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(54) **THERMAL MANAGEMENT SYSTEM AND AN ELECTRIC VEHICLE INCLUDING THE THERMAL MANAGEMENT SYSTEM**

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(57)

ABSTRACT

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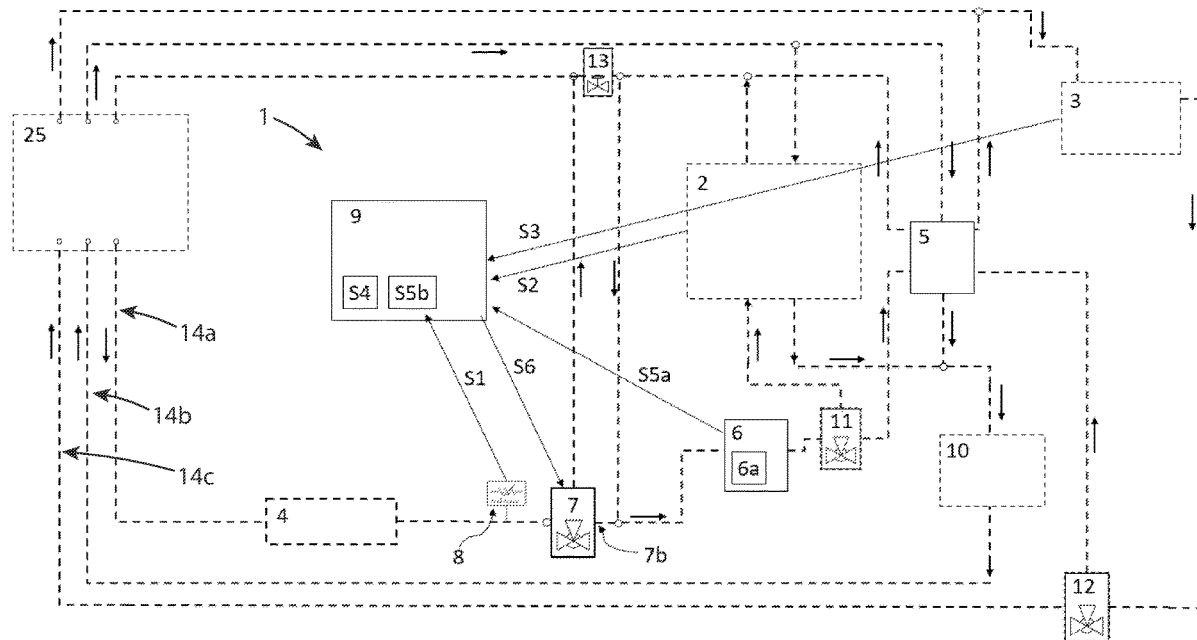
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A thermal management system (1) for controlling the temperature in a cabin (2) and an energy storage system (3) of an electric vehicle including a vehicle component (4). Also, an electric vehicle comprising the thermal management system (1). The system (1) comprises one heat exchanger (5) and one heater (6) arranged to heat the cabin (2) and to provide heat to the heat exchanger (5). The system (1) comprises a first valve (7) for thermal fluid, a first temperature sensor (8) and a control unit (9) arranged to determine (S4) if the cabin (2) or the energy storage system (3) is to be heated, based on a received temperature of the first temperature sensor (8), the temperature in the cabin (2) and in the energy storage system (3), to determine (S5) if there is excess heat in the thermal fluid, and to control (S6) the opening and closing of the first valve (7) so that the thermal fluid is provided to the heater (6) when there is excess heat in the thermal fluid and any of the energy storage system (3) and the cabin (2) is to be heated.



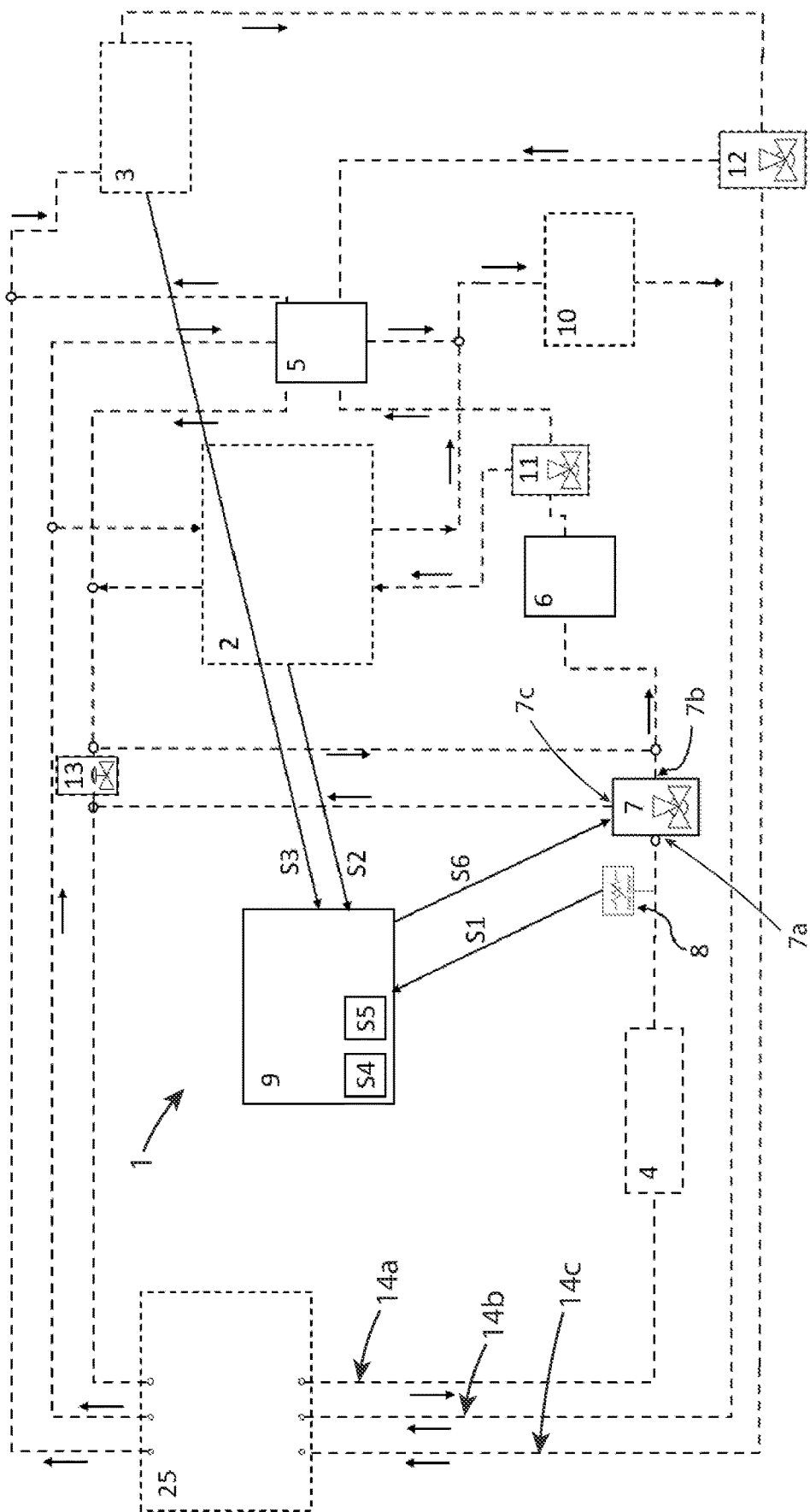


Fig. 1

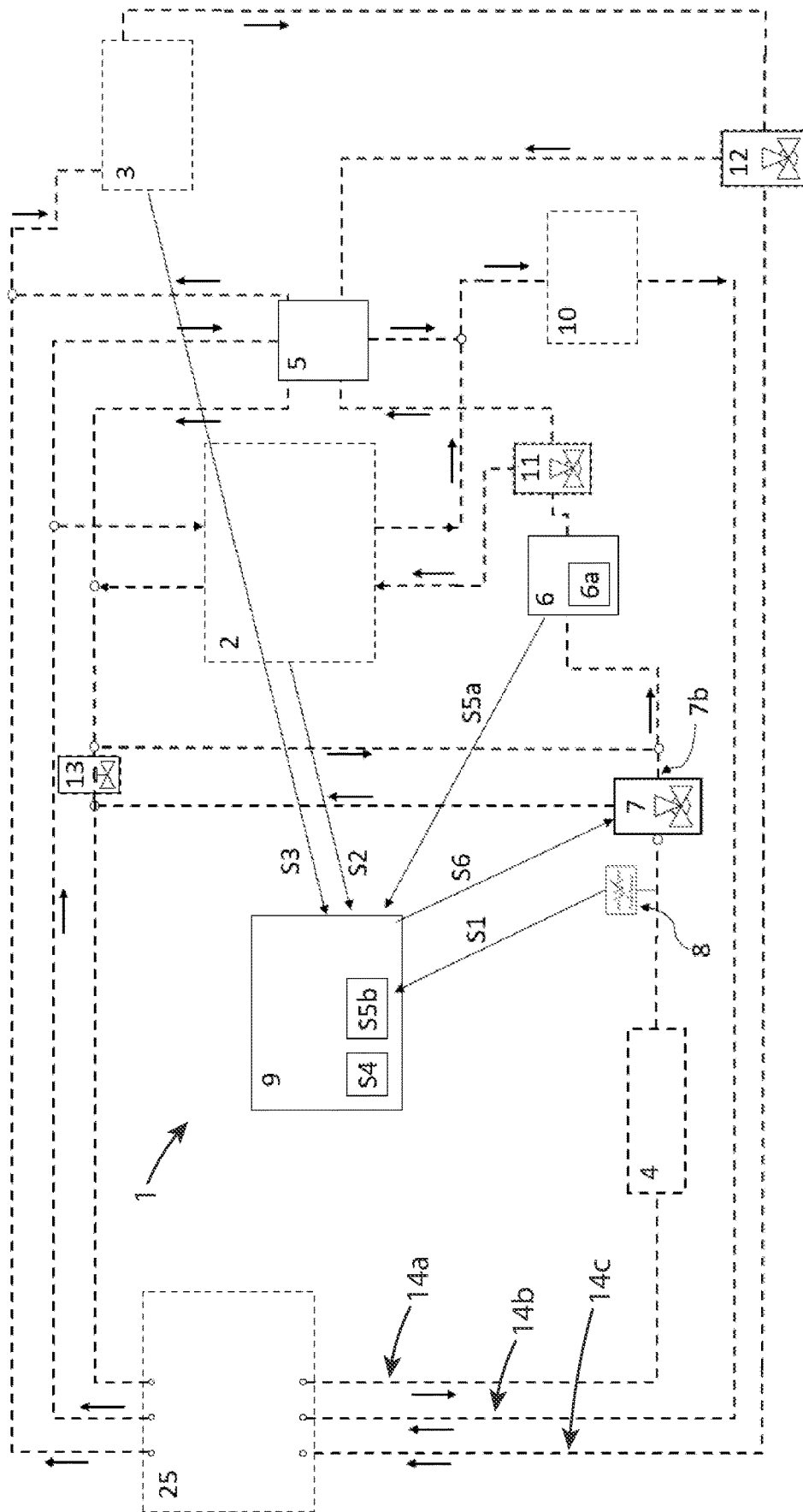


Fig. 2

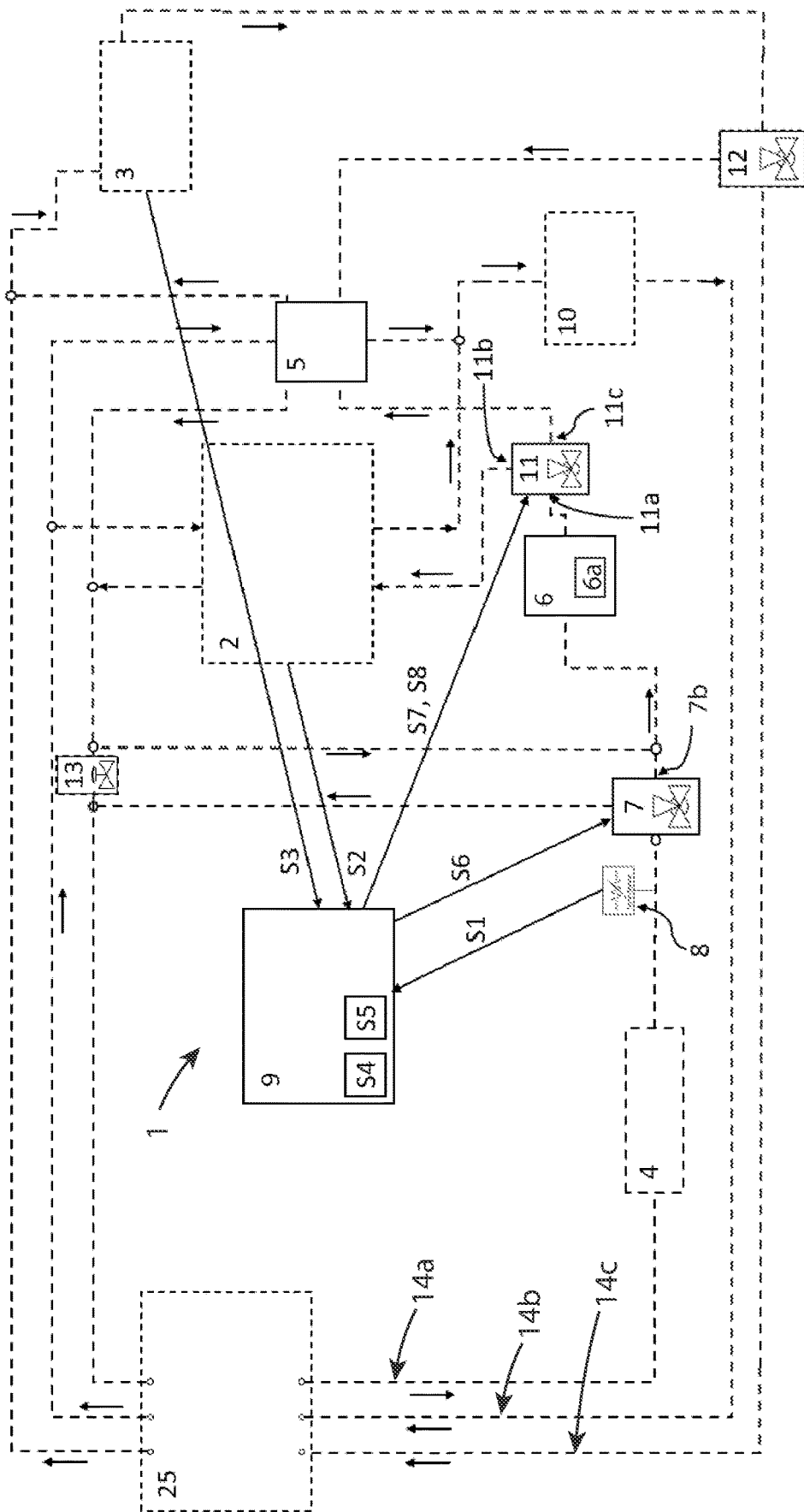


Fig. 3

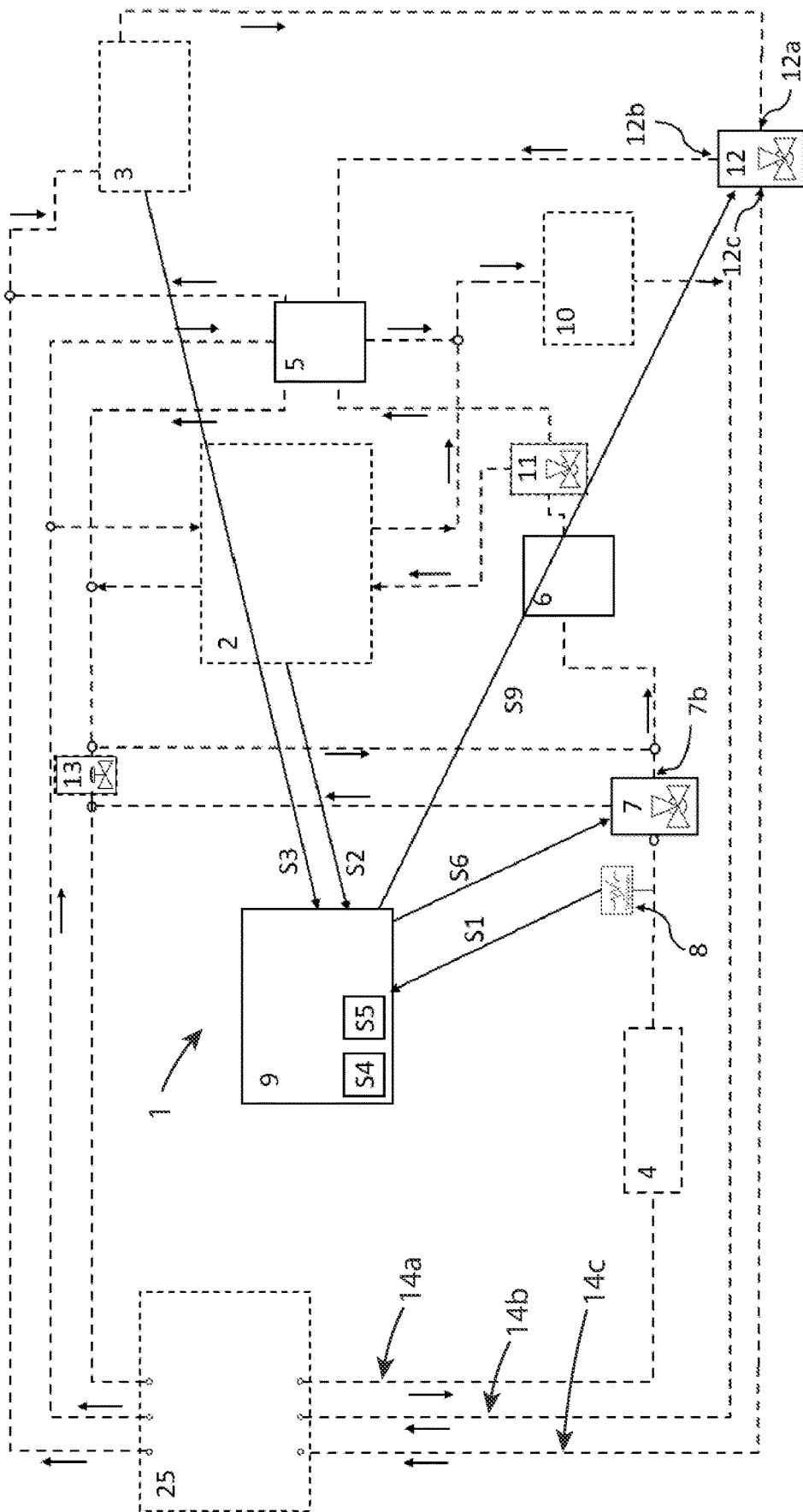


Fig. 4

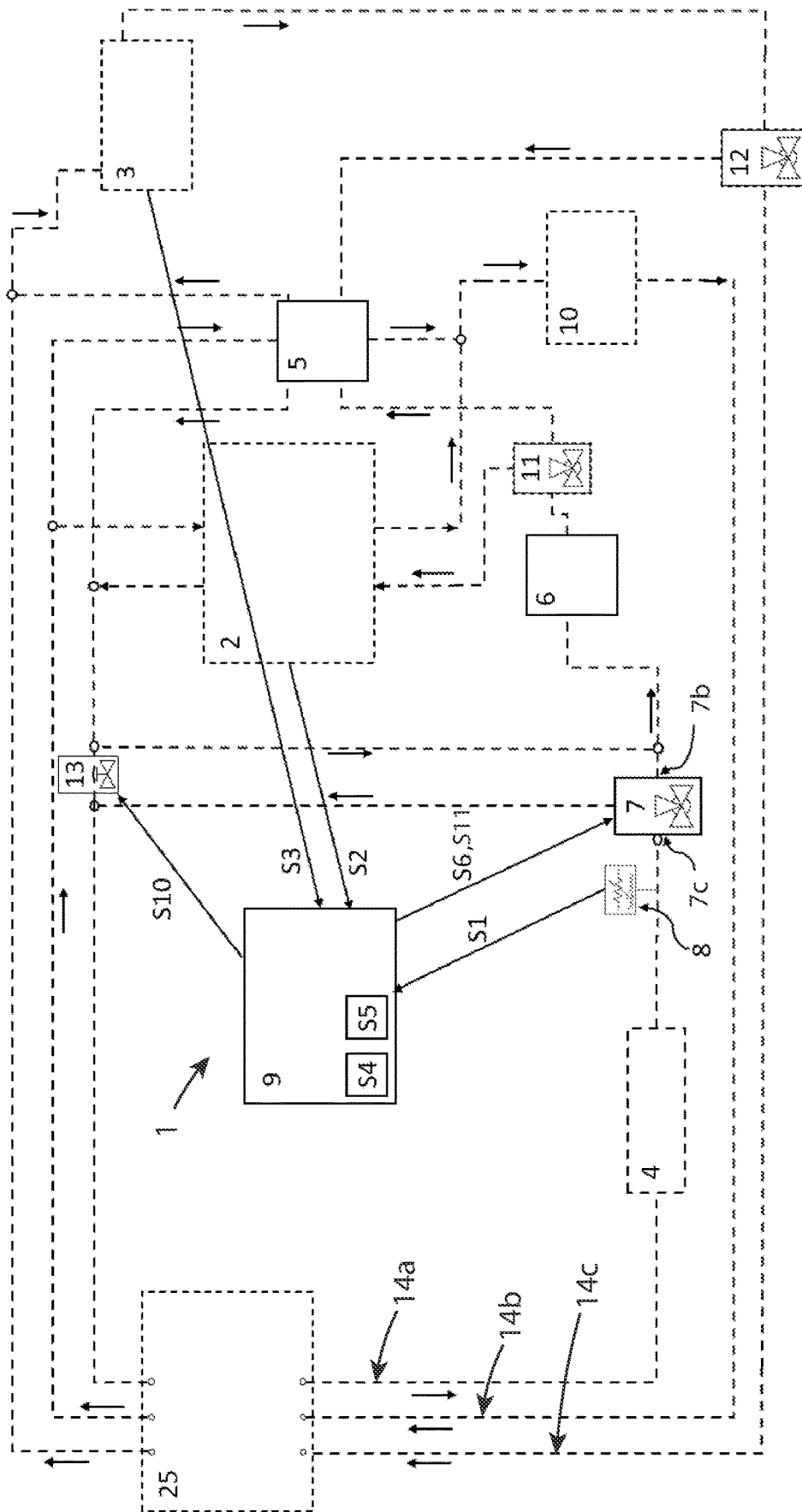


Fig. 6

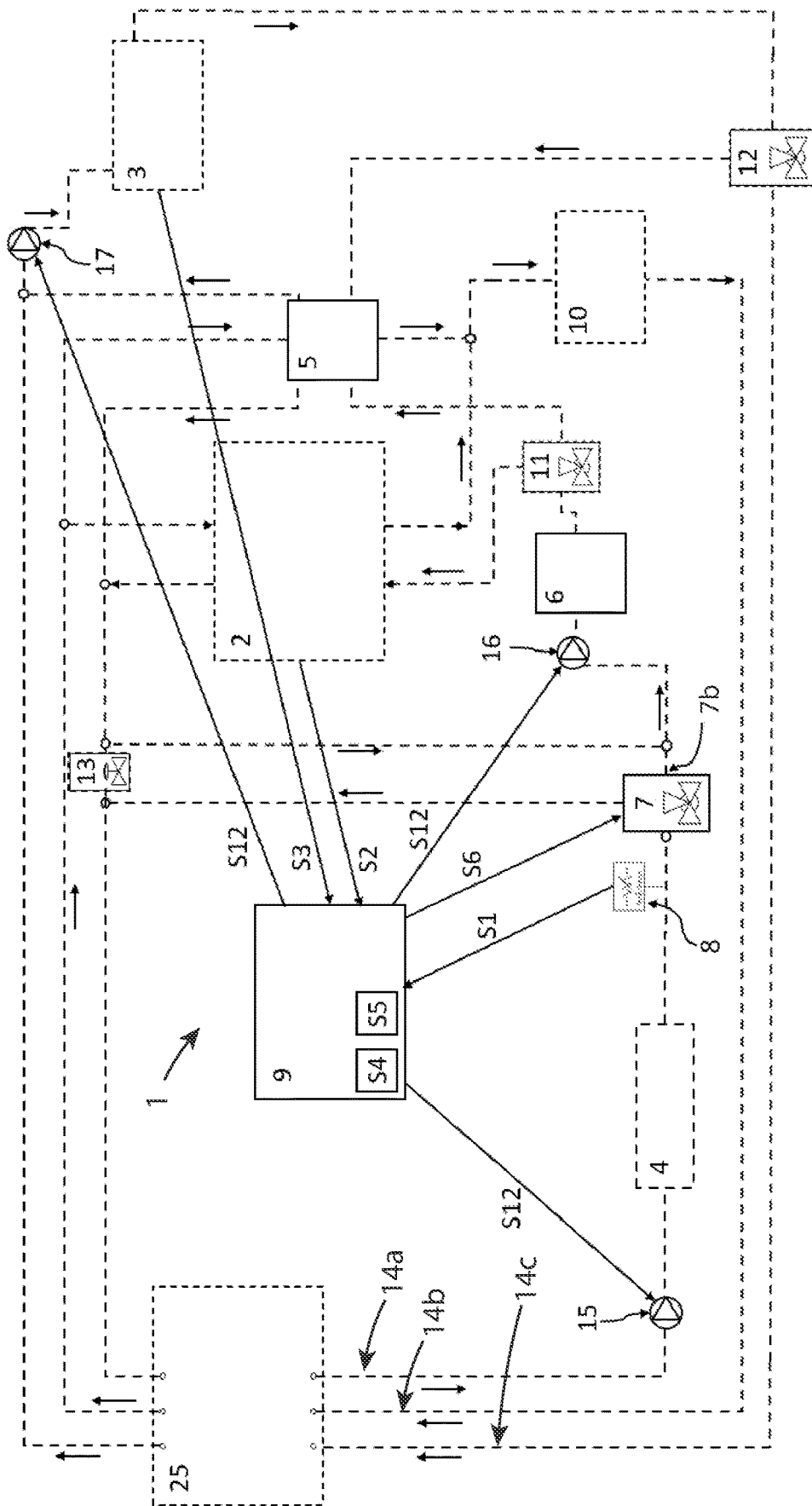


Fig. 7

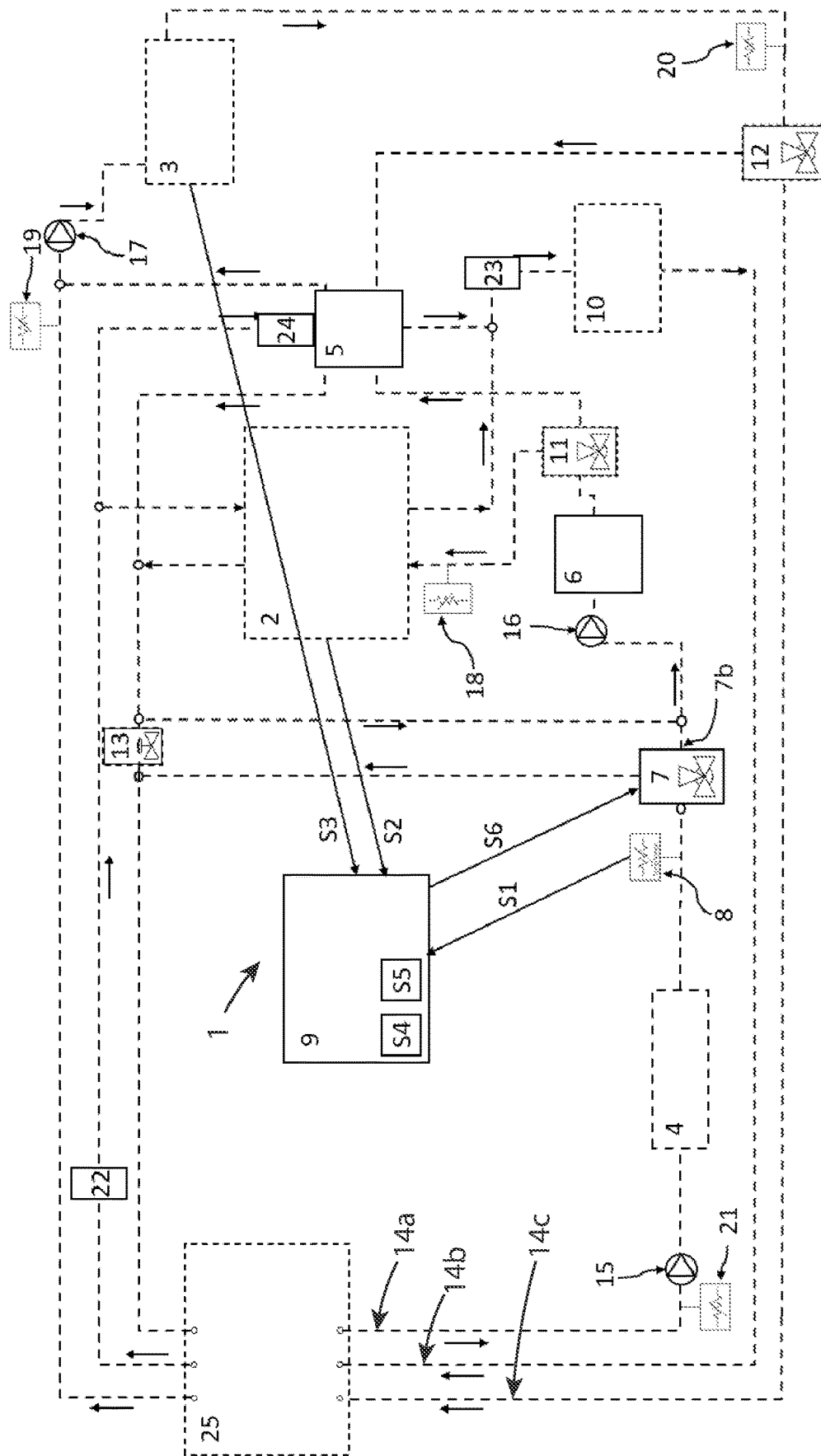


Fig. 8

**THERMAL MANAGEMENT SYSTEM AND
AN ELECTRIC VEHICLE INCLUDING THE
THERMAL MANAGEMENT SYSTEM**

TECHNICAL FIELD

[0001] The present disclosure relates to a thermal management system for controlling the temperature in a cabin and an energy storage system of an electric vehicle including a vehicle component. The present disclosure also relates to an electric vehicle comprising the thermal management system.

BACKGROUND

[0002] Electric vehicles are becoming more and more popular. On the one hand side they are preferable for environmental reasons, by avoiding fossil fuels, and on the other hand side they are, most of the cases, preferred in regard to reduced total cost of ownership.

[0003] Cars are not the only type of vehicle that can be an electric vehicle. For example, boats, trucks, locomotives, airplanes and heavy-duty vehicles are also available as electrical vehicles.

[0004] Electric vehicles are usually powered by an energy storage system during operation. The energy storage system here being defined as any kind of battery, battery pack or series of batteries for powering the electric vehicle.

[0005] For the usability of electric vehicles, it is important that the energy storage system has a long lifetime, i.e. a large number of charge/discharge cycles possible before the cells fail to operate satisfactorily. Keeping the energy storage system in an optimal temperature range is essential to maximize the lifetime.

[0006] Besides improving the energy storage system lifetime, keeping the energy storage system within the optimal temperature range during operation ensures that the energy storage system deliver as much power as possible.

[0007] As well as keeping the energy storage system at an optimal temperature, the temperature in the cabin, where the operator and passengers of the vehicle are housed, should also be regulated.

[0008] There are many systems for managing temperatures in the energy storage system and the cabin. For example in U.S. Pat. No. 7,789,176 B2, a thermal management system is presented which has a cooling loop for cooling the drive motor, a refrigeration subsystem which provides cooling to a heat exchanger, an energy storage cooling subsystem with a coolant cooled via heat transfer in the heat exchanger, and a HVAC subsystem that provides temperature control for the vehicle's passenger cabin. The HVAC subsystem is also coupled to the heat exchanger for its coolant to be cooled by the refrigeration subsystem and to the cooling loop for cooling the drive motor for its coolant to be heated by the cooling loop. In this solution, heat in the cooling loop for the drive motor can be used for heating the cabin and cold from the refrigeration subsystem can be used to cool both the energy storage system and the cabin. The energy storage cooling subsystem also has a heater if the energy storage system needs heating.

[0009] In an electric vehicle, the power for heating and cooling comes from the energy storage system. Therefore, it is essential that the thermal management is as energy efficient as possible so that more of the power of the energy storage system can be used for operating the electric vehicle.

[0010] Another important aspect of thermal management in an electric vehicle is that it takes up space in the vehicle as well as increases the weight. A space efficient and weight optimized thermal management system is therefore preferable.

SUMMARY

[0011] It is an aim of the present disclosure to at least partly overcome the above problems, and to provide an improved thermal management system for controlling the temperature in a cabin and an energy storage system of an electric vehicle including a vehicle component.

[0012] This aim is achieved by a device as defined in claim 1.

[0013] The disclosure provides a thermal management system for controlling the temperature in a cabin and an energy storage system of an electric vehicle including a vehicle component. The system comprises one heat exchanger arranged to heat the energy storage system, one heater arranged to heat the cabin when the cabin temperature is colder than a user selected temperature and to provide heat to the heat exchanger when the energy storage system is colder than a minimum temperature, a first valve arranged to receive thermal fluid that has been used for cooling the vehicle component, the first valve having an openable and closable outlet in fluid communication with the heater, a first temperature sensor arranged to measure the temperature of the received thermal fluid, and a control unit. The control unit is arranged to:

[0014] receive the measured temperature of the thermal fluid from the first temperature sensor,

[0015] receive data associated with a measured temperature in the cabin,

[0016] receive data associated with a measured temperature in the energy storage system,

[0017] determine if any of the cabin or the energy storage system is to be heated, based on the received data,

[0018] determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid, and

[0019] control the opening and closing of the outlet of the first valve so that the thermal fluid is provided to the heater via the outlet of the first valve when there is excess heat in the thermal fluid and any of the energy storage system and the cabin is to be heated.

[0020] The vehicle component can be any component of the electric vehicle that requires cooling with a thermal fluid. For example, the vehicle component can be one or more parts of the power train, any kind of e-motor, inverter or DC/DC converter.

[0021] The thermal management system is arranged so that excess heat from cooling the vehicle component can be used to heat the cabin and the energy storage system. For example, the excess heat can be used to heat both the cabin and the energy storage system. For the cabin, the heat is provided to a cooling and heating unit, e.g. a heating, ventilation, and air conditioning, HVAC unit, arranged in the cabin.

[0022] Using the data from the temperature sensor and input data associated with a measured temperature in the cabin and the energy storage system, the control unit can control the first valve so that excess heat from the vehicle component can be used in the cabin, the energy storage

system or in both. Thus, the use of energy from the energy storage system for heating the cabin and the energy storage system is reduced. Accordingly, the energy in the energy storage system will last longer, and the energy storage system needs to be charged less frequently.

[0023] The same heater is used to heat both the cabin and the energy storage system. By minimizing the number of heaters, the weight of the system is minimized. Furthermore, during operation of the electric vehicle, it is the energy storage system that powers any heaters. Therefore, it is also an advantage that only one heater is used for all heating in the thermal management system. Cost is also reduced by having only one heater.

[0024] With the term “to determine if there is excess heat in the thermal fluid” is meant to determine if the thermal fluid is warm enough to contribute to the heating of the cabin and the energy storage system.

[0025] According to some aspects, the heater comprises a heater temperature sensor arranged to measure the temperature of the thermal fluid in the heater, and the control unit is arranged to receive the measured temperature of the thermal fluid in the heater from the heater temperature sensor and to determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid from the first temperature sensor and the measured temperature of the thermal fluid in the heater.

[0026] According to some aspects, the control unit is arranged to determine that there is excess heat in the thermal fluid if the measured temperature of the thermal fluid from the first temperature sensor is warmer than the measured temperature of the thermal fluid in the heater. Thus, an efficient way of determining if there is excess heat in the thermal fluid that has been used for cooling the vehicle component, is achieved. If the measured temperature of the thermal fluid from the first temperature sensor is warmer than the measured temperature of the thermal fluid in the heater, the thermal fluid from cooling the vehicle component will be useful for heating the cabin and/or the energy storage system.

[0027] In other words, if the thermal fluid from cooling the vehicle component is warmer than the thermal fluid entering the heater, the thermal fluid from cooling the vehicle component would heat the thermal fluid entering the heater and accordingly there is excess heat in the thermal fluid from cooling the vehicle component.

[0028] According to some aspects, the thermal management system comprises one cooling unit arranged to cool the cabin when the cabin is warmer than a user selected temperature and to provide cold to the heat exchanger for cooling the energy storage system when the energy storage system is warmer than a predetermined maximum temperature. The same cooling unit is thus used for cooling both the cabin and the energy storage system. By minimizing the number of heaters and cooling units, the weight of the unit is minimized. Since, during operation of the electric vehicle, it is the energy storage system that powers the heater and the cooling unit, it is also an advantage that only one heater and only one cooling unit is used for all heating and cooling. Cost is also reduced by having only one cooling unit.

[0029] According to some aspects, the thermal management system comprises a second valve, which is a three-way valve, arranged with an inlet from the heater, a first outlet to the cabin and a second outlet to the heat exchanger, and the control unit is arranged to control the flow of thermal fluid

through the second valve. The control unit thus controls the flow to the cabin and the energy storage system via the second valve. In other words, the control unit controls the second valve to control if the thermal fluid is to flow to the cabin, to the energy storage system or to both.

[0030] According to some aspects, the control unit is arranged to:

[0031] control the opening and closing of the first outlet of the second valve so that the thermal fluid is provided to the cabin when there is excess heat in the thermal fluid and the cabin is to be heated,

[0032] control the opening and closing of the second outlet of the second valve so that the thermal fluid is provided to the heat exchanger when there is excess heat in the thermal fluid and the energy storage system is to be heated.

[0033] According to some aspects, the thermal management system comprises a third valve, which is a three-way valve, arranged with an inlet from the energy storage system, a first outlet to the heat exchanger and a second outlet to an external passive cooling system, and wherein the control unit is arranged to:

[0034] control the opening and closing of the first outlet and second outlet of the third valve so that a third thermal fluid which is used to heat or cool the energy storage system is directed either to the heat exchanger or to the external passive cooling system.

[0035] In a case when there is no need to heat or cool the energy storage system, the control unit may control the third valve so that the thermal fluid does not pass the heat exchanger. The valve can also be controlled so that the fluid only passes the heat exchanger.

[0036] According to some aspects, the thermal management system comprises a second temperature sensor, arranged to measure the temperature of the thermal fluid entering the third valve. The control unit is arranged to:

[0037] receive the measured temperature of the third thermal fluid from the second temperature sensor,

[0038] control the opening and closing of the first outlet and the second outlet of the third valve based on the received temperature.

[0039] With the measured temperature, together with the data associated with a measured temperature in the energy storage system, it is known if the energy storage system needs heating or cooling. The control unit may thus control the third valve based on the received data. It should be noted that the second temperature sensor may be external to the thermal management system.

[0040] According to some aspects, the first valve has a second openable and closable outlet and the thermal management system comprises a fourth valve. The control unit is arranged to:

[0041] control the opening and closing of the fourth valve so that it is opened when the first outlet of the first valve is opened and closed when the first outlet of the first valve is closed, and

[0042] control the opening and closing of the second outlet so that it is opened when the first outlet of the first valve is closed and opened when the first outlet of the first valve is closed.

[0043] With this, it is possible to have a loop for the thermal fluid for cooling the vehicle component when there is no excess heat in the thermal fluid or if the cabin or energy storage system does not need any heat.

[0044] According to some aspects, the thermal management system comprises one or more pumps and wherein the control unit is arranged to:

[0045] control the speed of the one or more pumps based on the based on the received the received data and on the received measured temperature.

[0046] Thus, besides controlling one or more valves, the control unit may also control the flow of thermal fluid through one or more pumps. The control unit can thus have more control over the system and also use flow rate as a factor when heating or cooling.

[0047] According to some aspects, the heat exchanger is a chiller. A chiller is a plate-to-plate heat exchanger that transfers thermal energy from a thermal fluid to another thermal fluid, or from one fluid to several fluids.

[0048] The aim is also achieved by an electric vehicle as defined in claim 12. The vehicle comprises a cabin, an energy storage system, a vehicle component, a thermal fluid for cooling the vehicle component, and the thermal management system according to the invention. The vehicle is, for example, of a short-distance type, such as bulldozers and excavators, which are carrying out work within a small area and not intended for long distance travels. The vehicle can also be of a long-distance type, such as cars, busses and trucks, intended for transportation of people and/or goods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] The invention will now be explained more closely by the description of different aspects and with reference to the appended figures.

[0050] FIG. 1 shows a schematic diagram of an example thermal management system.

[0051] FIG. 2 shows a schematic diagram of an example thermal management system with added input of a temperature sensor.

[0052] FIG. 3 shows a schematic diagram of an example thermal management system with added control of an additional valve.

[0053] FIG. 4 shows a schematic diagram of an example thermal management system with added control of an additional valve.

[0054] FIG. 5 shows a schematic diagram of an example thermal management system with added input of an additional temperature sensor.

[0055] FIG. 6 shows a schematic diagram of an example thermal management system with added control of an additional valve.

[0056] FIG. 7 shows a schematic diagram of an example thermal management system with added control of one or more pumps.

[0057] FIG. 8 shows a schematic diagram of an example thermal management system with examples of added temperature sensors, pumps, pressure sensors and a thermal expansion valve.

DETAILED DESCRIPTION

[0058] The present invention is not limited to the embodiments disclosed but may be varied and modified within the scope of the following claims. For example, pumps, temperature sensors and pressure sensors may be added to many different places in the thermal management system. Some

examples of where it may be advantageous to add pumps, temperature sensors and/or pressure sensors are described below.

[0059] Aspects of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings. The thermal management system disclosed herein can, however, be realized in many different forms and should not be construed as being limited to the aspects set forth herein. Like numbers in the drawings refer to like elements throughout.

[0060] The terminology used herein is for the purpose of describing particular aspects of the disclosure only and is not intended to limit the disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs.

[0061] As also stated in the background section, an energy storage system is herein being defined as any kind of battery pack or series of batteries for powering the electric motor of the electric vehicle. In other words, when the term energy storage system is used in this disclosure, a singular battery or a plurality of batteries is included in the term. An energy storage system for an electric vehicle usually comprises several batteries in series.

[0062] FIG. 1 shows a schematic diagram of an example thermal management system 1. The thermal management system 1 is for controlling the temperature in a cabin 2 and an energy storage system 3 of an electric vehicle including a vehicle component 4. Dotted lines in FIG. 1 represents parts that are not included in the thermal management system 1. Continuous lines represent included parts. The same applies to aspects described below with the associated figures.

[0063] The vehicle component is any component of the electric vehicle that requires cooling with a thermal fluid. For example, the vehicle component can be any kind of e-motor, inverter or

[0064] DC/DC converter.

[0065] The thermal management system 1 comprises one heat exchanger 5 arranged to heat the energy storage system 3, one heater 6 arranged to heat the cabin 2 when the cabin temperature is colder than a user selected temperature, and to provide heat to the heat exchanger 5 when the energy storage system 3 is colder than a minimum temperature. The heat exchanger 5 is arranged to transfer thermal energy from a thermal fluid to another thermal fluid, or from one fluid to several fluids. The heat exchanger 5 is, for example, a chiller. A chiller is a plate-to-plate heat exchanger that transfers thermal energy from a thermal fluid to another thermal fluid, or from one fluid to several fluids. The heater 6 is for example a high voltage heater, a Low-Voltage resistor heater, a PTC-type heater, or an AC-powered heater. It could also be the condensing part of a heat-pump system. The heater 6 may be any heater for heating thermal fluids suitable to be arranged in an electric vehicle. It should be noted that the same heater 6 is used to both heat the cabin 2 and to heat the energy storage system 3. The heater is powered by the energy storage system 3 but it may also be powered by an external power source when the electric vehicle is connected to such, for example when it is charging.

[0066] The system 1 comprises a first valve 7 having an inlet 7a arranged to receive a thermal fluid from the vehicle component 4, which thermal fluid has been used for cooling the vehicle component 4. The first valve 7 has an openable and closable first outlet 7b in fluid communication with the heater 6. In other words, the first valve 7 receives thermal fluid that has been used to cool the vehicle component 4 of the electric vehicle. The thermal fluid passes on to the heater 6 if the first outlet 7b is open. The thermal fluid is transported in a passage 14a, the passage being for example piping. In the figures, the passages 14a-c are illustrated as lines, and arrows in connection with the lines show the flow direction of the thermal fluid. The first valve 7 can be any kind of valve with an inlet and an openable and closable outlet. The valve is a valve that can be controlled via signals from a control unit, either via wire or wireless signals. The same applies to any valves described below.

[0067] A first temperature sensor 8 is arranged to measure the temperature of the received thermal fluid that has been used for cooling the vehicle component 4. The first temperature sensor 8 is, for example, arranged in the first valve 7 or in a passage before the thermal fluid enters the first valve 7.

[0068] The thermal management system 1 comprises a control unit 9. The control unit 9 is arranged to:

[0069] receive S1 the measured temperature of the thermal fluid from the first temperature sensor 8,

[0070] receive S2 data associated with a measured temperature in the cabin 2,

[0071] receive S3 data associated with a measured temperature in the energy storage system 3,

[0072] determine S4 if any of the cabin 2 or the energy storage system 3 are to be heated, based on the received data,

[0073] determine S5 if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid, and

[0074] control S6 the opening and closing of the first outlet 7b of the first valve 7 so that the thermal fluid is provided to the heater 6 via the first outlet 7b of the first valve 7 when there is excess heat in the thermal fluid and any of the energy storage system 3 and the cabin 2 is to be heated.

[0075] The thermal management system 1 is arranged so that excess heat from cooling the vehicle component 4 can be used for heating and cooling in the cabin 2 and in an energy storage system 3. The same heater 6 in the unit is used to heat both the cabin 2 and the energy storage system 3. Using the data from the temperature sensor and input data associated with a measured temperature in the cabin 2 and the energy storage system 3, the control unit 9 can control the first valve 7 so that excess heat from the vehicle component 4 can be used in the cabin 2, the energy storage system 3 or in both.

[0076] By minimizing the number of heaters, the weight of the system is minimized. Furthermore, during operation of the electric vehicle, it is the energy storage system 3 that powers any heaters. Therefore, it is also an advantage that only one heater 6 is used for all heating in the thermal management system 1. Cost is also reduced by having only one heater 6.

[0077] The steps S1 to S6 are illustrated in FIG. 1. The control unit 9 comprises processing circuitry for processing data and either comprises communication circuitry or is

connected to communication circuitry for receiving sensor data and sending instructions for the components it is controlling. Communication between the control unit 9 and the components, i.e. any valves, pumps, pressure sensors and/or thermal expansion valves, may comprise wired or wireless communication.

[0078] The data associated with a measured temperature in the cabin 2 may be data indicating an actual temperature in the cabin 2 or a number of degrees that the cabin 2 is differing from a desired temperature. For example, if the cabin 2 is set to be 22° C. to be comfortable to an operator of the electric vehicle, and the actual temperature is 20° C., the data associated with a measured temperature in the cabin 2 may be 20° C. In such a case the control unit 9 compares the desired temperature to the measured temperature to determine that more heat is needed. It may also be that the data associated with a measured temperature in the cabin 2 is -2° C. to indicate that the cabin 2 needs two more degrees to reach the desired temperature. It may also be that the data associated with a measured temperature only gives an indication that more heat is needed, without a specific number. It may also be that the data associated with a measured temperature is given in percent where, for example, 0% is an indication that no heating or cooling is required, and each percent represents a predetermined number of degrees to be changed.

[0079] The data associated with a measured temperature in the energy storage system 3 may be in a corresponding form. Either an actual temperature is sent to the control unit 9, and in the case of large battery packs, the actual temperature may be an average of several temperature sensors arranged in different locations in the energy storage system 3, or the difference between the actual temperature is sent, or only an indication of whether the energy storage system 3 needs to be heated is sent.

[0080] The data associated with a measured temperature in the cabin 2 and the energy storage system 3 may also be indicated in other ways than described above.

[0081] To determine S4 if any of the cabin 2 or the energy storage system 3 is to be heated, based on the received data, may be different depending on in which way the received data indicates the measured temperature as discussed above. If an actual temperature of the cabin 2 or energy storage system 3 is received, determining S4 if any of the cabin 2 or the energy storage system 3 is to be heated may comprise comparing the received data to a reference list or to a previously received desired temperature of the cabin 2. If it is a difference in desired temperature and actual temperature, the determining may be to determine if the cabin 2 or energy storage system 3 is too warm or too cold. If the data associated with a measured temperature only gives an indication that more heat is needed, then the determining may only be to check the received data.

[0082] To control S6 the opening and closing of the first outlet 7b of the first valve 7 so that the thermal fluid is provided to the heater 6 via the first outlet 7b of the first valve 7 when there is excess heat in the thermal fluid and any of the energy storage system 3 and the cabin 2 is to be heated may comprise to send a signal to the valve with instructions to open the first outlet 7b. This is done when the thermal fluid from the vehicle component 4 is so warm that it can be used to heat the cabin 2 or the energy storage system 3.

[0083] The control unit 9 may also be arranged to communicate with the electric vehicle and receive instructions,

give feedback to the electric vehicle, as well as receive and transmit states of the electric vehicle and the thermal management system and potential errors in the thermal management system **1** or the used components.

[0084] It should be noted that there are parts illustrated in the FIGS. **1-7** that are not part of the thermal management system **1**. For example, the vehicle component **4**, and its cooling system with thermal fluid, are parts of the vehicle. Also, a passive cooling system **25**, is often present in electric vehicles but are not part of the described thermal management system **1**. The cabin **2** and the heating and cooling system, e.g. HVAC, of the cabin **2** are parts of the vehicle and not included in the thermal management system **1**. A cooling unit **10** is optional in the system and is described below. Valves **11**, **12** and **13** are also optional for the system.

[0085] In FIG. **1**, an example of how the thermal management system **1** can be connected to parts in the vehicle is illustrated. Three passages **14a-c** for cooling is passing a passive cooling system **25** of the vehicle. The inner passage **14a** is used to cool the vehicle component **4** of the electric vehicle. The thermal management system **1** comprises a temperature sensor **8** to determine if there is excess heat in the thermal fluid. This means to determine if the thermal fluid used for cooling the external component is warm enough to contribute to the heating of the cabin and the energy storage system. If not, the thermal fluid can be circled back to the passive cooling system **25** via a second outlet **7c** of the first valve **7**. If there is excessive heat, the thermal fluid can be passed on to the heater **6**, via the first outlet **7b** of the valve **7** so that the heater can heat the thermal fluid less than without the heat from the thermal fluid from the vehicle component. In this example, the thermal management system **1** comprises a second valve **11** which can be used to determine if the thermal fluid then should be used to heat the cabin or the energy storage system via the heat exchanger or both.

[0086] The middle passage **14b** via the passive cooling system **25** goes via a cooling unit **10** and a second thermal fluid in this passage **14b** is used to cool the cabin and/or the energy storage system via the heat exchanger **5**.

[0087] The thermal management system may comprise a third valve **12**. The outer passage **14c** is used for cooling the energy storage system and is selectively connected to the heat exchanger **5** via the third valve **12**. The third thermal fluid of the outer passage **14c** can be both heated and cooled at the heat exchanger. When it is to be cooled, it is cooled via the heat exchanger by the second thermal fluid and when it is heated, it is heated via the heat exchanger by the thermal fluid from the heater **6**.

[0088] The heater **6** may comprise a heater temperature sensor **6a** arranged to measure the temperature of the thermal fluid in the heater **6**, as illustrated in FIG. **2**. In that case, to determine **S5** if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid comprises to receive **S5a** the measured temperature of the thermal fluid in the heater **6** from the heater temperature sensor, and to determine **S5b** if the measured temperature of the thermal fluid from the first temperature sensor **8** is warmer than the measured temperature of the thermal fluid in the heater **6**. Thus, an efficient way of determining if there is excess heat in the thermal fluid that has been used for cooling the vehicle component, is achieved. If the measured temperature of the thermal fluid from the first temperature sensor is warmer than the mea-

asured temperature of the thermal fluid in the heater, the thermal fluid from cooling the vehicle component will be useful for heating the cabin and/or the energy storage system. In other words, if the thermal fluid from cooling the vehicle component is warmer than the thermal fluid entering the heater, the thermal fluid from cooling the vehicle component would heat the thermal fluid entering the heater and accordingly there is excess heat in the thermal fluid from cooling the vehicle component. The heater temperature sensor **6a** may also be arranged outside of the heater **6** as a separate component.

[0089] An alternative way to determine **S5**, if there is excess heat in the thermal fluid used for cooling the vehicle component **4** based on the received measured temperature of the thermal fluid, is to compare the received measured temperature in the thermal fluid used for cooling the vehicle component **4** to a temperature of the thermal fluid measured at a fourth temperature sensor **18**, which is described further below in association with FIG. **8**.

[0090] The thermal management system **1** may comprise one cooling unit **10** arranged to cool the cabin **2** when the cabin **2** is warmer than a user selected temperature and to provide cold to the heat exchanger **5** for cooling the energy storage system **3** when the energy storage system **3** is warmer than a predetermined maximum temperature. The same cooling unit **10** is thus used for cooling both the cabin **2** and the energy storage system **3**. By minimizing the number of heaters and cooling units, the weight of the unit is minimized. Since, during operation of the electric vehicle, it is the energy storage system **3** that powers the heater **6** and the cooling unit **10**, it is also an advantage that only one heater **6**, and only one cooling unit **10** is used for all heating and cooling. The cost of the system is also minimized by having only one heater **6** and one cooling unit **10**.

[0091] The cooling unit **10** is for example a compressor which, together with a thermal expansion valve arranged in association with an evaporator in the cabin and the heat exchanger, forms two refrigeration machines. In such a case, the middle passage **14b** that is connected to the compressor **10** is for transporting a second thermal fluid in the form of a thermal vapor. The cooling unit **10** may also be a heat-pump system.

[0092] The control unit **9** may also be arranged to control the power to the heater **6** and thus how much the thermal fluid flowing through the heater **6** should be heated. The control may be based on the same parameters as the control of the first valve **7**, i.e. the temperature of the thermal fluid and the data associated with the temperature of the cabin **2** and/or energy storage system **3**.

[0093] FIG. **3** shows a schematic diagram of an example thermal management system **1** with added control of an additional valve. The thermal management system **1** may comprise a second valve **11**, which is a three-way valve, arranged with an inlet **11a** from the heater **6**, a first outlet **11b** to the cabin **2** and a second outlet **11c** to the heat exchanger **5**, and the control unit **9** is arranged to control the flow of thermal fluid through the second valve **11**. The control unit **9** thus controls the flow to the cabin **2** and the energy storage system **3** via the second valve **11**. In other words, the control unit **9** controls the second valve and thus if the thermal fluid is to flow from the heater **6** to the cabin **2**, to the energy storage system **3** or to both.

[0094] To control the second valve **11**, the control unit **9** may be arranged to control **S7** the opening and closing of the

first outlet **11b** of the second valve **11** so that the thermal fluid is provided to the cabin **2** when there is excess heat in the thermal fluid, and the cabin **2** is to be heated, and to control **S8** the opening and closing of the second outlet **11c** of the second valve **11** so that the thermal fluid is provided to the heat exchanger **5** when there is excess heat in the thermal fluid and the energy storage system **3** is to be heated.

[0095] FIG. 4 shows a schematic diagram of an example thermal management system **1** with added control of an additional valve. The thermal management system **1** may comprise a third valve **12**, which is a three-way valve, arranged with an inlet **12a** from the energy storage system **3**, a first outlet **12b** to the heat exchanger **5** and a second outlet **12c** to a passive cooling system **25** of the vehicle, and wherein the control unit **9** is arranged to control **S9** the opening and closing of the first outlet **12b** and second outlet **12c** of the third valve **12** so that a second thermal fluid which is used to heat or cool the energy storage system **3** is directed either to the heat exchanger **5** or to the passive cooling system **25**. In a case when there is no need to heat or cool the energy storage system **3**, the control unit **9** may control the third valve so that the thermal fluid does not pass the heat exchanger **5**, i.e. close the first outlet **12b**. The valve can also be controlled so that the fluid only passes the heat exchanger **5**, i.e. open the first outlet **12b** and close the second outlet **12c**.

[0096] FIG. 5 shows a schematic diagram of an example thermal management system **1** with added input of an additional temperature sensor. The thermal management system **1** may comprise a second temperature sensor **20**, arranged to measure the temperature of the thermal fluid entering the third valve **12**. The control unit **9** is then arranged to receive **S9a** the measured temperature of the thermal fluid from the second temperature sensor **20** and to control **S9b** the opening and closing of the first outlet **12b** and the second outlet **12c** of the third valve **12** based on the received temperature.

[0097] With the measured temperature, together with the data associated with a measured temperature in the energy storage system **3**, it is known if the energy storage system **3** needs heating or cooling. The control unit **9** may thus control the third valve **12** based on the received data. It should be noted that the second temperature sensor **20** may be a part of the vehicle comprising the thermal management system **1**.

[0098] FIG. 6 shows a schematic diagram of an example thermal management system **1** with added control of an additional valve. The first valve **7** has a second openable and closable outlet **7c**. The thermal management system **1** comprises a fourth valve **13**. The control unit **9** is then arranged to control **S10** the opening and closing of the fourth valve **13** so that it is opened when the first outlet **7b** of the first valve **7** is opened, and closed when the first outlet **7b** of the first valve **7** is closed, and to control **S11** the opening and closing of the second outlet **7c** so that it is opened when the first outlet **7b** of the first valve **7** is closed and opened when the first outlet **7b** of the first valve **7** is closed.

[0099] With this, it is possible to have a loop for the thermal fluid for cooling the vehicle component **4** when there is no excess heat in the thermal fluid or if the cabin **2** or energy storage system **3** does not need any heat. As can be seen in FIG. 6, if the first valve **7** and the fourth valve **13** are both closed, a loop where the vehicle component **4** is cooled via the passive cooling system **25** is created. When

both valves **7**, **13** are open, the thermal fluid from cooling the vehicle component **4** is used to heat the cabin **2** or the energy storage system **3** or both.

[0100] FIG. 7 shows a schematic diagram of an example thermal management system **1** with added control of one or more pumps **15**, **16**, **17**. The thermal management system **1** may comprise one or more pumps **15**, **16**, **17** and the control unit **9** is then arranged to control **S12** the speed of the one or more pumps **15**, **16**, **17** based on the based on the received data and the received measured temperature. Thus, besides controlling one or more valves, the control unit **9** may also control the flow of thermal fluid through one or more pumps **15**, **16**, **17**. The control unit **9** can thus have more control over the system and also use flow rate as a factor when heating or cooling. The first pump **15**, the second pump **16** and the third pump **17** may be added to the system independently from each other.

[0101] The controlling of all valves and pumps may also be based on the selected temperature and the predetermined minimum temperature of the energy storage system **3**.

[0102] FIG. 8 shows a schematic diagram of an example thermal management system **1** with examples of added temperature sensors **18**, **19**, **20**, **21**, pumps **15**, **16**, **17**, pressure sensors **22**, **23** and a thermal expansion valve **24**. Only the parts described in claim **1** are necessary to achieve the aim of the disclosure. Other parts are optional or arranged outside of the system as has also been explained above.

[0103] The pressure sensors **22**, **23** are indicative of the temperature if the passages **14** are transporting refrigerant gas. The pressure sensors **22**, **23** may be arranged in the vehicle comprising the system **1**. The control unit can use input from the pressure sensor to, for example, control the thermal expansion valve **24** and/or the cooling unit **10**. When the thermal fluid is a refrigerant gas, it is for example R134a or R1234YF or similar. It should be noted that different parts of the piping may hold different types of thermal fluid, such as a glycol coolant, water or a refrigerant gas. In general, passages that transport thermal fluid for cooling has a refrigerant gas and passages for heating comprises a thermal liquid. But other solutions are possible.

[0104] The thermal expansion valve **24** controls the amount of refrigerant released into the evaporator, which is a part of the heat exchanger and is intended to regulate the superheat of the vapor leaving the evaporator. The thermal expansion valve may also be integrated in the heat exchanger, or a thermal expansion valve may be arranged in the vehicle comprising the system **1**. The thermal expansion valve can be pressure controlled or electrical controlled.

[0105] It can be electrically engaged (normally closed or normally opened) or just pressure engaged.

LIST OF REFERENCES

- [0106]** 1. Thermal management system
- [0107]** 2. Cabin
- [0108]** 3. Energy storage system
- [0109]** 4. Vehicle component
- [0110]** 5. Heat exchanger
- [0111]** 6. Heater
- [0112]** a. Heater temperature sensor
- [0113]** 7. First valve
- [0114]** a. Inlet
- [0115]** b. First outlet
- [0116]** c. Second outlet

- [0117] 8. First temperature sensor
- [0118] 9. Control unit
- [0119] 10. Cooling unit
- [0120] 11. Second valve
- [0121] a. Inlet
- [0122] b. First outlet
- [0123] c. Second outlet
- [0124] 12. Third valve
- [0125] a. Inlet
- [0126] b. First outlet
- [0127] c. Second outlet
- [0128] 13. Fourth valve
- [0129] 14. Passage for thermal fluid
- [0130] a. First passage
- [0131] b. Second passage
- [0132] c. Third passage
- [0133] 15. First pump
- [0134] 16. Second pump
- [0135] 17. Third pump
- [0136] 18. Fourth temperature sensor
- [0137] 19. Third temperature sensor
- [0138] 20. Second temperature sensor
- [0139] 21. Fifth temperature sensor
- [0140] 22. First pressure sensor
- [0141] 23. Second pressure sensor
- [0142] 24. Thermal expansion valve
- [0143] 25. External passive cooling system

1. A thermal management system for controlling the temperature in a cabin and an energy storage system of an electric vehicle including a vehicle component, the system comprising:

- one heat exchanger arranged to heat the energy storage system,
- one heater arranged to heat the cabin when the cabin temperature is colder than a user selected temperature and to provide heat to the heat exchanger when the energy storage system is colder than a minimum temperature,
- a first valve arranged to receive a thermal fluid that has been used for cooling the vehicle component, the first valve having an openable and closable outlet in fluid communication with the heater,
- a first temperature sensor arranged to measure the temperature of the received thermal fluid, and
- a control unit arranged to:
 - receive the measured temperature of the thermal fluid from the first temperature sensor,
 - receive data associated with a measured temperature in the cabin,
 - receive data associated with a measured temperature in the energy storage system,
 - determine if any of the cabin or the energy storage system is to be heated, based on the received data,
 - determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid used for cooling the vehicle component, and
 - control the opening and closing of the outlet of the first valve so that the thermal fluid is provided to the heater via the outlet of the first valve when there is excess heat in the thermal fluid and any of the energy storage system and the cabin is to be heated.

2. The thermal management system according to claim 1, wherein the heater comprises a heater temperature sensor

arranged to measure the temperature of the thermal fluid in the heater, and the control unit is arranged to receive the measured temperature of the thermal fluid in the heater from the heater temperature sensor and to determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid from the first temperature sensor and the measured temperature of the thermal fluid in the heater.

3. The thermal management system according to claim 1, comprising:

- one cooling unit arranged to cool the cabin when the cabin is warmer than a user selected temperature and to provide cold to the heat exchanger for cooling the energy storage system when the energy storage system is warmer than a predetermined maximum temperature.

4. The thermal management system according to claim 1, comprising a second valve, which is a three-way valve, arranged with an inlet arranged to receive the thermal fluid from the heater, a first outlet in fluid communication with the cabin and a second outlet in fluid communication with the heat exchanger, and the control unit is arranged to control the flow of thermal fluid through the second valve.

5. The thermal management system according to claim 4, wherein the control unit is arranged to:

- control the opening and closing of the first outlet of the second valve so that the thermal fluid is provided to the cabin when there is excess heat in the thermal fluid and the cabin is to be heated,
- control the opening and closing of the second outlet of the second valve so that the thermal fluid is provided to the heat exchanger when there is excess heat in the thermal fluid and the energy storage system is to be heated.

6. The thermal management system according to claim 1, comprising a third valve, which is a three-way valve, arranged with an inlet from the energy storage system, a first outlet to the heat exchanger and a second outlet to an external passive cooling system, and wherein the control unit (is arranged to:

- control the opening and closing of the first outlet and second outlet of the third valve so that a third thermal fluid which is used to heat or cool the energy storage system is directed either to the heat exchanger or to the external passive cooling system.

7. The thermal management system according to claim 6, comprising a second temperature sensor, arranged to measure the temperature of the third thermal fluid entering the third valve, and wherein the control unit is arranged to:

- receive the measured temperature of the third thermal fluid from the second temperature sensor,
- control the opening and closing of the first outlet and the second outlet of the third valve based on the received temperature.

8. The thermal management system according to claim 1, wherein the first valve has a second openable and closeable outlet and the thermal management system comprises a fourth valve wherein the control unit is arranged to:

- control the opening and closing of the fourth valve so that it is opened when the first outlet of the first valve is opened and closed when the first outlet of the first valve is closed, and
- control the opening and closing of the second outlet so that it is opened when the first outlet of the first valve is closed and opened when the first outlet of the first valve is closed.

9. The thermal management system according to claim **1**, comprising one or more pumps and wherein the control unit is arranged to:

control the speed of the one or more pumps based on the received data and on the received measured temperature.

10. The thermal management system according to claim **1**, wherein the heat exchanger is a chiller.

11. An electric vehicle comprising a cabin, an energy storage system, a vehicle component, a thermal fluid for cooling the vehicle component, and a thermal management system including:

one heat exchanger arranged to heat the energy storage system

one heater arranged to heat the cabin when the cabin temperature is colder than a user selected temperature and to provide heat to the heat exchanger when the energy storage system is colder than a minimum temperature,

a first valve arranged to receive a thermal fluid that has been used for cooling the vehicle component, the first valve having an openable and closable outlet in fluid communication with the heater,

a first temperature sensor arranged to measure the temperature of the received thermal fluid, and

a control unit arranged to:

receive the measured temperature of the thermal fluid from the first temperature sensor,

receive data associated with a measured temperature in the cabin,

receive data associated with a measured temperature in the energy storage system,

determine if any of the cabin or the energy storage system is to be heated, based on the received data,

determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid used for cooling the vehicle component, and

control the opening and closing of the outlet of the first valve so that the thermal fluid is provided to the heater via the outlet of the first valve when there is

excess heat in the thermal fluid and any of the energy storage system and the cabin is to be heated.

12. The electric vehicle according to claim **11**, wherein the thermal management system further comprises a heater temperature sensor arranged to measure the temperature of the thermal fluid in the heater, and the control unit is arranged to receive the measured temperature of the thermal fluid in the heater from the heater temperature sensor and to determine if there is excess heat in the thermal fluid based on the received measured temperature of the thermal fluid from the first temperature sensor and the measured temperature of the thermal fluid in the heater.

13. The electric vehicle according to claim **11**, wherein the thermal management system further comprises one cooling unit arranged to cool the cabin when the cabin is warmer than a user selected temperature and to provide cold to the heat exchanger for cooling the energy storage system when the energy storage system is warmer than a predetermined maximum temperature.

14. The electric vehicle according to claim **11**, wherein the thermal management system further comprises a second valve, which is a three-way valve, arranged with an inlet arranged to receive the thermal fluid from the heater, a first outlet in fluid communication with the cabin and a second outlet in fluid communication with the heat exchanger, and the control unit is arranged to control the flow of thermal fluid through the second valve.

15. The electric vehicle according to claim **11**, wherein the control unit is arranged to:

control the opening and closing of the first outlet of the second valve so that the thermal fluid is provided to the cabin when there is excess heat in the thermal fluid and the cabin is to be heated,

control the opening and closing of the second outlet of the second valve so that the thermal fluid is provided to the heat exchanger when there is excess heat in the thermal fluid and the energy storage system is to be heated.

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