THERMAL MANAGEMENT SYSTEM AND METHOD, COMPUTER DEVICE, VEHICLE, AND STORAGE MEDIUM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Chinese Patent Application No. 202411477457.1, filed with the China National Intellectual Property Administration on October 22, 2024 and entitled "THERMAL MANAGEMENT SYSTEM AND METHOD, COMPUTER DEVICE, VEHICLE, AND STORAGE MEDIUM", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present application relates to the field of new energy technologies, and specifically to a thermal management system and method, a computer device, a vehicle, and a storage medium.

BACKGROUND ART

[0003] With the development and growing popularity of new energy vehicles, an increasing number of users have gradually recognized new energy vehicles. When making a replacement purchase or buying a new car, an increasing number of users opt for new energy vehicles. However, power batteries tend to perform poorly in low-temperature environments, leading to a significant drop in the range of the vehicle, which greatly affects the driving mileage of the vehicle. In addition, public charging infrastructure is still not widely available. For first-time car buyers and users replacing their only family car, pure electric vehicles are often ruled out due to concerns over long-distance travel during holidays. In such cases, hybrid models become a preferable alternative.

[0004] As battery costs decline, the all-electric range of hybrid models is continuously increasing, supporting a driving solution in which only the electric motor is operating, i.e., in pure electric mode. However, when vehicles are in low-temperature vehicle driving scenarios, existing thermal management system architectures are primarily designed for the normal operation of the powertrain. Heating for the passenger compartment or battery relies on engine waste heat or a water heater. In pure electric mode, engine waste heat is unavailable, and heating with the water heater leads to high overall energy consumption of the vehicle.

SUMMARY

[0005] In view of this, the present application provides a thermal management system and method, a computer device, a vehicle, and a storage medium, to solve the issue that in year-round high-

temperature vehicle usage scenarios, heat pump systems increase system costs and resource waste, resulting in design redundancy.

[0006] According to a first aspect, the present application provides a thermal management system. The thermal management system includes at least a heating circuit, a refrigerant circuit, a battery circuit, a first three-way valve, and a water-cooled condenser, and the refrigerant circuit includes an electric compressor, where the heating circuit is coupled to the refrigerant circuit via the water-cooled condenser, and the water-cooled condenser is configured to transfer heat of a high-temperature refrigerant discharged from the electric compressor in the refrigerant circuit to the heating circuit; and the first three-way valve has a first port connected to the heating circuit, a second port connected to a heater unit in a passenger compartment, and a third port connected to the battery circuit, and is configured to adjust a connection relationship among the heating circuit, the heater unit, and the battery circuit.

[0007] For the thermal management system provided in the present application, the designed water-cooled condenser connects the refrigerant circuit to the heating circuit, so that heat of the high-temperature refrigerant discharged from the electric compressor in the refrigerant circuit is transferred to the heating circuit. In addition, the designed first three-way valve enables the heating circuit to use heat-exchanged coolant to selectively heat the passenger compartment and the battery, so that in pure electric mode, a vehicle can use the refrigerant circuit, rather than an engine and a water heater, to heat the passenger compartment and the battery, thereby saving energy consumption.

[0008] In an optional implementation, the thermal management system further includes an electric drive cooling circuit, a waste heat recovery unit, and a second three-way valve, and the electric drive cooling circuit includes at least a low-temperature radiator, a motor controller, a rear electric drive, and a water-cooled intercooler, where the second three-way valve has a fourth port coupled to the refrigerant circuit via the waste heat recovery unit, a fifth port disposed on a pipeline through which coolant flows after absorbing waste heat from the motor controller, the rear electric drive, and the water-cooled intercooler, and a sixth port disposed at an inlet of the low-temperature radiator in the electric drive cooling circuit, and is configured to adjust a flow direction of coolant carrying electric drive waste heat, and the waste heat recovery unit is configured to utilize recovered electric drive waste heat to increase a temperature of a refrigerant.

[0009] The second three-way valve in the present application regulates the flow direction of the coolant carrying the electric drive waste heat, so that the electric drive waste heat enters the waste heat recovery unit, enabling the refrigerant after heat exchange, throttling, and pressure reduction to absorb the electric drive waste heat to raise the temperature of the refrigerant, and then the refrigerant with

the raised temperature returns to the electric compressor, thereby reducing the work done by the electric compressor and reducing the energy consumption of the thermal management system.

[0010] In an optional implementation, the thermal management system further includes a first refrigerant shut-off valve and a second refrigerant shut-off valve, and the refrigerant circuit further includes a condenser and an electronic expansion valve, where the first refrigerant shut-off valve is disposed on a pipeline interconnecting the electric compressor and the waste heat recovery unit, and is configured to control the refrigerant discharged from the electric compressor to flow through the electronic expansion valve and the condenser before entering a passenger compartment evaporator or the battery circuit; and the second refrigerant shut-off valve is disposed on a pipeline interconnecting the electric compressor and the water-cooled condenser, and is configured to control the high-temperature refrigerant discharged from the electric compressor to enter the water-cooled condenser.

[0011] The present application achieves cooling or heating of the passenger compartment and/or the battery through the refrigerant circuit by setting the communication states of the first refrigerant shut-off valve and the second refrigerant shut-off valve, respectively.

[0012] In an optional implementation, the battery circuit includes at least a battery cooler and a battery, where the first port of the first three-way valve is connected to an outlet of the water-cooled condenser, the second port thereof is connected to the heater unit in the passenger compartment, and the third port thereof is connected to the battery cooler in the battery circuit; and the battery cooler is connected to the battery, and is configured to receive coolant flowing out of the battery, perform heat exchange, and return the heat-exchanged coolant to the battery.

[0013] The present application designs the first three-way valve to enable the heating circuit to heat the passenger compartment and/or the battery.

[0014] In an optional implementation, the thermal management system further includes an engine circuit and a four-way valve, where the four-way valve has a seventh port and an eighth port connected to the engine circuit and a ninth port and a tenth port connected to the heating circuit, and is configured to adjust a connection relationship between the engine circuit and the heating circuit.

[0015] In an optional implementation, the engine circuit includes at least an engine and an electronic main water pump, where the seventh port of the four-way valve is connected to an inlet of the engine, the eighth port thereof is coupled to an outlet of the engine via the electronic main water pump, the ninth port thereof is connected to the heater unit in the passenger compartment, and the tenth port thereof is connected to an inlet of the water-cooled condenser.

[0016] The four-way valve of the present application can support direct heating of the passenger compartment and the battery using waste heat in an engine operating state, and can also support heating

of the passenger compartment and the battery the refrigerant circuit in pure electric mode, thereby improving the energy utilization efficiency and capacity of the entire system, avoiding energy waste, and comprehensively improving energy utilization by more than 5%.

[0017] In an optional implementation, the thermal management system further includes a first refrigerant expansion valve and a second refrigerant expansion valve, and the battery circuit includes at least a battery cooler and a battery, where the first refrigerant expansion valve is disposed on a pipeline interconnecting the condenser and the passenger compartment evaporator, and is configured to control the refrigerant discharged from the condenser to enter the passenger compartment evaporator; and the second refrigerant expansion valve is disposed on a pipeline interconnecting the battery cooler and the condenser, and is configured to control the refrigerant discharged from the condenser to enter the battery cooler, and the battery cooler is connected to the battery, and is configured to receive coolant flowing out of the battery, perform heat exchange, and return the heat-exchanged coolant to the battery.

[0018] The present application achieves cooling of the passenger compartment and/or the battery through the refrigerant circuit by arranging the first refrigerant expansion valve and the second refrigerant expansion valve and based on the respective communication states of the two refrigerant expansion valves, thereby rendering the application scenarios of the thermal management system more comprehensive.

[0019] In an optional implementation, the first three-way valve is a three-way proportional valve.

[0020] The three-way proportional valve designed in the present application can set a corresponding outflow ratio based on the requirements of the thermal management system during simultaneous heating of the passenger compartment and the battery, thereby improving the flexibility of system heating.

[0021] According to a second aspect, the present application provides a thermal management method, applied by the thermal management system according to the first aspect or any one of the corresponding implementations thereof. The method includes: obtaining a current driving mode of a vehicle, an operating status of a battery, and a temperature of a passenger compartment; determining a battery temperature requirement based on the operating status of the battery, and determining a current thermal management requirement based on the current driving mode of the vehicle, a relationship between a current battery temperature and the battery temperature requirement, and a relationship between the temperature of the passenger compartment and a temperature requirement of a user for the passenger compartment; and controlling port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement to change an operating state of the thermal management system, to meet the current thermal

management requirement.

[0022] In the thermal management method provided in the present application, the battery temperature requirement is determined based on the current driving mode of the vehicle and the operating status of the battery, the current thermal management requirement is determined based on the relationship between the current battery temperature and the battery temperature requirement, and the relationship between the current temperature of the passenger compartment and the temperature requirement of the user for the passenger compartment, and then the ports of the first three-way valve, the second three-way valve, and the four-way valve are controlled to be mutually connected based on the determined thermal management requirement, thereby meeting the current thermal management requirement.

[0023] In an optional implementation, the step of determining a battery temperature requirement based on the operating status of the battery, and determining a current thermal management requirement based on the current driving mode of the vehicle, a relationship between a current battery temperature and the battery temperature requirement, and a relationship between the temperature of the passenger compartment and a temperature requirement of a user for the passenger compartment includes: if the current battery temperature is within a battery temperature requirement range but a current temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a first thermal management requirement of cooling the passenger compartment by a refrigerant circuit, or if a current operating status of the battery is a charging state, or the current battery temperature is above the battery temperature requirement range, and the current temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a second thermal management requirement of cooling the passenger compartment and the battery by the refrigerant circuit, or if the current driving mode of the vehicle is an engine operating mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a third thermal management requirement of heating the passenger compartment by an engine circuit, or if the current driving mode of the vehicle is the engine operating mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a fourth thermal management requirement of heating the

passenger compartment and the battery by the engine circuit, or if the current driving mode of the vehicle is pure electric mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a fifth thermal management requirement of heating the passenger compartment by the refrigerant circuit, or if the current driving mode of the vehicle is pure electric mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a sixth thermal management requirement of heating the passenger compartment and the battery by the refrigerant circuit.

[0024] The present application takes into account different thermal management requirements corresponding to different scenarios, and controls the communication states of the first three-way valve, the second three-way valve, and the four-way valve based on the different thermal management requirements, thereby changing the operating state of the system to meet the thermal management requirements in a more comprehensive manner.

[0025] In an optional implementation, the step of controlling port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement includes: if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, controlling a fifth port and a sixth port of the second three-way valve to be mutually connected, controlling the first three-way valve to be closed, and controlling the four-way valve to be closed; if the current thermal management requirement is the third thermal management requirement, controlling the fifth port and the sixth port of the second three-way valve to be mutually connected, controlling a first port and a second port of the first three-way valve to be mutually connected, controlling a seventh port and a ninth port of the four-way valve to be mutually connected, and controlling an eighth port and a tenth port of the four-way valve to be mutually connected; if the current thermal management requirement is the fourth thermal management requirement, controlling the fifth port and the sixth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and a third port of the first three-way valve to be mutually connected, controlling the seventh port and the ninth port of the four-way valve to be mutually connected, and controlling the eighth port and the tenth port of the four-way valve to be mutually connected; if the current thermal management requirement is the fifth thermal management requirement, controlling a fourth port and the fifth port of the second three-way valve to

be mutually connected, controlling the first port and the second port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected; and if the current thermal management requirement is the sixth thermal management requirement, controlling the fourth port and the fifth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and the third port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected.

[0026] In an optional implementation, the method further includes: if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, controlling a first refrigerant shut-off valve to be opened and a second refrigerant shut-off valve to be closed; if the current thermal management requirement is the third thermal management requirement or the fourth thermal management requirement, controlling both the first refrigerant shut-off valve and the second refrigerant shut-off valve to be closed; and if the current thermal management requirement is the fifth thermal management requirement or the sixth thermal management requirement, controlling the first refrigerant shut-off valve to be closed and the second refrigerant shut-off valve to be opened.

[0027] In an optional implementation, the method further includes: if the current thermal management requirement is the first thermal management requirement, controlling a first refrigerant expansion valve to be opened and a second refrigerant expansion valve to be closed; if the current thermal management requirement is the second thermal management requirement, controlling both the first refrigerant expansion valve and the second refrigerant expansion valve to be opened; and if the current thermal management requirement is the third thermal management requirement, the fourth thermal management requirement, the fifth thermal management requirement, or the sixth thermal management requirement, controlling both the first refrigerant expansion valve and the second refrigerant expansion valve to be closed.

[0028] According to a third aspect, the present application provides a computer device, including: a memory and a processor. The memory and the processor are communicatively connected to each other. The memory has computer instructions stored therein. The processor is configured to execute the computer instructions to perform the foregoing thermal management method of the second aspect or any one of the corresponding implementations thereof.

[0029] According to a fourth aspect, the present application provides a vehicle. The vehicle

includes the thermal management system according to the first aspect or any one of the corresponding implementations thereof and a controller. The controller is configured to perform the thermal management method according to the second aspect or any one of the corresponding implementations thereof.

[0030] According to a fifth aspect, the present application provides a computer-readable storage medium. The computer-readable storage medium has computer instructions stored therein. The computer instructions are configured to enable a computer to perform the thermal management method of the second aspect or any one of the corresponding implementations thereof.

[0031] For the thermal management system provided in the present application, the designed water-cooled condenser connects the refrigerant circuit to the heating circuit, so that heat of the high-temperature refrigerant discharged from the electric compressor in the refrigerant circuit is transferred to the heating circuit. In addition, the designed first three-way valve enables the heating circuit to use heat-exchanged coolant to selectively heat the passenger compartment and the battery, so that in pure electric mode, a vehicle can use the refrigerant circuit, rather than an engine and a water heater, to heat the passenger compartment and the battery, thereby saving energy consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] To describe the technical solutions in specific implementations of the present application or the prior art more clearly, the following briefly introduces the accompanying drawings required for describing the specific implementations or the prior art. Apparently, the accompanying drawings in the following description show some implementations of the present application, and persons of ordinary skill in the art may still derive other drawings from these accompanying drawings without creative efforts.

[0033] FIG. 1 is an example structural diagram of a thermal management system according to an embodiment of the present application;

[0034] FIG. 2 is a schematic flowchart of a thermal management method according to an embodiment of the present application;

[0035] FIG. 3 is an example flowchart of a first thermal management requirement in a thermal management method according to an embodiment of the present application;

[0036] FIG. 4 is an example flowchart of a second thermal management requirement in a thermal management method according to an embodiment of the present application;

[0037] FIG. 5 is an example flowchart of a third thermal management requirement in a thermal management method according to an embodiment of the present application;

[0038] FIG. 6 is an example flowchart of a fourth thermal management requirement in a thermal management method according to an embodiment of the present application;

[0039] FIG. 7 is an example flowchart of a fifth thermal management requirement in a thermal management method according to an embodiment of the present application;

[0040] FIG. 8 is an example flowchart of a sixth thermal management requirement in a thermal management method according to an embodiment of the present application;

[0041] FIG. 9 is a schematic diagram of a hardware structure of a computer device according to an embodiment of the present application; and

[0042] FIG. 10 is an example structural diagram of a vehicle according to an embodiment of the present application.

[0043] In the figures: electric compressor 1, second refrigerant shut-off valve 2, water-cooled condenser 3, first refrigerant shut-off valve 4, electronic expansion valve 5, waste heat recovery unit 6, condenser 7, first refrigerant expansion valve 8, second refrigerant expansion valve 9, evaporator 10, battery cooler 11, engine 12, electronic main water pump 13, fifth water temperature sensor 14, high-temperature radiator 15, second water temperature sensor 16, high-temperature expansion tank 17, cooling fan 18, generator 19, first electronic auxiliary water pump 20, first water temperature sensor 21, generator radiator 22, low-temperature expansion tank 23, water-cooled intercooler 24, rear electric drive 25, motor controller 26, second electronic auxiliary water pump 27, fourth water temperature sensor 28, low-temperature radiator 29, second three-way valve 30, four-way valve 31, third electronic auxiliary water pump 32, heater unit 33, first three-way valve 34, third water temperature sensor 35, battery 36, fourth electronic auxiliary water pump 37, battery expansion tank 38, and refrigerant check valve 39.

DETAILED DESCRIPTION

[0044] To make the objectives, technical solutions, and advantages of embodiments of the present application clearer, the following clearly and completely describes the technical solutions in embodiments of the present application with reference to the accompanying drawings in embodiments of the present application. It is clear that the described embodiments are merely some rather than all of embodiments of the present application. All other embodiments obtained by persons skilled in the art based on embodiments of the present application without creative efforts shall fall within the scope of protection of the present application.

[0045] Power batteries tend to perform poorly at low temperatures, leading to a significant drop in the range of the vehicle, which greatly affects the driving mileage of the vehicle. In addition, public

charging infrastructure is still not widely available. For first-time car buyers and users replacing their only family car, pure electric vehicles are often ruled out due to concerns over long-distance travel during holidays. In such cases, hybrid models become a preferable alternative.

[0046] As battery costs decline, the all-electric range of hybrid models is continuously increasing. Existing thermal management system architectures are primarily designed for the normal operation of the powertrain, and the refrigerant circuit fails to take into account the use of a heat pump system. Heating for the passenger compartment relies on engine waste heat or a water heater. However, in pure electric mode, engine waste heat is unavailable, and the use of the water heater leads to high energy consumption. In pure electric mode, the use of waste heat from the engine is not considered. Under low-temperature operating conditions, the refrigerant system fails to be effectively integrated with the coolant system, resulting in energy waste. The architecture design focuses more on heat dissipation of the powertrain or battery cooling under high-temperature operating conditions, without considering energy-saving designs for low-temperature operating conditions. Low-temperature heating relies more on engine waste heat, without considering the design of the heating system and energy consumption reduction in pure electric mode, among a series of other issues.

[0047] In the description of the present application, it needs to be noted that orientation or location relationships indicated by terms "center", "up", "down", "left", "right", "vertical", "horizontal", "inside", and "outside" are based on orientation or location relationships shown in the accompanying drawings, and are only used to facilitate description of the present application and simplify description, but are not used to indicate or imply that the apparatuses or elements must have specific orientations or are constructed and operated by using specific orientations, and therefore, cannot be understood as a limitation to the present application. In addition, the terms "first", "second", and "third" are used only for description, but are not intended to indicate or imply relative importance.

[0048] In the description of the present application, it needs to be noted that unless otherwise expressly specified and defined, "mounted", "connected", and "connection" should be understood in a broad sense, for example, fixedly connected, detachably connected, or integrally connected; or mechanically connected, or electrically connected; or connected directly or through an intermediate, or two elements communicated internally, or connected wirelessly, or connected in a wired manner. For persons skilled in the art, specific meanings of the terms in the present application should be understood according to specific conditions.

[0049] In addition, the technical features involved in different implementations of the present application described below can be combined with each other as long as they do not constitute a conflict between them. Embodiments of the present application disclose a thermal management system.

As shown in FIG. 1, the thermal management system includes a heating circuit, a refrigerant circuit, and a battery circuit, and further includes a first three-way valve 34 and a water-cooled condenser 3. The heating circuit is coupled to the refrigerant circuit via the water-cooled condenser 3. The water-cooled condenser 3 is configured to transfer heat of a high-temperature refrigerant discharged from an electric compressor 1 in the refrigerant circuit to the heating circuit. The first three-way valve 34 has a first port connected to the heating circuit, a second port connected to a heater unit 33 in a passenger compartment, and a third port connected to the battery circuit, and is configured to adjust a connection relationship among the heating circuit, the heater unit, and the battery circuit.

[0050] As shown in FIG. 1, the thermal management system in the embodiments of the present application further includes a generator circuit. The generator circuit includes a generator radiator 22, a first water temperature sensor 21, a first electronic auxiliary water pump 20, a generator 19, a low-temperature expansion tank 23, and a cooling fan 18. The operating state of the generator circuit is as follows: Coolant flowing out of the generator radiator 22 passes through the first water temperature sensor 21 and enters the first electronic auxiliary water pump 20. After flowing out of the first electronic auxiliary water pump 20, the coolant enters the generator 19. After flowing out of the generator 19, the coolant returns to the generator radiator 22 for heat exchange with air. A make-up line of the low-temperature expansion tank 23 is connected upstream of the first electronic auxiliary water pump 20. A coolant outlet of the generator 19 is connected to a degas port of the low-temperature expansion tank 23. The engine circuit includes an engine 12, an electronic main water pump 13, a second water temperature sensor 14, a high-temperature radiator 15, a fifth water temperature sensor 16, a high-temperature expansion tank 17, and the cooling fan 18. The operating state of the engine circuit is as follows: Coolant flowing out of the engine 12 enters the electronic main water pump 13. After flowing out of the electronic main water pump 13, the coolant passes through the second water temperature sensor 14 and enters the high-temperature radiator 15. After heat exchange with air, the coolant flows out of the high-temperature radiator 15, passes through the fifth water temperature sensor 16, and returns to the engine 12. An outlet of the high-temperature radiator 15 is connected to a degas port of the high-temperature expansion tank 17. A make-up line of the high-temperature expansion tank 17 is connected to a coolant outlet of the electronic main water pump 13. This is provided by way of example only. The engine circuit and the generator circuit are automatically closed or opened based on requirements. The heating circuit includes a third electronic auxiliary water pump 32 and the heater unit 33 in the passenger compartment. The specific principle of the heating circuit belongs to the prior art and is used for heating the passenger compartment and/or the battery. Details are not described herein again. The refrigerant circuit in the embodiments of the present application includes the electric

compressor 1, a refrigerant check valve 39, and an electronic expansion valve 5. The heating circuit is coupled to the refrigerant circuit via the water-cooled condenser 3. The water-cooled condenser 3 is configured to transfer heat of the high-temperature refrigerant discharged from the refrigerant circuit to the heating circuit. When the vehicle is in pure electric mode and under low-temperature operating conditions and the engine 12 is not operating, the passenger compartment and/or the battery is heated by the refrigerant circuit. The high-temperature and high-pressure refrigerant discharged from the electric compressor 1 enters the water-cooled condenser 3. The water-cooled condenser 3 is configured to perform heat exchange between the high-temperature refrigerant and the coolant in the heating circuit, thereby increasing the temperature of the coolant circulating in the heating circuit. The heat-exchanged refrigerant flows out of the water-cooled condenser 3, passes through the refrigerant check valve 39, then passes through the electronic expansion valve 5 for throttling and pressure reduction, and enters the waste heat recovery unit 6. At this time, the refrigerant entering the waste heat recovery unit 6 has a low temperature after heat exchange, throttling, and pressure reduction by the electronic expansion valve 5.

[0051] The coolant circulating in the heating circuit in the embodiments of the present application exchanges heat with the high-temperature refrigerant via the water-cooled condenser, and then enters the first port of the first three-way valve 34. Based on the communication mode of the first three-way valve 34, the heat-exchanged coolant can flow out from the second port thereof or the third port thereof, thereby achieving the heating of the passenger compartment or the battery.

[0052] For the thermal management system provided in the present application, the designed water-cooled condenser connects the refrigerant circuit to the heating circuit, so that heat of the high-temperature refrigerant discharged from the electric compressor in the refrigerant circuit is transferred to the heating circuit. In addition, the designed first three-way valve enables the heating circuit to use heat-exchanged coolant to selectively heat the passenger compartment and the battery, so that in pure electric mode, a vehicle can use the refrigerant circuit, rather than an engine and a water heater, to heat the passenger compartment and the battery, thereby saving energy consumption.

[0053] In some optional implementations, the thermal management system further includes an electric drive cooling circuit, a waste heat recovery unit, and a second three-way valve 30. The electric drive cooling circuit includes at least a low-temperature radiator 29, a motor controller 26, a rear electric drive 25, and a water-cooled intercooler 24. The second three-way valve 30 has a fourth port coupled to the refrigerant circuit via the waste heat recovery unit 6, a fifth port disposed on a pipeline through which coolant flows after absorbing waste heat from the motor controller 26, the rear electric drive 25, and the water-cooled intercooler 24, and a sixth port disposed at an inlet of the low-

temperature radiator 29 in the electric drive cooling circuit, and is configured to adjust a flow direction of coolant carrying electric drive waste heat. The waste heat recovery unit 6 is configured to utilize recovered electric drive waste heat to increase a temperature of a refrigerant.

[0054] As shown in FIG. 1, the electric drive cooling circuit in the embodiments of the present application includes the low-temperature radiator 29, a fourth water temperature sensor 28, a second electronic auxiliary water pump 27, the motor controller 26, the rear electric drive 25, the water-cooled intercooler 24, and the like. The fourth port of the second three-way valve 30 is coupled to the refrigerant circuit via the waste heat recovery unit 6, the fifth port thereof is coupled to the low-temperature radiator 29 via the motor controller 26, the rear electric drive 25, and the water-cooled intercooler 24, and the sixth port thereof is connected to the inlet of the low-temperature radiator 29, to adjust the flow direction of the coolant carrying the electric drive waste heat based on the communication mode of the second three-way valve 30. The operating state of the electric drive cooling circuit is as follows: The coolant flowing out of the low-temperature radiator 29 passes through the fourth water temperature sensor 28 and enters the second electronic auxiliary water pump 27. After flowing out of the second electronic auxiliary water pump 27, the coolant separately enters the motor controller 26, the rear electric drive 25, and the water-cooled intercooler 24. After flowing out of the motor controller 26, the rear electric drive 25, and the water-cooled intercooler 24, the coolant is combined into one stream and enters the second three-way valve 30 through the fifth port of the second three-way valve 30. The coolant carrying waste heat discharged from the motor controller 26, the rear electric drive 25, and the water-cooled intercooler 24 flows into the pipeline for circulation. At this time, the electric drive waste heat enters the fifth port of the second three-way valve 30. Next, based on the communication mode of the second three-way valve 30, the coolant carrying the electric drive waste heat and flowing into the fifth port thereof can flow out of the fourth port thereof or the sixth port thereof, thereby respectively achieving different functions. For example, under high-temperature operating conditions, the fourth port is closed to avoid the impact of the electric drive waste heat on the heat dissipation of the refrigerant circuit under high-temperature operating conditions. When the vehicle is in pure electric mode and under low-temperature operating conditions and the engine 12 is not operating, the fourth port is opened, so that the coolant carrying the electric drive waste heat flows into the waste heat recovery unit 6 through the fourth port. Next, the refrigerant entering the waste heat recovery unit 6 absorbs the electric drive waste heat, thereby further increasing the temperature of the refrigerant. The refrigerant that has absorbed the electric drive waste heat flows out of the waste heat recovery unit 6, passes through the condenser 7, the first refrigerant expansion valve 8, and the evaporator 10, and finally returns to the electric compressor 1, to reduce the work done by the electric

compressor 1, thereby further reducing system energy consumption and achieving energy saving.

[0055] The second three-way valve designed in the present application is used to prevent the electric drive waste heat from affecting the heat dissipation of the refrigerant system under high-temperature operating conditions, while allowing the refrigerant to absorb the electric drive waste heat through the waste heat recovery unit under low-temperature operating conditions, thereby reducing energy consumption.

[0056] In some optional implementations, the thermal management system further includes a first refrigerant shut-off valve 4 and a second refrigerant shut-off valve 2, and the refrigerant circuit includes at least the condenser 7 and the electronic expansion valve 5. The first refrigerant shut-off valve 4 is disposed on a pipeline interconnecting the electric compressor 1 and the waste heat recovery unit 6, and is configured to control the refrigerant discharged from the electric compressor 1 to flow through the electronic expansion valve 5 and the condenser 7 before entering a passenger compartment evaporator 10 or the battery circuit. The second refrigerant shut-off valve 2 is disposed on a pipeline interconnecting the electric compressor 1 and the water-cooled condenser 3, and is configured to control the high-temperature refrigerant discharged from the electric compressor 1 to enter the water-cooled condenser 3.

[0057] As shown in FIG. 1, the thermal management system further includes the first refrigerant shut-off valve 4 and the second refrigerant shut-off valve 2. The first refrigerant shut-off valve 4 is disposed on the pipeline interconnecting the electric compressor 1 and the electronic expansion valve 5. When the first refrigerant expansion valve 8 is opened, the high-temperature refrigerant discharged from the electric compressor 1 flows through the first refrigerant shut-off valve 4, undergoes throttling and pressure reduction by the electronic expansion valve 5, and then passes through the waste heat recovery unit 6 and the condenser to enter the passenger compartment evaporator 10 and/or the battery circuit. The second refrigerant shut-off valve 2 is disposed on the pipeline interconnecting the electric compressor 1 and the water-cooled condenser 3. When the second refrigerant shut-off valve 2 is opened, the high-temperature refrigerant discharged from the electric compressor 1 flows directly through the second refrigerant shut-off valve 2 into the water-cooled condenser 3 for heat exchange. This is provided by way of example only.

[0058] The present application achieves cooling or heating of the passenger compartment and/or the battery through the refrigerant circuit by setting the communication states of the first refrigerant shut-off valve and the second refrigerant shut-off valve, respectively.

[0059] Specifically, the thermal management system further includes a first refrigerant expansion valve 8 and a second refrigerant expansion valve 9, and the battery circuit includes at least a battery

cooler 11 and a battery. The first refrigerant expansion valve 8 is disposed on a pipeline interconnecting the condenser 7 and the passenger compartment evaporator 10, and is configured to control the refrigerant discharged from the condenser 7 to enter the passenger compartment evaporator 10. The second refrigerant expansion valve 9 is disposed on a pipeline interconnecting the battery cooler 11 and the condenser 7, and is configured to control the refrigerant discharged from the condenser 7 to enter the battery cooler 11. The battery cooler 11 is connected to the battery 36, and is configured to receive coolant flowing out of the battery, perform heat exchange, and return the heat-exchanged coolant to the battery.

[0060] The first refrigerant expansion valve 8 designed in the embodiments of the present application is disposed on a pipeline interconnecting the condenser 7 and the passenger compartment evaporator 10. The second refrigerant expansion valve 9 is disposed on the pipeline interconnecting the battery cooler 11 and the condenser 7. When the thermal management requirement is a cooling requirement, the first refrigerant shut-off valve 4 is opened, and the refrigerant discharged from the electric compressor 1 passes through the electronic expansion valve 5 for throttling and pressure reduction, then flows through the waste heat recovery unit 6 and the condenser 7, and subsequently enters the first refrigerant expansion valve 8 and the second refrigerant expansion valve 9. If the first refrigerant expansion valve 8 is opened, the refrigerant flows into the first refrigerant expansion valve 8, enters the passenger compartment evaporator 10, exchanges heat with passenger compartment air, then flows out of the passenger compartment evaporator 10, and finally flows into the electric compressor 1. If the second refrigerant expansion valve 9 is opened, the refrigerant flows into the second refrigerant expansion valve 9 and enters the battery cooler 11. The battery circuit includes at least the battery 36, a fourth electronic auxiliary water pump 37, a battery expansion tank 38, and a third water temperature sensor 35. Coolant flowing out of the battery enters the fourth electronic auxiliary water pump 37, then flows out of the fourth electronic auxiliary water pump 37 into the battery expansion tank 38, and then flows out of the battery expansion tank 38 into the battery cooler 11. After the battery cooler 11 performs heat exchange between the coolant flowing out of the battery 36 and the refrigerant, the coolant flows out of the battery cooler 11, passes through the third water temperature sensor, and then enters the battery 36. This is provided by way of example only.

[0061] The present application achieves cooling of the passenger compartment and/or the battery through the refrigerant circuit by arranging the first refrigerant expansion valve and the second refrigerant expansion valve and based on the respective communication states of the two refrigerant expansion valves, thereby rendering the application scenarios of the thermal management system more comprehensive.

[0062] In some optional implementations, the battery circuit includes at least the battery cooler 11 and the battery 36. The first port of the first three-way valve 34 is connected to an outlet of the water-cooled condenser 3, the second port thereof is connected to the heater unit 33 in the passenger compartment, and the third port thereof is connected to the battery cooler 11 in the battery circuit. The battery cooler 11 is connected to the battery 36, and is configured to receive coolant flowing out of the battery 36, perform heat exchange, and return the heat-exchanged coolant to the battery 36.

[0063] As shown in FIG. 1, the first port of the first three-way valve 34 designed in the embodiments of the present application is connected to the outlet of the water-cooled condenser 3. After heat exchange with the high-temperature refrigerant through the water-cooled condenser 3, the heat-exchanged coolant can directly enter the first port of the first three-way valve 34. The second port of the first three-way valve 34 is connected to the heater unit 33 in the passenger compartment. The heater unit 33 in the passenger compartment may be a heater core. This is provided by way of example only. The third port thereof is connected to the battery cooler 11 in the battery circuit. Accordingly, based on the communication mode of the first three-way valve 34, the heating circuit can achieve heating of the battery 36 and/or the passenger compartment.

[0064] Specifically, the first three-way valve 34 is a three-way proportional valve. The heat outflow ratio of the second port thereof to the third port thereof can be adjusted based on the requirements of the thermal management system to set corresponding proportional streams. One stream enters the heater unit 33, and the other stream enters the battery cooler 11. This is provided by way of example only.

[0065] The three-way proportional valve designed in the present application can set a corresponding outflow ratio based on the requirements of the thermal management system during simultaneous heating of the passenger compartment and the battery, thereby improving the flexibility of system heating.

[0066] In some optional implementations, the thermal management system further includes an engine circuit and a four-way valve 31. The four-way valve 31 has a seventh port and an eighth port connected to the engine circuit and a ninth port and a tenth port connected to the heating circuit, and is configured to adjust a connection relationship between the engine circuit and the heating circuit.

[0067] As shown in FIG. 1, the seventh port and the eighth port of the four-way valve 31 are connected to the engine circuit, and the ninth port and the tenth port of the four-way valve 31 are connected to the heating circuit, to adjust the connection relationship between the engine circuit and the heating circuit. For example, the seventh port and the ninth port of the four-way valve are controlled to be mutually connected, and the eighth port and the tenth port of the four-way valve are controlled

to be mutually connected, thereby realizing the series connection between the engine circuit and the heating circuit, so that waste heat of the engine 12 flows through the open four-way valve 31 into the heater unit 33 in the passenger compartment to heat the passenger compartment. When the vehicle is in pure electric mode, the engine 12 is not operating. Correspondingly, the seventh port and the eighth port of the four-way valve 31 are controlled to be mutually connected, and the ninth port and the tenth port of the four-way valve are controlled to be mutually connected, thereby disconnecting the engine circuit from the heating circuit. This is provided by way of example only. The specific connection manner may be set based on actual conditions.

[0068] Specifically, the engine circuit includes at least an engine 12 and an electronic main water pump 13. The seventh port of the four-way valve 31 is connected to an inlet of the engine 12. The eighth port thereof is coupled to an outlet of the engine 12 via the electronic main water pump 13. The ninth port thereof is connected to the heater unit 33 in the passenger compartment. The tenth port thereof is connected to an inlet of the water-cooled condenser 3.

[0069] The seventh port of the four-way valve 31 designed in the embodiments of the present application is connected to the inlet of the engine 12. The eighth port thereof is coupled to the outlet of the engine 12 via the electronic main water pump 13. The ninth port thereof is connected to the heater unit 33 in the passenger compartment. The tenth port thereof is connected to the inlet of the water-cooled condenser 3. When the vehicle is in the engine operating state, the seventh port and the ninth port of the four-way valve are correspondingly mutually connected, and the eighth port and the tenth port of the four-way valve are controlled to be mutually connected. The coolant flowing out of the engine 12 enters the electronic main water pump 13. After flowing out of the electronic main water pump 13, the coolant enters the four-way valve 31 through the eighth port of the four-way valve 31 and flows out through the tenth port thereof. The coolant passes through the water-cooled condenser 3, enters the first three-way valve 34, flows in through the first port of the first three-way valve 34, and flows out through the second port thereof and/or the third port thereof. After passing through the heater unit 33 and/or the battery cooler 11, the coolant flows out, passes through the ninth port thereof and the seventh port thereof, and flows back into the engine 12. This is provided by way of example only. If the vehicle is in pure electric mode, the engine 12 is not operating. Correspondingly, the seventh port thereof and the eighth port thereof are opened, and the ninth port thereof and the tenth port thereof are opened. This is provided by way of example only.

[0070] The four-way valve of the present application can support direct heating of the passenger compartment and the battery using waste heat in an engine operating state, and can also support heating of the passenger compartment and the battery by the refrigerant circuit in pure electric mode, thereby

improving the energy utilization efficiency and capacity of the entire system, avoiding energy waste, and comprehensively improving energy utilization by more than 5%.

[0071] According to embodiments of the present application, an embodiment of a thermal management method is provided. It should be noted that the steps illustrated in the flowchart of the accompanying drawings may be performed in a computer system such as a set of computer-executable instructions, and that, although a logical sequence is shown in the flowchart, in some cases the steps shown or described may be performed in an order different from that shown herein.

[0072] A thermal management method is provided in this embodiment, applicable to the thermal management system described in the foregoing embodiments. FIG. 2 is a flowchart of a thermal management method according to an embodiment of the present application. As shown in FIG. 2, the procedure includes the following steps.

[0073] Step S201: Obtain a current driving mode of a vehicle, an operating status of a battery, and a temperature of a passenger compartment.

[0074] Step S202: Determine a battery temperature requirement based on the operating status of the battery, and determine a current thermal management requirement based on the current driving mode of the vehicle, a relationship between a current battery temperature and the battery temperature requirement, and a relationship between the temperature of the passenger compartment and a temperature requirement of a user for the passenger compartment.

[0075] Step S203: Control port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement to change an operating state of the thermal management system, to meet the current thermal management requirement.

[0076] In the embodiments of the present application, the current driving mode of the vehicle may be obtained, and includes, but is not limited to, pure electric mode or hybrid mode. If the vehicle is in pure electric mode, a generator circuit in the corresponding thermal management system is operating, and an engine circuit is not operating. If the vehicle is in hybrid mode, the engine circuit and the generator circuit are automatically opened or closed based on requirements. The operating status of the battery may include, but is not limited to, a driving operating condition and a charging operating condition. Under the driving operating condition, when the battery temperature is higher than a preset battery temperature threshold, the battery issues a cooling request. When the battery is under the charging operating condition, the battery cooling requirement may be directly requested. Alternatively, the current battery temperature and the current temperature of the passenger compartment may be acquired in real time via sensors or other acquisition devices, and the current

battery status may also be acquired in real time. Different operating states of the battery correspond to respective normal temperature requirement ranges. The current battery temperature may be compared with the normal temperature requirement range corresponding to the current operating status of the battery. If the current battery temperature is lower than the normal temperature requirement range, it is determined that the current thermal management requirement is to heat the battery. The user may set a comfort temperature for the passenger compartment based on personal preference, and the set comfort temperature is compared with the acquired current temperature of the passenger compartment. For example, if the current temperature of the passenger compartment is lower than the comfort temperature set by the user, it is determined that the current thermal management requirement is to heat the passenger compartment. This is provided by way of example only. Next, based on the determined thermal management requirement, the communication states of the first three-way valve, the second three-way valve, and the four-way valve can be controlled to change the operating state of the thermal management system. For example, when it is determined that the current thermal management requirement is that the refrigerant circuit heats the passenger compartment in pure electric mode, correspondingly, a first port and a second port of the first three-way valve are controlled to be mutually connected, a fourth port and a fifth port of the second three-way valve are opened, a seventh port and an eighth port of the four-way valve are opened, and a ninth port thereof and a tenth port thereof are opened. This is provided by way of example only.

[0077] In the thermal management method provided in the present application, the battery temperature requirement is determined based on the current driving mode of the vehicle and the operating status of the battery, the current thermal management requirement is determined based on the relationship between the current battery temperature and the battery temperature requirement, and the relationship between the current temperature of the passenger compartment and the temperature requirement of the user for the passenger compartment, and then the ports of the first three-way valve, the second three-way valve, and the four-way valve are controlled to be mutually connected based on the determined thermal management requirement, thereby meeting the current thermal management requirement.

[0078] Specifically, if the current battery temperature is within a battery temperature requirement range but a current temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a first thermal management requirement of cooling the passenger compartment by a refrigerant circuit, or if a current operating status of the battery is a charging state, or the current battery temperature is above the battery temperature requirement range, and the current

temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a second thermal management requirement of cooling the passenger compartment and the battery by the refrigerant circuit, or if the current driving mode of the vehicle is an engine operating mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a third thermal management requirement of heating the passenger compartment by an engine circuit, or if the current driving mode of the vehicle is the engine operating mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a fourth thermal management requirement of heating the passenger compartment and the battery by the engine circuit, or if the current driving mode of the vehicle is pure electric mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a fifth thermal management requirement of heating the passenger compartment by the refrigerant circuit, or if the current driving mode of the vehicle is pure electric mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, it is determined that the current thermal management requirement is a sixth thermal management requirement of heating the passenger compartment and the battery by the refrigerant circuit.

[0079] In the present application, the thermal management requirements corresponding to all possible situations that may occur in the battery and the passenger compartment during vehicle driving are determined, thereby broadening the application scenarios of the thermal management method.

[0080] Specifically, the step of controlling port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement includes: if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, controlling a fifth port and a sixth port of the second three-way valve to be mutually connected, controlling the first three-way valve to be closed, and controlling the four-way valve to be closed; if the current thermal management requirement is the third thermal management requirement, controlling the fifth port and the sixth port of the second three-way

valve to be mutually connected, controlling a first port and a second port of the first three-way valve to be mutually connected, controlling a seventh port and a ninth port of the four-way valve to be mutually connected, and controlling an eighth port and a tenth port of the four-way valve to be mutually connected; if the current thermal management requirement is the fourth thermal management requirement, controlling the fifth port and the sixth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and a third port of the first three-way valve to be mutually connected, controlling the seventh port and the ninth port of the four-way valve to be mutually connected, and controlling the eighth port and the tenth port of the four-way valve to be mutually connected; if the current thermal management requirement is the fifth thermal management requirement, controlling a fourth port and the fifth port of the second three-way valve to be mutually connected, controlling the first port and the second port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected; and if the current thermal management requirement is the sixth thermal management requirement, controlling the fourth port and the fifth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and the third port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected.

[0081] In an optional implementation, if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, a first refrigerant shut-off valve is controlled to be opened and a second refrigerant shut-off valve is controlled to be closed; if the current thermal management requirement is the third thermal management requirement or the fourth thermal management requirement, both the first refrigerant shut-off valve and the second refrigerant shut-off valve are controlled to be closed; and if the current thermal management requirement is the fifth thermal management requirement or the sixth thermal management requirement, the first refrigerant shut-off valve is controlled to be closed and the second refrigerant shut-off valve is controlled to be opened.

[0082] In an optional implementation, if the current thermal management requirement is the first thermal management requirement, a first refrigerant expansion valve is controlled to be opened and a second refrigerant expansion valve is controlled to be closed; if the current thermal management requirement is the second thermal management requirement, both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be opened; and if the current thermal

management requirement is the third thermal management requirement, the fourth thermal management requirement, the fifth thermal management requirement, or the sixth thermal management requirement, both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be closed.

[0083] As shown in FIG. 3, the dashed lines represent lines through which the circulation does not involve, and the solid lines represent lines through which the heat-carrying coolant or refrigerant flows. When the current thermal management requirement is the first thermal management requirement, namely, during cooling of the passenger compartment, the refrigerant circuit and the electric drive cooling circuit are operating, the engine circuit and the generator circuit are automatically opened or closed based on requirements, and the heating circuit and the battery circuit are not operating. The fifth port and the sixth port of the second three-way valve are controlled to be mutually connected, the first three-way valve is controlled to be closed, the four-way valve is controlled to be closed, the first refrigerant shut-off valve is controlled to be opened, the second refrigerant shut-off valve is controlled to be closed, the first refrigerant expansion valve is controlled to be opened, and the second refrigerant expansion valve is controlled to be closed. The refrigerant circuit is as follows: The high-temperature and high-pressure refrigerant discharged from the electric compressor 1 passes through the first refrigerant shut-off valve, the electronic expansion valve, and the waste heat recovery unit, enters the condenser, and exchanges heat with air. The heat-exchanged refrigerant enters the first refrigerant expansion valve. After throttling and pressure reduction by the first refrigerant expansion valve, the refrigerant enters the evaporator, exchanges heat with the air in the vehicle, flows out of the evaporator after heat exchange, and returns to the electric compressor 1. The operation of the electric drive cooling circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream and enters the second three-way valve. The second three-way valve may also be a three-way proportional valve. The coolant enters through the fifth port (Port B) of the second three-way valve, flows out through the sixth port (Port A) thereof, and returns to the low-temperature radiator. A make-up line of the low-temperature expansion tank is connected upstream of the second electronic auxiliary water pump. A coolant outlet of the low-temperature radiator is connected to a degas port of the low-temperature expansion tank.

[0084] As shown in FIG. 4, when the current thermal management requirement is the second

thermal management requirement, the refrigerant circuit, the low-temperature circuit and the battery circuit are operating, the engine circuit and the generator circuit are automatically opened or closed based on requirements, and the heating circuit is not operating. The fifth port and the sixth port of the second three-way valve are controlled to be mutually connected, the first three-way valve is controlled to be closed, the four-way valve is controlled to be closed, the first refrigerant shut-off valve is controlled to be opened, the second refrigerant shut-off valve is controlled to be closed, and both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be opened. The refrigerant circuit is as follows: The high-temperature and high-pressure refrigerant discharged from the electric compressor 1 passes through the first refrigerant shut-off valve, the electronic expansion valve, and the waste heat recovery unit, enters the condenser, and exchanges heat with air. The refrigerant is then divided into two streams. One stream enters the first refrigerant expansion valve, and the other stream enters the second refrigerant expansion valve. After throttling and pressure reduction through the first refrigerant expansion valve and the second refrigerant expansion valve, the refrigerant streams respectively enter the evaporator and the battery cooler. The refrigerant entering the evaporator exchanges heat with the air in the vehicle, and the refrigerant entering the battery cooler exchanges heat with the battery circuit coolant in the battery cooler. The heat-exchanged refrigerant flows out of the evaporator and the battery cooler, is combined into one stream, and returns to the electric compressor 1. The low-temperature circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream and enters the second three-way valve. The second three-way valve may also be a three-way proportional valve. The coolant enters through the fifth port (Port B) of the second three-way valve, flows out through the sixth port (Port A) thereof, and returns to the low-temperature radiator. A make-up line of the low-temperature expansion tank is connected upstream of the second electronic auxiliary water pump. A coolant outlet of the low-temperature radiator is connected to a degas port of the low-temperature expansion tank.

[0085] As shown in FIG. 5, when the current thermal management requirement is the third thermal management requirement, the engine circuit, the generator circuit, the low-temperature circuit, and the heating circuit are operating, and the refrigerant circuit and the battery circuit are not operating. The fifth port and the sixth port of the second three-way valve are controlled to be mutually connected, the first port and the second port of the first three-way valve are controlled to be mutually connected,

the seventh port and the ninth port of the four-way valve are controlled to be mutually connected, and the eighth port and the tenth port of the four-way valve are controlled to be mutually connected. Both the first refrigerant shut-off valve and the second refrigerant shut-off valve are closed, and both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be closed. The engine circuit is as follows: Coolant flowing out of the engine enters the electronic main water pump. After flowing out of the electronic main water pump, the coolant passes through the second water temperature sensor and enters the high-temperature radiator. After heat exchange with air, the coolant flows out of the high-temperature radiator, passes through the fifth water temperature sensor, and returns to the engine. An outlet of the high-temperature radiator is connected to a degas port of the high-temperature expansion tank. A make-up line of the high-temperature expansion tank is connected to a coolant outlet of the electronic main water pump. The generator circuit is as follows: Coolant flowing out of the generator radiator passes through the first water temperature sensor and enters the first electronic auxiliary water pump. After flowing out of the first electronic auxiliary water pump, the coolant enters the generator. After flowing out of the generator, the coolant returns to the generator radiator for heat exchange with air. A make-up line of the low-temperature expansion tank is connected upstream of the first electronic auxiliary water pump. A coolant outlet of the generator is connected to a degas port of the low-temperature expansion tank. The low-temperature circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream and enters the second three-way valve. The coolant enters through the fifth port (Port B) of the second three-way valve, flows out through the sixth port (Port A) thereof, and returns to the low-temperature radiator. A make-up line of the low-temperature expansion tank is connected upstream of the second electronic auxiliary water pump. A coolant outlet of the low-temperature radiator is connected to a degas port of the low-temperature expansion tank. The heating circuit is as follows: Coolant flowing out of the engine enters the electronic main water pump. After flowing out of the electronic main water pump, the coolant enters the four-way valve through the eighth port (Port B) of the four-way valve, and flows out from the tenth port (Port C) thereof. After passing through the water-cooled condenser, the coolant enters the first three-way valve through the first port (Port B) of the first three-way valve and flows out through the second port (Port A) thereof. The coolant enters the heater core, exchanges heat with air in the vehicle, flows out of the heater core after heat exchange, and enters the third electronic auxiliary

water pump. After flowing out of the third electronic auxiliary water pump, the coolant enters the four-way valve through the ninth port (Port D) of the four-way valve, flows out through the seventh port (Port A) thereof, and returns to the engine.

[0086] As shown in FIG. 6, when the current thermal management requirement is the fourth thermal management requirement, the engine circuit, the generator circuit, the low-temperature circuit, the heating circuit, and the battery circuit are operating, and the refrigerant circuit is not operating. The fifth port and the sixth port of the second three-way valve are controlled to be mutually connected, all the first port, the second port, and the third port of the first three-way valve are controlled to be mutually connected, the seventh port and the ninth port of the four-way valve are controlled to be mutually connected, and the eighth port and the tenth port of the four-way valve are controlled to be mutually connected. Both the first refrigerant shut-off valve and the second refrigerant shut-off valve are closed, and both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be closed. The operating state of the engine circuit is as follows: Coolant flowing out of the engine enters the electronic main water pump. After flowing out of the electronic main water pump, the coolant passes through the second water temperature sensor and enters the high-temperature radiator. After heat exchange with air, the coolant flows out of the high-temperature radiator, passes through the fifth water temperature sensor, and returns to the engine. An outlet of the high-temperature radiator is connected to a degas port of the high-temperature expansion tank. A make-up line of the high-temperature expansion tank is connected to a coolant outlet of the electronic main water pump. The operating state of the generator circuit is as follows: Coolant flowing out of the generator radiator passes through the first water temperature sensor and enters the first electronic auxiliary water pump. After flowing out of the first electronic auxiliary water pump, the coolant enters the generator. After flowing out of the generator, the coolant returns to the generator radiator for heat exchange with air. A make-up line of the low-temperature expansion tank is connected upstream of the first electronic auxiliary water pump. A coolant outlet of the generator is connected to a degas port of the low-temperature expansion tank. The low-temperature circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream and enters the second three-way valve. The coolant enters through the fifth port (Port B) of the second three-way valve, flows out through the sixth port (Port A) thereof, and returns to the low-temperature radiator. A make-up line of the low-temperature expansion tank is

connected upstream of the second electronic auxiliary water pump. A coolant outlet of the low-temperature radiator is connected to a degas port of the low-temperature expansion tank. The heating circuit is as follows: Coolant flowing out of the engine enters the electronic main water pump. After flowing out of the electronic main water pump, the coolant enters the four-way valve through the eighth port (Port B) of the four-way valve and flows out through the tenth port (Port C) thereof. The coolant passes through the water-cooled condenser, enters the first three-way valve through the first port (Port B) of the first three-way valve, and flows out through the second port (Port A) thereof and the third port (Port C) thereof separately. The coolant flowing out through Port A enters the heater core and exchanges heat with the air in the vehicle, and flows out of the heater core after heat exchange. The coolant flowing out through Port C enters the battery cooler and exchanges heat with the battery circuit coolant. The coolant flowing out from the heater core and the battery cooler is combined into one stream and enters the third electronic auxiliary water pump. After flowing out of the third electronic auxiliary water pump, the coolant enters the four-way valve through the ninth port (Port D) of the four-way valve, flows out through the seventh port (Port A) thereof, and returns to the engine. The operating state of the battery circuit is as follows: Coolant flowing out of the battery enters the fourth electronic auxiliary water pump. After flowing out of the fourth electronic auxiliary water pump, the coolant enters the battery expansion tank. After flowing out of the battery expansion tank, the coolant enters the battery cooler, flows out of the battery cooler after heat exchange, passes through the third water temperature sensor, and enters the battery.

[0087] As shown in FIG. 7, when the current thermal management requirement is the fifth thermal management requirement, the refrigerant circuit, the low-temperature circuit, and the heating circuit are operating, the engine circuit and the generator circuit are automatically opened or closed based on requirements, and the battery circuit is not operating. The fourth port and the fifth port of the second three-way valve are controlled to be mutually connected, the first port and the second port of the first three-way valve are controlled to be mutually connected, the seventh port and the eighth port of the four-way valve are controlled to be connected, the ninth port and the tenth port of the four-way valve are controlled to be mutually connected, the first refrigerant shut-off valve is controlled to be closed, the second refrigerant shut-off valve is controlled to be opened, and both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be closed. The refrigerant circuit is as follows: The high-temperature and high-pressure refrigerant discharged from the electric compressor 1 passes through the second refrigerant shut-off valve, enters the water-cooled condenser, and exchanges heat with the heating circuit. The heat-exchanged refrigerant enters the electronic expansion valve. After throttling and pressure reduction by the electronic expansion valve, the

refrigerant enters the waste heat recovery unit to absorb electric drive waste heat. After flowing out of the waste heat recovery unit, the refrigerant passes through the condenser. After flowing out of the condenser, the refrigerant passes through the first refrigerant expansion valve and the evaporator and returns to the electric compressor 1. The operating state of the low-temperature circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream, enters the second three-way valve through the fifth port (Port B) of the second three-way valve, flows out through the fourth port (Port C) thereof, enters the waste heat recovery unit, exchanges heat with the refrigerant, and flows out of the waste heat recovery unit after heat exchange. The coolant returns to the low-temperature radiator. The make-up line of the low-temperature expansion tank is connected upstream of the second electronic auxiliary water pump. The coolant outlet of the low-temperature radiator is connected to the degas port of the low-temperature expansion tank. The heating circuit is as follows: The coolant after heat exchange with the refrigerant in the water-cooled condenser enters the first three-way valve through the first port (Port B) of the first three-way valve and flows out through the second port (Port A) thereof. The coolant enters the heater core, exchanges heat with air in the vehicle, flows out of the heater core after heat exchange, and enters the third electronic auxiliary water pump. After flowing out of the third electronic auxiliary water pump, the coolant enters the four-way valve through the ninth port (Port D) of the four-way valve, flows out through the tenth port (Port C) thereof, and returns to the water-cooled condenser.

[0088] As shown in FIG. 8, when the current thermal management requirement is the sixth thermal management requirement, the refrigerant circuit, the low-temperature circuit, the heating circuit, and the battery circuit are operating, and the engine circuit and the generator circuit are automatically opened or closed based on requirements. The fourth port and the fifth port of the second three-way valve are controlled to be mutually connected, all the first port, the second port, and the third port of the first three-way valve are controlled to be mutually connected, the seventh port and the eighth port of the four-way valve are controlled to be connected, the ninth port and the tenth port of the four-way valve are controlled to be mutually connected, the first refrigerant shut-off valve is controlled to be closed, the second refrigerant shut-off valve is controlled to be opened, and both the first refrigerant expansion valve and the second refrigerant expansion valve are controlled to be closed. The refrigerant circuit is as follows: The high-temperature and high-pressure refrigerant discharged

from the electric compressor 1 passes through the second refrigerant shut-off valve, enters the water-cooled condenser, and exchanges heat with the heating circuit. The heat-exchanged refrigerant enters the electronic expansion valve. After throttling and pressure reduction by the electronic expansion valve, the refrigerant enters the waste heat recovery unit to absorb electric drive waste heat. After flowing out of the waste heat recovery unit, the refrigerant passes through the condenser. After flowing out of the condenser, the refrigerant passes through the first refrigerant expansion valve and the evaporator and returns to the electric compressor 1. The operating state of the low-temperature circuit is as follows: The coolant flowing out of the low-temperature radiator passes through the fourth water temperature sensor and enters the second electronic auxiliary water pump. After flowing out of the second electronic auxiliary water pump, the coolant separately enters the motor controller, the rear electric drive, and the water-cooled intercooler. After flowing out of the motor controller, the rear electric drive, and the water-cooled intercooler, the coolant is combined into one stream, enters the second three-way valve through the fifth port (Port B) of the second three-way valve, flows out through the fourth port (Port C) thereof, enters the waste heat recovery unit, exchanges heat with the refrigerant, and flows out of the waste heat recovery unit after heat exchange. The coolant returns to the low-temperature radiator. The make-up line of the low-temperature expansion tank is connected upstream of the second electronic auxiliary water pump. The coolant outlet of the low-temperature radiator is connected to the degas port of the low-temperature expansion tank. The heating circuit is as follows: The coolant after heat exchange with the refrigerant in the water-cooled condenser enters the first three-way valve through the first port (Port B) of the first three-way valve, and flows out from the second port (Port A) thereof and the third port (Port C) thereof separately. The coolant flowing out through Port A enters the heater core, exchanges heat with the air in the vehicle, and flows out of the heater core after heat exchange. The coolant flowing out through Port C enters the battery cooler and exchanges heat with the battery circuit. The coolant flowing out from the heater core and the battery cooler is combined into one stream and enters the third electronic auxiliary water pump. After flowing out of the third electronic auxiliary water pump, the coolant enters the four-way valve through the ninth port (Port D) of the four-way valve, flows out through the tenth port (Port C) thereof, and returns to the water-cooled condenser. The battery circuit is as follows: Coolant flowing out of the battery enters the fourth electronic auxiliary water pump. After flowing out of the fourth electronic auxiliary water pump, the coolant enters the battery expansion tank. After flowing out of the battery expansion tank, the coolant enters the battery cooler, flows out of the battery cooler after heat exchange, passes through the third water temperature sensor, and enters the battery.

[0089] Refer to FIG. 9. FIG. 9 is a schematic structural diagram of a computer device according

to an optional embodiment of the present application. As shown in FIG. 9, the computer device includes one or more processors 40, a memory 50, and interfaces for connecting components, including high-speed and low-speed interfaces. The components are communicatively connected to each other by different buses and may be installed on a common motherboard or installed in other configurations as required The processor executes instructions within the computer device, including instructions stored in or on the memory to display graphical information for a GUI on an external input/output apparatus (e.g., a display device coupled to the interfaces). In some optional implementations, a plurality of processors and/or a plurality of buses may be employed with a plurality of memories when necessary. Similarly, a plurality of computer devices may be connected, each providing part of necessary operations (e.g., as a server array, a blade server group, or a multiprocessor system). One processor 40 is used as an example in FIG. 9.

[0090] The processor 40 may be a central processing unit, a network processor, or a combination thereof. The processor 40 may further include a hardware chip. The aforementioned hardware chip may be an application-specific integrated circuit, a programmable logic device, or a combination thereof. The programmable logic device may be a complex programmable logic device, a field-programmable gate array, a generic array logic, or any combination thereof.

[0091] The memory 50 has instructions executable by at least one processor 40 stored therein, enabling the at least one processor 40 to perform the methods shown in the aforementioned embodiments.

[0092] The memory 50 may include a program storage area and a data storage area. The program storage area may store an operating system and an application required for at least one function. The data storage area may store data created based on use of the computer device, and the like. Moreover, the memory 50 may include a high-speed random access memory (RAM), and may further include a non-transitory memory, for example, at least one magnetic disk storage device, flash storage device, or other non-transitory solid state storage device. In some optional implementations, the memory 50 optionally includes memories disposed remotely with respect to the processor 40. These remote memories may be connected to the computer device by a network. An example of the foregoing network includes, but is not limited to, the internet, an intranet, a local area network, a mobile communication network, and a combination thereof.

[0093] The memory 50 may include a volatile memory, for example, a random access memory; the memory may further include a non-volatile memory, for example, a flash memory, a hard disk drive, or a solid-state drive; and the memory 50 may further include a combination of the aforementioned types of memories.

[0094] The computer device further includes an input apparatus 60 and an output apparatus 70. The processor 40, the memory 50, the input apparatus 60, and the output apparatus 70 may be connected through a bus or in another manner. In FIG. 9, for example, a bus connection is used.

[0095] The input apparatus 60 may receive input numeric or character information and generate key signal inputs related to user settings and functional control of the computer device, and is, for example, a touchscreen, a keypad, a mouse, a trackpad, a touchpad, a pointing stick, one or more mouse buttons, a trackball, or a joystick. The output apparatus 70 may include a display device, an auxiliary lighting apparatus (e.g., an LED), a haptic feedback apparatus (e.g., a vibration motor), and the like. The aforementioned display device includes, but is not limited to, a liquid crystal display, a light-emitting diode, a display, and a plasma display. In some optional implementations, the display device may be a touchscreen.

[0096] Embodiments of the present application further provide a vehicle. As shown in FIG. 10, the vehicle includes a thermal management system and a controller. The controller performs the thermal management method in the foregoing embodiments.

[0097] Embodiments of the present application further provide a computer-readable storage medium. The methods according to the embodiments of the present application may be implemented in hardware or firmware, or may be implemented as computer code recorded on a storage medium, or implemented as computer code that is downloadable via a network, originally stored in a remote storage medium or non-transitory machine-readable storage medium, and subsequently stored in a local storage medium. Thus, the methods described herein may be processed by such software stored on a storage medium utilizing general-purpose computers, dedicated processors, or programmable/dedicated hardware. The storage medium may be a magnetic disk, an optical disc, a read-only memory, a random access memory, a flash memory, a hard disk drive, or a solid-state drive. Further, the storage medium may further include combinations of the aforementioned types of memories. It should be understood that computers, processors, microprocessor controllers, or programmable hardware include storage components capable of storing or receiving software or computer code. When accessed and executed by the computers, processors, or hardware, the software or computer code implements the methods illustrated in the above embodiments.

[0098] Although the embodiments of the present application are described in conjunction with the accompanying drawings, various modifications and variations may be made by those skilled in the art without departing from the spirit and scope of the present application, and such modifications and variations fall within the scope defined by the appended claims.

CLAIMS

The Listing of Claims:

1. A thermal management system, wherein the thermal management system comprises at least a heating circuit, a refrigerant circuit, a battery circuit, a first three-way valve, and a water-cooled condenser, and the refrigerant circuit comprises an electric compressor, wherein

the heating circuit is coupled to the refrigerant circuit via the water-cooled condenser, and the water-cooled condenser is configured to transfer heat of a high-temperature refrigerant discharged from the electric compressor in the refrigerant circuit to the heating circuit; and

the first three-way valve has a first port connected to the heating circuit, a second port connected to a heater unit in a passenger compartment, and a third port connected to the battery circuit, and is configured to adjust a connection relationship among the heating circuit, the heater unit, and the battery circuit.

2. The system according to claim 1, wherein the thermal management system further comprises an electric drive cooling circuit, a waste heat recovery unit, and a second three-way valve, and the electric drive cooling circuit comprises at least a low-temperature radiator, a motor controller, a rear electric drive, and a water-cooled intercooler, wherein

the second three-way valve has a fourth port coupled to the refrigerant circuit via the waste heat recovery unit, a fifth port disposed on a pipeline which coolant flows after absorbing waste heat from the motor controller, the rear electric drive, and the water-cooled intercooler, and a sixth port disposed at an inlet of the low-temperature radiator in the electric drive cooling circuit, and is configured to adjust a flow direction of coolant carrying electric drive waste heat, and the waste heat recovery unit is configured to utilize recovered electric drive waste heat to increase a temperature of a refrigerant.

3. The system according to claim 1, wherein the thermal management system further comprises a first refrigerant shut-off valve and a second refrigerant shut-off valve, and the refrigerant circuit further comprises a condenser and an electronic expansion valve, wherein

the first refrigerant shut-off valve is disposed on a pipeline interconnecting the electric compressor and the waste heat recovery unit, and is configured to control the refrigerant discharged from the electric compressor to flow through the electronic expansion valve and the condenser before entering a passenger compartment evaporator or the battery circuit; and

the second refrigerant shut-off valve is disposed on a pipeline interconnecting the electric

compressor and the water-cooled condenser, and is configured to control the high-temperature refrigerant discharged from the electric compressor to enter the water-cooled condenser.

4. The system according to claim 1, wherein the battery circuit comprises at least a battery cooler and a battery, wherein

the first port of the first three-way valve is connected to an outlet of the water-cooled condenser, the second port thereof is connected to the heater unit in the passenger compartment, and the third port thereof is connected to the battery cooler in the battery circuit; and

the battery cooler is connected to the battery, and is configured to receive coolant flowing out of the battery, perform heat exchange, and return the heat-exchanged coolant to the battery.

5. The system according to claim 1, wherein the thermal management system further comprises an engine circuit and a four-way valve, wherein

the four-way valve has a seventh port and an eighth port connected to the engine circuit and a ninth port and a tenth port connected to the heating circuit, and is configured to adjust a connection relationship between the engine circuit and the heating circuit.

6. The system according to claim 1, wherein the engine circuit comprises at least an engine and an electronic main water pump, wherein

the seventh port of the four-way valve is connected to an inlet of the engine, the eighth port thereof is coupled to an outlet of the engine via the electronic main water pump, the ninth port thereof is connected to the heater unit in the passenger compartment, and the tenth port thereof is connected to an inlet of the water-cooled condenser.

7. The system according to claim 3, wherein the thermal management system further comprises a first refrigerant expansion valve and a second refrigerant expansion valve, and the battery circuit comprises at least a battery cooler and a battery, wherein

the first refrigerant expansion valve is disposed on a pipeline interconnecting the condenser and the passenger compartment evaporator, and is configured to control the refrigerant discharged from the condenser to enter the passenger compartment evaporator; and

the second refrigerant expansion valve is disposed on a pipeline interconnecting the battery cooler and the condenser, and is configured to control the refrigerant discharged from the condenser to enter the battery cooler, and the battery cooler is connected to the battery, and is configured to receive coolant

flowing out of the battery, perform heat exchange, and return the heat-exchanged coolant to the battery.

8. The system according to claim 1 or 4, wherein the first three-way valve is a three-way proportional valve.

9. A thermal management method, applied by the thermal management system of any one of claims 1 to 8, wherein the method comprises:

obtaining a current driving mode of a vehicle, an operating status of a battery, and a temperature of a passenger compartment;

determining a battery temperature requirement based on the operating status of the battery, and determining a current thermal management requirement based on the current driving mode of the vehicle, a relationship between a current battery temperature and the battery temperature requirement, and a relationship between the temperature of the passenger compartment and a temperature requirement of a user for the passenger compartment; and

controlling port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement to change an operating state of the thermal management system, to meet the current thermal management requirement.

10. The method according to claim 9, wherein the step of determining a battery temperature requirement based on the operating status of the battery, and determining a current thermal management requirement based on the current driving mode of the vehicle, a relationship between a current battery temperature and the battery temperature requirement, and a relationship between the temperature of the passenger compartment and a temperature requirement of a user for the passenger compartment comprises:

if the current battery temperature is within a battery temperature requirement range but a current temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a first thermal management requirement of cooling the passenger compartment by a refrigerant circuit, or

if a current operating status of the battery is a charging state, or the current battery temperature is above the battery temperature requirement range, and the current temperature of the passenger compartment is higher than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a second thermal management requirement of cooling the passenger compartment and the battery by the refrigerant circuit, or

if the current driving mode of the vehicle is an engine operating mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a third thermal management requirement of heating the passenger compartment by an engine circuit, or

if the current driving mode of the vehicle is the engine operating mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a fourth thermal management requirement of heating the passenger compartment and the battery by the engine circuit, or

if the current driving mode of the vehicle is pure electric mode, and the current battery temperature is within the battery temperature requirement range, but the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a fifth thermal management requirement of heating the passenger compartment by the refrigerant circuit, or

if the current driving mode of the vehicle is pure electric mode, the current battery temperature is below the battery temperature requirement range, and the current temperature of the passenger compartment is lower than the temperature requirement of the user for the passenger compartment, determining that the current thermal management requirement is a sixth thermal management requirement of heating the passenger compartment and the battery by the refrigerant circuit.

11. The method according to claim 10, wherein the step of controlling port communication states of a first three-way valve, a second three-way valve, and a four-way valve based on the current thermal management requirement comprises:

if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, controlling a fifth port and a sixth port of the second three-way valve to be mutually connected, controlling the first three-way valve to be closed, and controlling the four-way valve to be closed;

if the current thermal management requirement is the third thermal management requirement, controlling the fifth port and the sixth port of the second three-way valve to be mutually connected, controlling a first port and a second port of the first three-way valve to be mutually connected, controlling a seventh port and a ninth port of the four-way valve to be mutually connected, and

controlling an eighth port and a tenth port of the four-way valve to be mutually connected;

if the current thermal management requirement is the fourth thermal management requirement, controlling the fifth port and the sixth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and a third port of the first three-way valve to be mutually connected, controlling the seventh port and the ninth port of the four-way valve to be mutually connected, and controlling the eighth port and the tenth port of the four-way valve to be mutually connected;

if the current thermal management requirement is the fifth thermal management requirement, controlling a fourth port and the fifth port of the second three-way valve to be mutually connected, controlling the first port and the second port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected; and

if the current thermal management requirement is the sixth thermal management requirement, controlling the fourth port and the fifth port of the second three-way valve to be mutually connected, controlling all the first port, the second port, and the third port of the first three-way valve to be mutually connected, controlling the seventh port and the eighth port of the four-way valve to be mutually connected, and controlling the ninth port and the tenth port of the four-way valve to be mutually connected.

12. The method according to claim 10, wherein the method further comprises:

if the current thermal management requirement is the first thermal management requirement or the second thermal management requirement, controlling a first refrigerant shut-off valve to be opened and a second refrigerant shut-off valve to be closed;

if the current thermal management requirement is the third thermal management requirement or the fourth thermal management requirement, controlling both the first refrigerant shut-off valve and the second refrigerant shut-off valve to be closed; and

if the current thermal management requirement is the fifth thermal management requirement or the sixth thermal management requirement, controlling the first refrigerant shut-off valve to be closed and the second refrigerant shut-off valve to be opened.

13. The method according to claim 10 or 12, wherein the method further comprises:

if the current thermal management requirement is the first thermal management requirement, controlling a first refrigerant expansion valve to be opened and a second refrigerant expansion valve

to be closed;

if the current thermal management requirement is the second thermal management requirement, controlling both the first refrigerant expansion valve and the second refrigerant expansion valve to be opened; and

if the current thermal management requirement is the third thermal management requirement, the fourth thermal management requirement, the fifth thermal management requirement, or the sixth thermal management requirement, controlling both the first refrigerant expansion valve and the second refrigerant expansion valve to be closed.

14. A computer device, comprising:

a memory and a processor, wherein the memory and the processor are communicatively connected to each other, the memory has computer instructions stored therein, and the processor is configured to execute the computer instructions to perform thermal management method of any one of claims 9 to 13.

15. A vehicle, wherein the vehicle comprises a controller and the thermal management system of any one of claims 1 to 8, and the controller is configured to perform the thermal management method of any one of claims 9 to 13.

16. A computer-readable storage medium, wherein the computer-readable storage medium has computer instructions stored therein, and the computer instructions are configured to enable a computer to perform the thermal management method of any one of claims 9 to 13.