging, and operation over a wide temperature range, thermal management has become a critical factor affecting vehicle safety, service life, driving range, and overall vehicle efficiency. This paper systematically reviews thermal management technologies for traction batteries, motors, power electronic devices, cabins, and integrated vehicle systems. It first analyzes the major heat sources in new energy vehicles and their temperature effects; it then compares the heat-transfer characteristics, performance boundaries, and engineering applicability of air cooling, indirect liquid cooling, direct liquid cooling, phase change materials, heat pipes, and hybrid thermal management technologies; finally, it discusses motor and power electronics cooling, heat-pump air conditioning, waste-heat recovery, and multi-loop coupling. The comprehensive analysis indicates that indirect liquid cooling remains the mainstream approach for traction battery thermal management at present; direct liquid cooling and hybrid thermal management have considerable potential under high-rate and ultra-fast-charging conditions; and the focus of vehicle thermal management is shifting from local temperature control to multi-heat-source coordination and energy optimization. Future research should focus on breakthroughs in high-heat-flux fast charging, efficient low-temperature heating, suppression of thermal-runaway propagation, long-term reliability of advanced materials, and predictive control integrating models and data, while establishing a comprehensive evaluation system that considers safety, energy consumption, cost, and life-cycle impacts.

Keywords: new energy vehicles, traction batteries, thermal management, liquid cooling, phase change materials

1. Introduction

With the ongoing transformation of the global energy structure and the continued advancement of the "dual-carbon" goals, the demand for low-carbon development in the transportation sector is increasing, and new energy vehicles have become an important direction in the green transformation of the automotive industry. In recent years, advances in traction battery technology, improvements in charging infrastructure, and enhanced vehicle performance have driven new energy vehicles into a stage of large-scale development, and China has also become an important part of the global new energy vehicle industry [1, 2]. Meanwhile, new energy vehicles are developing toward longer

driving ranges, higher power output, and faster charging, while the energy density and charge-discharge rates of traction batteries continue to increase [3]. The resulting heat accumulation, temperature nonuniformity, and thermal safety issues have become key challenges for new energy vehicles [4].

Traction batteries exhibit pronounced temperature sensitivity. High temperatures intensify internal side reactions and capacity degradation and may induce thermal runaway in severe cases; low temperatures increase battery internal resistance and reduce charge-discharge capability and output performance [5, 6]. Temperature differences within a battery pack also cause inconsistent aging among cells, affecting system life and reliability. Therefore, traction battery thermal management must maintain an appropriate temperature and control temperature differences under different environments and operating conditions [7]. In addition to traction batteries, drive motors, power electronic devices, and cabin air-conditioning systems also require thermal management [8]. As vehicle power density and integration continue to increase, conventional independent thermal management is gradually evolving toward integrated thermal management in which the traction battery, motor, electronic control system, and air-conditioning system operate collaboratively, thereby improving overall vehicle energy-use efficiency [9, 10].

Accordingly, this paper reviews traction battery and vehicle thermal management technologies for new energy vehicles, analyzes the major heat sources and temperature effects of traction batteries, motors, and power electronic devices, compares the performance characteristics and applicable scenarios of air cooling, liquid cooling, phase change materials, heat pipes, and hybrid thermal management technologies, and discusses the development trends of heat-pump air conditioning, waste-heat recovery, and integrated vehicle thermal management. The analysis framework is based on thermal-load characteristics, heat-transfer paths, system penalties, and engineering applicability, with particular attention to the overall trade-offs among temperature-control performance, auxiliary energy consumption, structural complexity, reliability, and cost.

2. Fundamentals of thermal management for new energy vehicles

2.1. Major heat sources and temperature effects

The heat generated during the operation of new energy vehicles mainly originates from traction batteries, motors, and power electronic devices. Lithium-ion batteries generate irreversible heat, reversible entropic heat, and abnormal reaction heat during charging and discharging. Irreversible heat is mainly caused by internal resistance and electrochemical polarization, while entropic heat is related to the entropy change of the battery reaction. Under abnormal conditions such as overcharging, short circuits, or mechanical damage, internal side reactions may continuously release heat and further induce thermal runaway.

The heat generated by drive motors mainly originates from copper losses caused by winding resistance, hysteresis and eddy-current losses in the iron core, and mechanical losses such as bearing friction and rotor windage. Power electronic devices mainly generate conduction and switching losses, and excessive junction temperatures reduce device reliability and service life [11].

Temperature has a significant effect on traction battery performance. High temperatures accelerate internal side reactions and material aging and may trigger thermal runaway in severe cases; low temperatures reduce ion diffusion and charge-transfer rates, resulting in increased internal resistance and decreased capacity and power. Temperature differences within a battery pack also cause inconsistent aging among cells, reducing overall service life and reliability [5, 6].

2.2. Thermal management objectives and basic methods

The main objectives of thermal management for new energy vehicles are to control the maximum temperature of key components, reduce temperature differences within the system, and account for safety, reliability, and auxiliary energy consumption. The basic heat-transfer processes include heat conduction, convective heat transfer, and phase-change thermal storage. Heat conduction transfers heat from inside a cell or device to an external cooling structure; convective heat transfer removes heat through the flow of air, coolant, or refrigerant; and phase-change thermal storage uses the latent heat of a material to absorb transient heat and provide temperature buffering [12]. According to their operating mechanisms, thermal management methods can be classified as active, passive, and hybrid, and the specific technologies are discussed below.

Overall, thermal management for new energy vehicles does not simply pursue the lowest possible temperature; rather, it seeks a balance among an appropriate temperature range, temperature uniformity, auxiliary energy consumption, and system reliability. Because the thermal loads and allowable temperature ranges of different components vary, targeted thermal management technologies are required.

3. Research progress in traction battery thermal management technologies

Based on the thermal management mechanisms described above, current traction battery thermal management mainly includes air cooling, liquid cooling, phase change materials, and hybrid thermal management. These technologies differ substantially in heat-dissipation capability, system energy consumption, structural complexity, and engineering maturity.

3.1. Air-cooling technology

Air cooling was among the earliest thermal management methods adopted for traction batteries in new energy vehicles. It removes heat from the battery surface through airflow and offers the advantages of a simple structure, low cost, convenient maintenance, and no risk of liquid leakage [13]. The system generally consists of fans, air ducts, and battery modules, and its heat-dissipation performance is mainly affected by cell arrangement, air-duct structure, and flow distribution.

Because air has a relatively low specific heat capacity and thermal conductivity, greater airflow is required to meet heat-dissipation demands as battery energy density, charge-discharge rate, and fast-charging power increase. This leads to increased fan energy consumption, noise, and space requirements. In addition, the air temperature gradually rises along the flow direction, which can easily cause nonuniform temperature distribution within the battery pack [13, 14]. Therefore, air cooling is more suitable for low-thermal-load, small-capacity, and cost-sensitive vehicles, and its applicability in high-performance traction battery systems is relatively limited.

3.2. Liquid-cooling technology

Liquid cooling takes advantage of the higher specific heat capacity and heat-transfer capability of coolants to remove more heat at a lower flow rate, providing better control of the maximum battery temperature and the temperature difference within a module. It has therefore become the mainstream solution for traction battery thermal management in current new energy vehicles [7, 15].

3.2.1. Indirect liquid cooling

Indirect liquid cooling circulates coolant through cold plates, pipes, or jackets without allowing the cooling medium to directly contact the cells. Battery heat is transferred successively through the casing, thermal interface material, and cooling structure to the coolant and is then discharged through a radiator. This mature approach can improve heat-dissipation performance by optimizing channel structures, coolant flow direction, and flow distribution. It offers substantial advantages in safety, reliability, and engineering application and is therefore widely used [7, 15].

Its limitations are that cold plates and interface materials introduce additional thermal resistance, while pumps, valves, and piping increase system mass, cost, and auxiliary energy consumption and present a certain risk of leakage. Therefore, liquid-cooling system design must comprehensively consider heat-dissipation capability, temperature uniformity, pressure loss, and operating energy consumption.

3.2.2. Direct liquid cooling

Direct liquid cooling uses an electrically insulating cooling medium in direct contact with the battery surface, effectively reducing heat-transfer resistance and improving heat-transfer efficiency. Immersion cooling can be divided into single-phase and two-phase cooling. Two-phase systems use the latent heat of vaporization of the working fluid to absorb large amounts of heat and have considerable application potential under high-rate discharge and ultra-fast-charging conditions [7].

However, direct liquid cooling still faces problems such as the high cost of cooling media, stringent material-compatibility requirements, and insufficient validation of sealing reliability and long-term durability. It is currently still at the stage of ongoing research and engineering validation.

3.3. Phase change materials and hybrid thermal management technologies

Phase change materials (PCMs) absorb latent heat during solid-liquid phase transitions, effectively suppressing transient temperature rises caused by fast charging and high-rate discharge and improving temperature uniformity within the battery pack [16]. However, PCMs have low thermal conductivity and are prone to local overheating when the system remains under a high thermal load. Their thermal-buffering capacity also decreases significantly after the material has completely melted [16, 17].

To improve heat-transfer efficiency, researchers commonly add thermally conductive materials such as graphite, graphene, and metal foam to form composite PCMs. Heat pipes can also be combined with PCMs to rapidly spread localized heat and thereby improve temperature uniformity. However, thermally conductive enhancement materials increase system mass and cost, requiring a comprehensive trade-off among thermal conductivity, heat-storage capacity, and lightweight design.

Because no single method can simultaneously satisfy high heat dissipation, low energy consumption, and high reliability, hybrid thermal management has become an important development direction [5, 17]. Combining liquid cooling with PCMs provides both continuous heat dissipation and transient thermal buffering, while combining heat pipes with PCMs improves the spreading of localized hot spots. Future hybrid thermal management will integrate information such as temperature, current, state of charge, and ambient conditions and use intelligent control to optimize cooling, heating, and energy consumption.

In summary, different thermal management technologies vary substantially in heat-dissipation capability, system complexity, cost, and applicable scenarios. Table 1 summarizes the main

characteristics of various traction battery thermal management technologies for comparison.

Table 1. Comparison of traction battery thermal management technologies

Technical Approach	Main Advantages	Main Limitations	Application and Development Positioning
Air Cooling	Low cost, simple structure, and convenient maintenance	Limited heat-transfer capability and relatively poor temperature uniformity	Low-thermal-load and small-capacity systems
Indirect Liquid Cooling	Mature technology, strong heat-dissipation capability, and stable temperature control	Complex system, with pump energy consumption and leakage risk	Current mainstream traction battery solution
Direct Liquid Cooling	Low thermal resistance, high heat-transfer efficiency, and rapid response	Relatively high cost; reliability still requires validation	High-power and ultra-fast-charging applications
PCMs and Hybrid Thermal Management	Buffers peak temperature rise and improves temperature uniformity	Relatively high cost and control complexity	Development direction for high-performance traction batteries

Overall, traction battery thermal management has gradually shifted from a single cooling method to the coordinated use of multiple technologies. Future solutions should be selected through a comprehensive trade-off based on battery thermal load, vehicle positioning, operating environment, and cost targets, rather than solely on a single heat-dissipation performance indicator.

4. Thermal management technologies for motors and electronic control systems

4.1. Thermal management of motors and power electronics

Drive motors in new energy vehicles generate substantial thermal loads under high-torque and high-speed operating conditions. Their heat mainly originates from copper losses caused by winding resistance; iron losses caused by core hysteresis and eddy currents; and mechanical losses such as bearing friction and rotor windage [18, 19]. Excessive temperatures reduce motor efficiency and accelerate the aging of insulation materials; therefore, motor thermal management must be designed according to the loss characteristics under different operating conditions.

Air cooling has a simple structure and relatively low cost, but its heat-transfer capability is limited, making it mainly suitable for low-power motors. Water-jacket liquid cooling circulates coolant through channels outside the stator and is a commonly used cooling method because of its technical maturity, stable heat dissipation, and strong engineering applicability [20]. However, its ability to cool internal motor heat sources is limited. Oil cooling allows an insulating coolant to approach the heat-generating regions more closely, shortening the heat-transfer path and improving the heat-dissipation capability of high-power-density motors [21, 22]. For electric drive systems operating continuously under high loads, water cooling and oil cooling can be combined to form a composite cooling structure.

The heat generated by power electronic devices mainly comes from conduction and switching losses. As system voltage, power density, and switching frequency increase, control of device junction temperature becomes an important factor affecting reliability and service life [23, 24]. At present, electronic control systems mainly use cold-plate liquid cooling to reduce junction temperature by shortening the heat-transfer path from the chip to the cooling medium; double-sided cooling can further improve the heat-dissipation capability of high-power modules [25]. Although

SiC devices offer high efficiency and high-temperature tolerance, operation at high power density still imposes more stringent requirements on cooling structures, packaging materials, and interfacial thermal resistance.

4.2. Trends in integrated thermal management of electric drive systems

As new energy vehicles develop toward higher power and greater integration, thermal management of motors and electronic control systems is gradually shifting from independent cooling to collaborative design. Sharing cooling loops, heat exchangers, and control components can reduce the number of pipes and auxiliary devices and improve system compactness. Waste heat generated by motors and power electronic devices can also be used through heat pumps or heat-exchange loops for traction battery preheating and cabin heating, thereby reducing additional energy consumption in low-temperature environments [10, 26].

Future electric drive thermal management will place greater emphasis on the coordinated optimization of cooling structures, heat-source characteristics, and control strategies. Coolant flow and loop states will be dynamically adjusted according to motor load, device junction temperature, and ambient conditions, reducing auxiliary energy consumption while ensuring reliability and enabling lightweight, integrated, and efficient development.

5. Integration of vehicle thermal management systems for new energy vehicles

As the performance of traction batteries, motors, and power electronic systems in new energy vehicles continues to improve, vehicle thermal management has shifted from temperature control of individual components to coordinated management of heat throughout the vehicle. Unlike conventional internal-combustion-engine vehicles, which can use engine waste heat, new energy vehicles must simultaneously meet the requirements of traction battery temperature control, electric drive system heat dissipation, and cabin thermal comfort. In winter, in particular, the lack of a stable waste-heat source means that heating energy consumption can significantly affect driving range. Therefore, the core of vehicle thermal management is to coordinate different heat and cold sources and improve energy-use efficiency [27, 28].

5.1. Heat-pump air-conditioning technology

Early new energy vehicles commonly used PTC electric heating for cabin heating. Although the structure is simple, it directly consumes energy from the traction battery and significantly reduces driving range in low-temperature environments. Heat-pump systems absorb low-grade heat from the environment or inside the vehicle through a refrigerant cycle and transfer it to the cabin, generally providing higher heating efficiency than PTC systems [29].

Current heat pumps for new energy vehicles mainly include air-source heat pumps, CO₂ heat pumps, and multi-source hybrid heat pumps. CO₂ heat pumps offer good environmental performance and potential adaptability to low temperatures. However, heat-pump systems still face reduced heating capacity under extremely low-temperature conditions, complex loop structures, and high control difficulty. Therefore, their development should focus on improving low-temperature performance and strengthening coordination with the thermal loops of the battery and electric drive system [30].

5.2. Integrated vehicle thermal management

Integrated thermal management uses unified cooling loops, heat exchangers, and control strategies to enable heat exchange among the traction battery, motor, electronic control system, and cabin [10, 27, 28]. In winter, waste heat from motors and power electronic devices can assist traction battery preheating or cabin heating. Under high-temperature conditions, the air-conditioning refrigeration loop can be used to enhance battery cooling, thereby reducing the energy consumption of independent heating or cooling equipment.

Future vehicle thermal management will further shift from fixed-loop control to dynamic regulation based on vehicle state. The system can integrate component temperature, ambient temperature, driving conditions, and state of charge to coordinate the operation of compressors, pumps, valves and heat-exchange loops, thereby reducing auxiliary energy consumption while meeting safety and comfort requirements. Consequently, the development objective of thermal management for new energy vehicles has shifted from "component temperature control" to comprehensive vehicle optimization for driving range, safety, and energy efficiency [31].

6. Conclusion

Thermal management for new energy vehicles has evolved from a component heat-dissipation issue into a vehicle-level systems engineering problem involving safety, performance, driving range, and energy allocation. For traction batteries, air cooling retains the advantages of low cost and simple structure and remains applicable to low-thermal-load and cost-sensitive scenarios, but it has difficulty meeting high-heat-flux operating conditions. Indirect liquid cooling provides a good balance among heat-dissipation capability, engineering maturity, and maintainability and remains the current mainstream solution. Direct liquid cooling, composite phase change materials, and hybrid thermal management show considerable potential in high-rate and ultra-fast-charging applications, but issues such as medium compatibility, long-term durability, system mass, and control complexity still need to be resolved.

The core of thermal management for motors and power electronic devices is to shorten the heat-transfer path from key heat sources to the cooling medium and to control the temperatures of windings, permanent magnets, and semiconductor device junctions under high-power-density conditions. Water-jacket liquid cooling is mature, while oil cooling, double-sided cooling, and high-thermal-conductivity packaging can further increase the limiting heat-dissipation capability. At the vehicle level, heat pumps, waste-heat recovery, and multi-loop coupling shift thermal management objectives from local temperature control to energy coordination, but system benefits still depend on loop architecture, control strategies, and environmental operating conditions.

Ultra-fast charging and high-power operation substantially increase the heat flux of traction batteries, and conventional air cooling and liquid cooling may be unable to suppress temperature rise promptly under extreme conditions. Future work should further optimize cold-plate channels, cooling media, and heat-transfer interfaces and jointly control charging power, battery state, and cooling capability to reduce temperature rise and aging risk while shortening charging time [32, 33].

Thermal management control will evolve from temperature feedback to thermal-state prediction. By integrating ambient temperature, vehicle operating conditions, battery state of charge, and state of health, the system can use model predictive control, machine learning, and digital-twin technologies to estimate future thermal loads and proactively adjust pumps, valves, compressors, and cooling power, thereby enabling fault warning and energy-consumption optimization [34, 35].

However, engineering applications remain constrained by model accuracy, computational load, sensor reliability, and algorithm interpretability.

In terms of materials, high-thermal-conductivity composite phase change materials, lightweight cold plates, fire-resistant thermal-insulation materials, and highly stable packaging materials have considerable application potential. Thermal-conduction networks constructed from expanded graphite, carbon materials, or metal foam can improve the thermal response rate of phase change materials [36]. Future material design should not pursue high thermal conductivity alone but should also comprehensively consider latent heat, mass, cost, flame retardancy, cycling stability, and recyclability.

In addition, evaluation of thermal management systems should be expanded from a single maximum-temperature indicator to include temperature difference, energy consumption, mass, cost, the environmental impact of refrigerants, and long-term reliability. Research should also strengthen experimental validation under extreme operating conditions such as fast charging, low temperatures, and thermal-runaway propagation, and establish multiscale thermal models and unified evaluation methods covering cells, battery packs, and complete vehicles.

Overall, thermal management for new energy vehicles will develop toward greater efficiency, integration, intelligence, and lower carbon emissions. The optimal thermal management solution does not pursue the extreme of any single performance indicator; instead, it achieves comprehensive optimization among safety, energy consumption, cost, mass, and life-cycle reliability according to vehicle positioning, regional climate, and actual operating conditions.

References

- [1] International Energy Agency. (2024). Global EV outlook 2024: Moving towards increased affordability. *International Energy Agency*. Paris, France.
- [2] China Association of Automobile Manufacturers. (2024). New energy vehicle production and sales data and industry development report. *China Association of Automobile Manufacturers*. Beijing.
- [3] Nitta, N., Wu, F., Lee, J. T., & Yushin, G. (2015). Lithium-ion battery materials: Present and future. *Materials Today*, 18(5), 252–264.
- [4] Wang, Y., Zhang, J., Zhang, G., et al. (2020). A comprehensive review of future thermal management systems for battery-electrified vehicles. *Renewable and Sustainable Energy Reviews*, 134, 110297.
- [5] Feng, X., Ouyang, M., Liu, X., et al. (2018). Thermal runaway mechanism of lithiumion battery for electric vehicles: A review. *Energy Storage Materials*, 10, 246–267.
- [6] Jaguemont, J., Boulon, L., & Dubé, Y. (2016). A comprehensive review of lithium-ion batteries used in hybrid and electric vehicles at cold temperatures. *Applied Energy*, 164, 99–114.
- [7] Zhao, C., Zhang, B., Zheng, Y., et al. (2020). Hybrid battery thermal management system in electrical vehicles: A review. *Energies*, 13(23), Article 6257.
- [8] Kalaf, O., Solyali, D., Asmael, M., et al. (2021). Experimental and simulation study of liquid coolant battery thermal management system for electric vehicles: A review. *International Journal of Energy Research*, 45, 13555–13587.
- [9] Wazeer, A., Das, A., Abeykoon, C., et al. (2022). Phase change materials for battery thermal management of electric and hybrid vehicles: A review. *Energy Nexus*, 7, Article 100131.
- [10] Lei, S., Xin, S., Liu, S., et al. (2022). Separate and integrated thermal management solutions for electric vehicles: A review. *Journal of Power Sources*, 550, Article 232133.
- [11] Pesaran, A. A. (2002). Battery thermal management in EVs and HEVs: Issues and solutions. National Renewable Energy Laboratory. USA.
- [12] Incropera, F. P., DeWitt, D. P., Bergman, T. L., & Lavine, A. S. (2017). *Fundamentals of heat and mass transfer* (8th ed.). Wiley. Hoboken, NJ, USA.
- [13] Kim, J., Oh, J., & Lee, H. (2019). Review on battery thermal management system for electric vehicles. *Applied Thermal Engineering*, 149, 192–212.

- [14] Akinlabi, A. A. H., & Solyali, D. (2020). Configuration, design, and optimization of air-cooled battery thermal management system for electric vehicles: A review. *Renewable and Sustainable Energy Reviews*, 125, 109815.
- [15] 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.
- [16] Chen, J., Kang, S., E, J., et al. (2019). Effects of different phase change material thermal management strategies on the cooling performance of power lithium-ion batteries: A review. *Journal of Power Sources*, 442, 227228.
- [17] Patel, J. R., & Rathod, M. K. (2020). Recent developments in the passive and hybrid thermal management techniques of lithium-ion batteries. *Journal of Power Sources*, 480, 228820.
- [18] Boglietti, A., Cavagnino, A., & Staton, D. A. (2009). Evolution and modern approaches for thermal analysis of electrical machines. *IEEE Transactions on Industrial Electronics*, 56(10), 4041–4052.
- [19] Boglietti, A., Cavagnino, A., Lazzari, M., & Pastorelli, M. (2003). Predicting iron losses in soft magnetic materials with arbitrary voltage supply: An engineering approach. *IEEE Transactions on Magnetics*, 39(2), 981–989.
- [20] Staton, D. A., Boglietti, A., & Cavagnino, A. (2005). Solving the more difficult aspects of electric motor thermal analysis in small and medium size industrial induction motors. *IEEE Transactions on Energy Conversion*, 20(3), 620–628.
- [21] Cavagnino, A., Lazzari, M., Profumo, F., & Tenconi, A. (2005). A thermal model for the analysis of permanent-magnet motors for electric vehicles. *IEEE Transactions on Industry Applications*, 41(3), 645–652.
- [22] Huang, Z., Nategh, S., Lassila, V., et al. (2019). Thermal management of high-power density electric machines: A review. *IEEE Transactions on Transportation Electrification*, 5(4), 1146–1162.
- [23] Kolar, J. W., Drofenik, U., & Bortis, D. (2010). Thermal management of power electronics systems. *IEEE Transactions on Components, Packaging and Manufacturing Technology*.
- [24] Wang, H., Ma, K., & Blaabjerg, F. (2013). Design for reliability of power electronic systems. *IEEE Industry Applications Magazine*, 19(5), 22–30.
- [25] Tulkoff, C., & Bar-Cohen, A. (2018). Thermal management of power electronics for electric vehicle applications. *IEEE Transactions on Components, Packaging and Manufacturing Technology*.
- [26] Xu, B., Chen, M., Wang, H., et al. (2021). Integrated thermal management system for electric vehicles: A review. *Energy Conversion and Management*.
- [27] Previati, G., Mastinu, G., & Gobbi, M. (2022). Thermal management of electrified vehicles—A review. *Energies*, 15(4), Article 1326.
- [28] Yu, B., Yang, Y., Zhang, X., et al. (2022). Review of thermal management technologies for electric vehicles. *Renewable and Sustainable Energy Reviews*.
- [29] Zhang, Z., Wang, J., & Zhang, X. (2023). Review of heat pump integrated energy systems for future zero-emission vehicles. *Energy*.
- [30] Zeng, X., Huang, Y., Song, D., & Gao, F. (2022). Design and research on the thermal management integrated control system of BEV based on heat pump air conditioner. *SAE International Journal of Passenger Vehicle Systems*, 15(2), 91–104.
- [31] Lee, S., Chung, Y., Kim, S., et al. (2022). Investigation on the performance enhancement of electric vehicle thermal management system utilizing floating loop with finite heat exchanger size. *Energy Conversion and Management*, 255, Art. no. 115265.
- [32] Zeng, Y., Chalise, D., Lubner, S. D., Kaur, S., & Prasher, R. S. (2021). A review of thermal physics and management inside lithium-ion batteries for high energy density and fast charging. *Energy Storage Materials*, 41, 264–288.
- [33] Lu, Z., Tu, H., Fang, H., Wang, Y., & Mou, S. (2024). Integrated optimal fast charging and active thermal management of lithium-ion batteries in extreme ambient temperatures. *IEEE Transactions on Control Systems Technology*. doi: 10.1109/TCST.2024.3498812.
- [34] Zhang, Y., Zhang, X., Chen, Z., et al. (2024). Advancements in battery thermal management for electric vehicles: Types, technologies, and control strategies including deep learning methods. *Ain Shams Engineering Journal*, 15, Art. no. 102908.
- [35] Liu, Z., Jiang, Y., Li, Y., & Wang, P. (2024). Physics-informed machine learning for battery pack thermal management. *arXiv preprint arXiv: 2411.09915*.
- [36] Liu, L., Zhang, X., & Lin, X. (2022). Recent developments of thermal management strategies for lithium-ion batteries: A state-of-the-art review. *Energy Technology*, 10, Art. no. 2101135.