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(54) Title: CHARGING SYSTEM FOR A VEHICLE ENERGY STORAGE SYSTEM

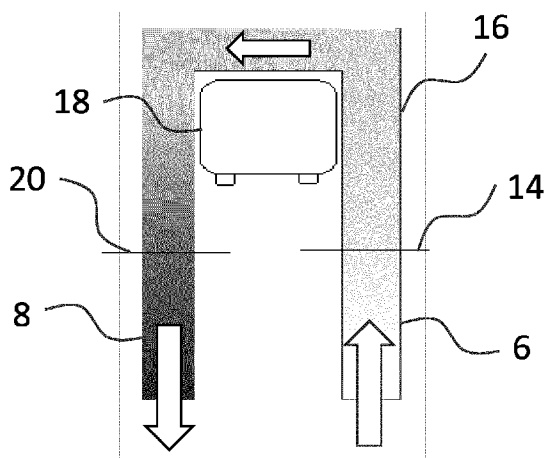


Fig. 2a

(57) Abstract: This invention provides a charging system for charging an energy storage system of a vehicle comprising a charging apparatus (4) comprising a charger (44) configured to supply power to the energy storage system of the vehicle (22), a cooling system for cooling the energy storage system of the vehicle and/or one or more components of the charging apparatus, and a controller. The cooling system comprises a pump (38) configured to pump a cooling fluid, a first fluid (6) line and a second fluid line (8), both fluid lines being in fluid communication with the pump (38) and configured for connection to opposite ends of an in-vehicle cooling line (16) for the energy storage system. The controller is configured to control the cooling fluid to selectively flow through the first fluid line (6), second fluid line (8), and the in-vehicle cooling line (16) in a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme.

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CHARGING SYSTEM FOR A VEHICLE ENERGY STORAGE SYSTEM

Field of the Invention

The present invention relates to a charging system for an energy storage system, and a method for controlling a controller of such a charging system.

5 Background

A significant amount of heat is generated in a vehicle battery and components of charging apparatus during fast charging with multiple megawatts (MW) of electrical power, which is required for industrial
10 electric or hybrid vehicles such as mining and marine vehicles (e.g., ships and mining trucks). Such heat can cause components to experience thermal stress, which can lead to degradation of the vehicle battery or batteries, charging connector, electrical connection cabling and
15 other vehicle and charging related components, as well as degradation inconsistencies of these components. This can lead to such components becoming less effective, needing to be replaced more quickly, and/or failing during operation.

20 There is a need to cool the vehicle battery and/or charging components during such high-power MW industrial fast charging processes.

Conventional cooling systems provide a flow of cooling fluid in one direction. However, this can lead to an
25 imbalance of thermal stresses. For example, when in-vehicle components are cooled, components closer to the entry point of the cooling fluid into the vehicle are cooled more than components closer to the exit of the cooling fluid.

30 The present disclosure seeks to alleviate such problems.

A known electric vehicle charging system is described in US patent US 9527403 B2. This document describes a method of thermally conditioning an energy storage of a vehicle while charging. The method includes receiving, at a charging station, thermal information about the energy storage, supplying by the charging station, electric energy to the energy storage in a charging session, and providing, by the charging station and based on the thermal information, thermal conditioning of the energy storage during at least part of the charging session.

A further known electric vehicle recharging station is described in US9586497. This document describes an electric vehicle recharging station with an electric power supply system for rapidly recharging an onboard electric vehicle battery. The electric power supply system includes a first energy source and a battery bank including one or more rechargeable charging batteries for rapidly recharging the onboard electric vehicle battery. The electric vehicle recharging station includes a temperature management system providing heat exchange fluid to both the onboard electric vehicle battery and the battery bank to thermally condition the onboard electric vehicle battery and the battery bank.

The present disclosure is advantageous over the documents identified above not least by its ability to cool across a wide power range, balance thermal stresses and reduce component degradation.

Summary of the Invention

According to one aspect of the present invention there is provided a charging system for charging an energy storage system of a vehicle 2 comprising a charging apparatus, a cooling system for cooling the vehicle energy storage system of the vehicle and/or one or more

components of the charging apparatus, and a controller.
The charging apparatus comprises a charger configured to supply power to the energy storage system of the vehicle.
The cooling system for cooling the energy storage system
5 of the vehicle comprises a pump configured to pump a cooling fluid, a first fluid line and a second fluid line, both fluid lines being in fluid communication with the pump and configured for connection to opposite ends of an in-vehicle cooling line for the energy storage system. The
10 controller is configured to control the cooling fluid to selectively flow through the first fluid line, second fluid line, and in-vehicle cooling line in a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme.

15 The one or more components of the charging apparatus may comprise a buffer battery, charger, charging connector and cabling.

 The cooling fluid flow programme may be based on thermal data relating to the energy storage system.

20 The cooling fluid flow programme may comprise a starting cooling fluid temperature, a flow rate for the cooling fluid, when the cooling fluid flows in the first direction and/or when the cooling fluid flows in the second direction.

25 The controller may be configured to control one or more charging parameters of the charger based on thermal data relating to the energy storage system of the vehicle.

 The thermal data may comprise a temperature of the energy storage system or a thermal distribution of
30 components of the energy storage system of the vehicle.
The cooling fluid flow programme may be based on data related to atmospheric conditions in the vicinity of the charger.

The controller may be configured to control one or more charging parameters of the charger based on data related to atmospheric conditions in the vicinity of the charger.

5 The cooling fluid programme may be based on a previous charging cycle of the vehicle 2.

 The controller may be configured to control one or more charging parameters of the charger based on data related to an operating condition and/or a charging
10 requirement of the vehicle 2.

 The cooling system may be configured to carry out pre-conditioning of the cooling fluid in response to determining that the vehicle 2 is approaching the charging apparatus.

15 Charging apparatuses for charging the batteries of industrial vehicles are not in constant use and always maintaining the temperature of cooling fluid for use in charging apparatus cooling systems can lead to energy being wasted. Only cooling the cooling fluid when the
20 cooling system of an electric charger is required means that a user would have to wait until the cooling fluid has cooled sufficiently before using the cooling system, which is also undesirable.

 Pre-conditioning the cooling fluid in response to
25 determining that the vehicle 2 is approaching alleviates these problems.

 The charging apparatus may be arranged to configure charging parameters of the charger in response to determining that the vehicle 2 is approaching the charging
30 apparatus.

 According to a further aspect of the present invention there is provided a method for controlling the controller of the charging system. The method comprises supplying power to the energy storage system of the

vehicle and cooling the energy storage system of the vehicle 2 and/or one or more components of the charging apparatus by pumping a cooling fluid, controlling the cooling fluid to selectively flow through the first fluid line, second fluid line, and in-vehicle cooling line in a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme.

The method may further comprise receiving thermal data relating to the energy storage system and controlling the cooling fluid to flow according to the cooling fluid flow programme based on the thermal data relating to the energy storage system.

The method may further comprise monitoring or receiving data related to atmospheric conditions and controlling the cooling fluid to flow according to the cooling fluid flow programme based on the measured or received atmospheric conditions and/or supplying power to the energy storage system based on the measured or received atmospheric conditions.

The method may further comprise receiving data related to a previous charging cycle of the vehicle and controlling the cooling fluid to flow according to the cooling fluid flow programme based on the previous charging cycle of the vehicle.

Brief Description of the Drawings

Figure 1 schematically illustrates a vehicle and charging apparatus according to an embodiment of the present disclosure.

Figure 2a schematically illustrates coolant flowing through a first fluid line, in-vehicle cooling line and second fluid line in a forward flow direction adjacent to a vehicle battery, and the resultant temperature gradient (with the darker colours illustrating warmer coolant).

Figure 2b schematically illustrates coolant flowing through a second fluid line, in-vehicle cooling line and first fluid line in a reverse flow direction adjacent to a vehicle battery, and the resultant temperature gradient (with the darker colours illustrating warmer coolant).

Figure 3a schematically illustrates a cooling fluid circuit showing the effect of cooling fluid on the temperature of battery banks in a vehicle battery, with the cooling fluid flowing in a forward flow direction. Warmer battery banks and warmer cooling fluid is shown with darker shading.

Figure 3b schematically illustrates the cooling fluid circuit of Figure 3a adjacent to battery banks in a vehicle battery, where the direction of coolant flow has been reversed. Warmer battery banks and cooling fluid is shown with darker shading.

Figure 3c schematically illustrates the effect of coolant on the temperature of battery banks in a vehicle battery, with the coolant flowing in a reverse flow direction. Warmer battery banks and cooling fluid is shown with darker shading.

Figure 4 schematically illustrates a block diagram of a charging system according to an embodiment of the present disclosure.

Figure 5 shows a method for controlling the controller of the charging system according to an embodiment of the present disclosure.

These drawings depict one or more implementations in accordance with the present teachings, by way of example only, not by way of limitation. In the figures, like reference numerals refer to the same or similar elements.

Detailed Description of the Drawings

The present disclosure seeks to address problems, identified above, associated with fast charging for

industrial electric or hybrid vehicles, by means of an integrated and external cooling system for an energy storage system and/or one or more components of a charging apparatus, such as a buffer battery, charger, charging connector and cabling.

The charging system may provide all equipment involved in the charging process. The charging system caters to cooling a wide power range by accounting for battery operating conditions as well as external atmospheric conditions, including that required for ultra-fast charging applications at operating levels not seen in conventional on-road electric vehicle applications. Furthermore, more optimal control of cooling and temperature balancing across the cooling circuit is possible by having a bi-directional cooling fluid flow. The cooling circuit may for example comprise the energy storage system of the vehicle, cabling, a buffer battery, the charger, a charging connector, and/or other components of the vehicle and/or charging apparatus cooled by the cooling system.

According to an embodiment of the present invention, a vehicle 2, which is typically an industrial electric or hybrid vehicle such as a mining vehicle or ship, comprises an in-vehicle energy storage system, which may comprise a battery or a plurality of batteries. The term "vehicle battery" will be used henceforth, although any vehicle energy storage system may be used. Such a vehicle 2 may be provided with a first port for receiving cooling fluid, a second port for expelling cooling fluid and an in-vehicle cooling line which allows cooling fluid to flow adjacent to the vehicle battery 18. The vehicle 2 may also be provided with electrical pins configured to be connectable to a charging connector of an electric charging apparatus 4, a battery thermal management system and a transmitter

for communicating with the electric charging apparatus 4. The electric charging apparatus 4 may comprise a single unit or multiple units. The charging apparatus 4 may be a system comprised of several components. The charging apparatus 4 may comprise a charging connector for connecting to the vehicle and a charging cable 10 for supplying power to the vehicle 2. The electric charging apparatus 4 may further comprise a battery charger, a cooling fluid storage unit, a cooling fluid conditioning system, a pump, a cooling fluid management system, a controller, a processor, a communications system, and a receiver. A first fluid line 6 may extend from the cooling fluid storage unit to the first port to supply cooling fluid to the in-vehicle cooling line 16. The in-vehicle cooling line 16 may be connected to the second port where cooling fluid is expelled, and a second fluid line 8 may run from the second port to the charging apparatus 4, where it may be stored and conditioned (e.g., cooled) for subsequent use. The first and second fluid lines 6, 8 may be closely coupled to the charging cable 10, which supplies power to the vehicle 2. The cooling fluid may cool the charging cable 10 by cooled cooling fluid passing adjacent to the charging cable 10 in the first or second fluid line 6,8.

An example electric or hybrid industrial vehicle 2 and charging apparatus 4 is shown in Figure 1. The first fluid line 6, second fluid line 8 and charging cable 10 is shown extending from the charging apparatus 4 to the vehicle 2.

The vehicle 2 may be manufactured with an integrated in-vehicle cooling line 16 and vehicle battery 18 or such components may be fitted into the vehicle 2. The pump may be controlled by the controller to pump cooling fluid in a first direction, for example, in

sequence, from the cooling fluid storage unit, through the first fluid line 6 into the in-vehicle cooling line via the first port, then out of the second port, into the second fluid line 8 and back to the charging apparatus.

5 The controller may be configured to reverse the direction of fluid flow through the pump. For example, the direction of cooling fluid flow may be reversed such that it flows, in sequence, into the second fluid line 8, into the in-vehicle cooling line via the second port, out of the first
10 port into the first fluid line 6 and back into the charging apparatus. The reversal of the cooling fluid flow direction may occur during charging or between charging cycles. The direction of cooling fluid flow may for example be changed periodically, in between charging
15 cycles, or in response to a trigger.

The pump may be a bi-directional pump. Alternatively, the pump may be unidirectional, and a valve system may be used to reverse the direction of fluid flow.

As an alternative, or in addition to the pump, the
20 first fluid line may be configured to supply cooled cooling fluid and the second fluid line may be configured to retrieve warmed cooling fluid. A user may control whether the cooling fluid travels in the first or second direction (forward or reverse flow) by attaching the first
25 fluid line to the first port and the second fluid line to the second port, or the first fluid line to the second port and the second fluid line to the first port.

The cooling fluid may also optionally pass adjacent to the battery charger of the charging apparatus 4,
30 thereby cooling the battery charger. The cooling fluid may be passed adjacent to the battery charger before being directed through the first fluid line 6 and into the in-vehicle cooling line. When the direction of cooling fluid is reversed, the cooling fluid warmed by the vehicle

battery 18 may flow adjacent to the battery charger before returning to the cooling fluid storage unit of the charging apparatus.

5 The ability of the system to change the direction of cooling fluid flow helps to control the cooling and temperature balancing of components which typically heat during battery charging. It provides another parameter for controlling the cooling and temperature balancing of components such as battery banks in the vehicle battery 10 18, the charging connector, in-vehicle cooling line and battery charger. This helps reduce component degradation and degradation inconsistencies around the electrical charging system by allowing components which see a lower temperature difference between the cooling fluid 15 temperature and component temperature, and hence lower heat transfer and cooling of the component, in the forward flow direction to see the larger counterpart temperature difference in the reverse flow direction. Cooling fluid is cooler when it first enters the vehicle and progressively 20 warms up as it flows through the in-vehicle cooling line adjacent to the vehicle battery (due to heat being transferred from the vehicle battery to the cooling fluid). This means that, in the first direction of cooling fluid flow, vehicle batteries nearer the first port are 25 cooled down more than vehicle batteries nearer the second port. It also means that components of the vehicle and/or cooling system are cooled down more than components of the vehicle and/or cooling system nearer the second port. If the direction of the cooling fluid flow is reversed, the 30 vehicle batteries and components near the second port are cooled down more than the vehicle batteries and components near the first port. Allowing cooling fluid to flow both in forward and reverse directions in the in-vehicle cooling line therefore balances the thermal stresses that

each side of the cooling circuit would incur. Since components degrade more when subjected to higher temperatures, reversing the direction of cooling fluid flow reduces degradation inconsistencies and improves the life expectancy of the components. The thermal distribution in the vehicle batteries is more balanced, thereby increasing the allowable charge power and durability of the battery cells.

A further advantage of the described cooling system is that the charging apparatus 4 provides a significant amount of power for cooling the vehicle battery during charging meaning that this capability does not need to be integrated into the vehicle.

Figure 2a shows how the temperature of cooling fluid progressively increases as it flows through the first fluid line 6, enters the first port 14, flows through the in-vehicle cooling line 16 adjacent to the vehicle battery 18, exits the vehicle 2 at the second port 20 and flows through the second fluid line 8. This is because the cooling fluid is cold when it arrives at the vehicle 2 and is warmed by the vehicle battery 18.

Figure 2b shows how, when the direction of cooling fluid flow is reversed, the temperature of coolant progressively increases as it flows through the second fluid line 8, enters the vehicle 2 at the second port 20, flows through the in-vehicle cooling line 16 adjacent to the vehicle battery 18, exits the vehicle at the first port 14, and flows through the first fluid line 6. This is because cooling fluid is cold when it arrives at the vehicle 2 and is warmed by the vehicle battery.

Figures 3a, 3b and 3c show a further example of the described cooling system in operation. In Figure 3a, upper battery banks 24 of the vehicle battery 18 near the first port are shown to be cooled more than the lower battery

banks 26 when the cooling fluid is flowing in the forward flow direction (the first direction). In Figure 3b, the direction of the cooling fluid flow is reversed, and in Figure 3c the lower battery banks 26 receive more cooling than the upper battery banks 24 in the reverse flow direction (second direction).

Figure 4 is a block diagram of a vehicle 2 and charging apparatus 4. The charging apparatus 4 may comprise the receiver 28, cooling fluid management system 30, charging management module 32, processor 34, controller 36, pump 38, cooling fluid storage unit 40, cooling fluid conditioning system 42, battery charger 44, and charging connector 46. The charging apparatus 4 may further optionally include a buffer battery 48, particularly for use in fast charging due to the high energy demand on the national grid to reduce the impact of grid constraints on the charger 44 (e.g., for peak shaving). The charging apparatus 4 may optionally further include an atmospheric conditions module 50 configured to monitor or receive information relating to the atmospheric conditions where the charging apparatus/vehicle is situated, such as but not limited to the ambient temperature, atmospheric pressure, humidity, precipitation, and wind speed. The vehicle 2 may include the battery thermal management system 52, electric pins 54, transmitter 56, controller 58, first port 14, second port 20, vehicle battery 18 and in-vehicle cooling fluid line 16. The charging apparatus 4 may communicate with the vehicle 2 using a communication system 60 such as Cloud communications, for example so that vehicle data can be transmitted and received by the charging apparatus.

The battery thermal management system 52 may be configured to determine a thermal state of the vehicle battery 18. The thermal state may for example comprise the

temperature, or temperature distribution (e.g., thermal gradients) of components in the vehicle battery 18. The battery thermal management system 52 may be configured to monitor the temperature of different components, such as each battery cell within the vehicle battery 18, to determine the thermal distribution of the vehicle battery 18. The battery thermal management system may be configured to communicate with the charging apparatus, such as via the communication system 60, to transmit data relating to the thermal status of the vehicle battery 18 to the charging apparatus, such as to the cooling fluid management system 30 and/or charging management module. Such data may be transmitted as the vehicle approaches the charging apparatus 4 and/or during charging. This communication enables optimisation of the cooling system and charging settings based on on-board vehicle operating conditions and allows the charging system to determine preferential charge power (current) based on the thermal state of in-vehicle batteries and conduct flow reversal in response to thermal gradients detected in the vehicle battery 18. It also enables the charging system to be pre-conditioned (e.g., the cooling fluid cooled) prior to the vehicle's connection to the charger in preparation for charging.

The cooling fluid management system 30 may be configured to determine a cooling fluid flow programme, for example based on vehicle parameters received via the communication system 60. For example, the battery thermal management system of the vehicle may determine the temperature of the batteries of the vehicle battery 18 and send this, using the vehicle transmitter 56, to the cooling fluid management system 30 of the charging apparatus 4 via the receiver 28 of the charging apparatus. The cooling fluid management system 30 may be configured

to then determine the cooling fluid flow programme based on the temperature of the vehicle batteries. The cooling fluid flow programme may include, but is not limited to, a flow reversal frequency (e.g., number of times the flow is reversed per minute), flow speed, flow direction, the duration fluid flows in each direction (e.g., the fluid may flow for 5 minutes in a first direction and 2 minutes in a second direction), starting temperature of the cooling fluid and/or temperature of the cooling fluid at different stages of the cooling fluid circuit. Starting temperature of the cooling fluid may refer to the temperature the cooling fluid is cooled to before it is supplied to the in-vehicle cooling line for cooling the energy storage system of the vehicle. Other examples of vehicle parameters which may affect the cooling fluid flow programme include, but are not limited to, the age of the vehicle 2 or vehicle battery 18, the position of components within the vehicle 2 or IVESS 18 (e.g., since certain components may be more prone to over-heating or degradation than others), and the size of the vehicle battery 18 or in-vehicle cooling line (since a larger vehicle battery 18 may benefit from a lower flow reversal frequency - it takes longer for the cooling fluid to flow from the first port to the second port).

The cooling fluid flow programme may for example be determined using one or more computer models or machine learning.

The cooling fluid flow programme may be configured to optimise the cooling of the vehicle battery 18 in a more efficient way, minimising the energy used whilst effectively cooling the vehicle battery 18 during battery charging.

For example, if the vehicle 2 arrives at the charging apparatus 4 with a vehicle battery 18 at a high

temperature, the cooling fluid management system 30 may determine that the cooling fluid should be cooled to a lower temperature to assist with rapid cooling of the vehicle battery 18 so that the vehicle battery 18 can be charged effectively. If the vehicle 2 arrives at the charging apparatus 4 with a vehicle battery 18 with components that have degraded more closer to the first port compared to the components closer to the second port, the cooling fluid management system 30 may determine that the cooling fluid should predominately flow in the reverse flow direction, with a flow reversal frequency biased towards the reverse duration (e.g., direct cooling fluid to flow in the reverse direction for 5 minutes, and then be directed to flow in the forward direction for 1 minute).

The controller may be configured to receive instructions from the cooling fluid management system 30 relating to the cooling fluid flow programme, process them at the processor, and in turn send instructions to the pump and/or valve(s), which can direct the fluid to flow in either direction, and/or the cooling fluid conditioning system, which cools the cooling fluid, so the cooling fluid flow programme can be implemented.

The cooling fluid may be stored in the cooling fluid storage unit 40, which may or may not form part of the charging apparatus 4. The cooling fluid may be stored and/or conditioned in an accompanying system. There may be separate storage units for cooled cooling fluid and cooling fluid that has been warmed by the vehicle battery 18. The cooling fluid may be cooled and/or otherwise treated by the cooling fluid conditioning system so that it is ready to be directed into the in-vehicle cooling line to cool the vehicle battery 18. The terms coolant fluid and cooling fluid are used herein interchangeably.

The cooling fluid may cool the vehicle battery 18, battery charger 44 and/or buffer battery 48 using immersion and/or conventional forced convection heat transfer systems. For example, cooling fluid may be passed by an interface (e.g., a heat sink plate) and not be in direct contact with the vehicle battery. Alternatively, battery cells may be compatible to be in direct contact with cooling fluid and immersed in the cooling fluid. Such an approach would result in a more efficient transfer of heat. The most appropriate heat transfer option may be selected for the application.

The battery charger may be configured to supply power to the vehicle battery 18, via the charging cable and charging connector, which connects to the electric pins 54 of the vehicle 2.

The charging management module 32 may be configured to determine charging settings to charge the vehicle battery 18 of a particular vehicle 2 based on vehicle operating conditions, charging requirements, atmospheric conditions, and/or previous charging cycles. For example, the charge current may be regulated as a function of vehicle battery 18 or battery cell temperature, which helps to balance thermal distribution in the vehicle battery 18. The charging management module 32 may also be configured to determine a preferred charge power (current) based on the thermal state of the vehicle battery 18 of the vehicle 2. In another example, the charging management module 32 may be configured to determine that the vehicle battery 18 should be charged more slowly and with less power on a hot day to reduce the risk of the vehicle battery 18 over-heating whilst it is charged.

The charging management system may be configured to determine optimal charge settings using a computer model or machine learning.

In some embodiments, the charging apparatus 4 may include the buffer battery 48. Buffer batteries 48 are particularly useful when fast charging is required due to the high energy demand on the national grid, to reduce grid constraints on the charger (e.g., for peak shaving). The buffer battery 48 may be immersion cooled. Alternatively, cooling fluid may flow adjacent to the buffer battery in the first and/or second fluid line to cool the buffer battery 48. Cooling fluid may then flow adjacent to the battery charger 44 or along the first fluid line 6 to the vehicle 2. When the direction of cooling fluid is reversed, the cooling fluid warmed by the vehicle battery 18 may flow adjacent to the battery charger and then adjacent to the buffer battery. Alternatively, when the direction of cooling fluid is reversed, the cooling fluid warmed by the vehicle battery 18 may flow from the vehicle 2 to the buffer battery.

It is noted that the order in which components appear in the cooling fluid circuit may be different to that described. For example, the cooling fluid may flow adjacent to the battery charger before being directed to the buffer battery and in turn along the first fluid line 6 to the vehicle 2.

The cooling fluid conditioning system may for example be positioned between the battery charger and buffer battery.

The charging apparatus 4 may optionally comprise the atmospheric conditions module configured to monitor or receive information relating to the atmospheric conditions where the charging apparatus 4 is situated, such as but not limited to the ambient temperature, humidity, precipitation, and wind speed. The atmospheric conditions module may be configured to monitor the current atmospheric conditions, for example through use of a

thermometer to measure temperature, barometer to measure atmospheric pressure (high and rising pressure typically indicates sunny weather, and low and fall pressure typically indicates approaching rainstorms), a hygrometer to measure the humidity of air, and an anemometer to measure the direction and speed of wind, to name a few. Alternatively, or additionally, the atmospheric conditions module or cooling fluid management system 30 may be configured to receive data relating to the past, current, or expected future atmospheric conditions. The atmospheric conditions measured or received may be used to determine an optimised cooling fluid flow programme.

The optimised cooling fluid flow programme based on the past, current and/or future atmospheric conditions in the vicinity of the charging apparatus 4 may be determined using a computer model or machine learning.

For example, the atmospheric conditions module may receive a weather report indicating that high temperatures are expected, and the cooling fluid management system 30 may in response determine that the cooling fluid should be cooled to a lower temperature because it is likely that vehicle batteries 18 will have over-heated or require more cooling for optimal battery charging. The atmospheric pressure indicating an approaching rainstorm may indicate that the vehicle battery 18 should be cooled as quickly as possible so that charging has completed before the storm. By receiving an indication of the expected atmospheric conditions, the charging apparatus 4 can pre-emptively condition the cooling fluid and/or configure the charging settings before the atmospheric conditions (e.g., storm, high temperatures etc.) have arrived. For example, if it is expected to reach 30 degrees Celsius at midday, the cooling fluid conditioning system can begin cooling the

cooling fluid in the morning so that it has reached the desired temperature by midday.

The charging apparatus 4 may also be configured to communicate with vehicles as they approach the charging apparatus. Data relating to the vehicle 2, such as the thermal state of the vehicle's battery 18, thermal gradients in the vehicle battery 18 (indicating whether some components of the vehicle battery 18 are hotter than others), and the cooling fluid direction of the vehicle's previous charge cycle may be sent to the charging apparatus 4 via the communication system 60. The cooling fluid management system 30 and/or charging management module 32 may respectively be configured to determine a cooling fluid flow programme and charger settings based on the data received and pre-emptively condition the cooling fluid, configure the pump 38 such that coolant will flow in a particular direction, and/or configure the charging settings so that when the vehicle 2 arrives, or soon after, the cooling fluid has been conditioned (e.g., cooled to the desired temperature), the pump 38 is in the correct configuration to direct coolant to flow in a particular direction, and/or the optimal charging settings have been configured (e.g., the battery charger has been set to supply the desired current). This means that optimal charging and cooling can be achieved more quickly. A further advantage is that the temperature of the cooling fluid, or other desired parameter of the cooling fluid, does not have to be maintained at all times. Continuously keeping the cooling fluid cool uses energy and if the charging apparatus 4 is not used to charge the vehicle battery 18 of a vehicle 2, this energy may be wasted. Therefore, by conditioning the cooling fluid and configuring the settings of the battery charger in response to an indication that the vehicle 2 is

approaching the charging apparatus 4 means the energy consumption of the charging apparatus 4 is more efficient.

The cooling fluid management system 30 may also be configured to determine the optimal settings of the cooling fluid (e.g., temperature and other parameters of the cooling fluid) to balance energy consumption with time constraints. For example, the cooling fluid management system 30 may be configured to determine optimal settings for the cooling fluid and cooling fluid conditioning system taking into account the amount of energy required to maintain the cooling fluid at a particular temperature, the amount of energy required to cool the cooling fluid from a starting temperature, the time it would take to cool the cooling fluid from a starting temperature and/or acceptable waiting times for the cooling fluid to reach the desired settings once the vehicle 2 has arrived at the charging apparatus. The optimal settings may be determined using a model and/or machine learning.

The cooling fluid management system 30 may also be configured to determine the optimal settings of the cooling fluid (e.g., temperature and other parameters of the cooling fluid) based on the temperature of the one or more charging components, such as the charger, cabling, charger connector and buffer battery.

As indicated above, the charging apparatus 4 may be configured to receive data related to one or more previous charging cycles of a vehicle 2. The cooling fluid management system 30 may determine that since the fluid was directed in a forward flow direction (first direction) during the last charging cycle, fluid should be directed in a reverse flow direction (second direction) during the next charging cycle and vice versa. In another example, the cooling fluid management system 30 and charging management module 32 may respectively be configured to

assess how the vehicle 2 has reacted to previous cooling fluid and/or charging strategies and adapt the cooling fluid flow programme and/or charge settings accordingly. For example, the charging management module 32 may be configured to determine that the vehicle battery 18 of a particular vehicle 2 overheated quickly and in response determine that the cooling fluid flow programme should reverse the direction of fluid flow more often, or supply cooling fluid at a lower temperature. The previous cooling fluid and/or charge settings applied to vehicles and the effect they had (e.g., how long the vehicle 2 took to charge, the temperature of the components of the vehicle battery 18 during and after charging etc.) may be analysed and the cooling fluid flow programme and charge settings determined using a computer model or machine learning. The charge unit of vehicle 2 may comprise a data storage unit to store such data, or it may be stored remotely, such as on the Cloud.

The described cooling system may be cooling fluid agnostic. Any cooling fluid may be used in the described system.

There is also provided a method of controlling the controller of the charging system described above. As shown in Figure 5, the method may comprise supplying power to the energy storage system of the vehicle; and cooling the energy storage system of the vehicle and/or one or more components of the charging apparatus by pumping a cooling fluid and controlling the cooling fluid to selectively flow through the first fluid line, second fluid line, and in-vehicle cooling line a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme. The method may further comprise receiving thermal data relating to the energy storage system and controlling the cooling

fluid to flow according to the cooling fluid flow
programme based on the thermal data relating to the energy
storage system. The thermal data may comprise a
temperature of the vehicle battery, or a temperature
5 gradient of components in the vehicle battery.

While many possible variations of the cooling system
for a vehicle energy storage system have been described
above, it will be clear to the skilled person that
additional variations and modifications can be made
10 without departing from the scope of the invention as
claimed in the appended claims.

C L A I M S

1. A charging system for charging an energy storage system of a vehicle (2) comprising:

a charging apparatus (4) comprising:

a charger (44) configured to supply power to the energy storage system of the vehicle (2);

a cooling system for cooling the energy storage system of the vehicle (2) and/or one or more components of the charging apparatus (4), the cooling system comprising:

a pump (38) configured to pump a cooling fluid;

a first fluid line (6) and a second fluid line (8), both fluid lines being in fluid communication with the pump (38) and configured for connection to opposite ends of an in-vehicle cooling line (16) for the energy storage system; and,

a controller configured to control the cooling fluid to selectively flow through the first fluid line (6), second fluid line (8), and in-vehicle cooling line (16) in a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme.

2. A charging system as claimed in Claim 1, wherein the one or more components of the charging apparatus (4) comprises a buffer battery, charger, charging connector and cabling.

3. A charging system as claimed in Claim 1, wherein the cooling fluid flow programme is based on thermal data relating to the energy storage system.

4. A charging system as claimed in any preceding claim, wherein the cooling fluid flow programme comprises a starting cooling fluid temperature, a flow rate for the cooling fluid, when the cooling fluid flows in the first

direction and/or when the cooling fluid flows in the second direction.

5 5. A charging system as claimed in any preceding claim wherein the controller is configured to control one or more charging parameters of the charger (44) based on thermal data relating to the energy storage system of the vehicle (2).

10 6. A charging system as claimed in any preceding claim, wherein the cooling fluid flow programme is based on data related to atmospheric conditions in the vicinity of the charger (44).

15 7. A charging system as claimed in any preceding claim, wherein the controller is configured to control one or more charging parameters of the charger (44) based on data related to atmospheric conditions in the vicinity of the charger (44).

20 8. A charging system as claimed in any preceding claim, wherein the cooling fluid programme is based on a previous charging cycle of the vehicle (2).

25 9. A charging system as claimed in any preceding claim, wherein the controller is configured to control one or more charging parameters of the charger (44) based on data related to an operating condition and/or a charging requirement of the vehicle (2).

30 10. A charging system as claimed in any preceding claim, wherein the cooling system is configured to carry out pre-conditioning of the cooling fluid in response to determining that the vehicle (2) is approaching the charging apparatus.

35 11. A charging system as claimed in any preceding claim, wherein the charging apparatus is arranged to configure charging parameters of the charger (44) in response to determining that the vehicle (2) is approaching the charging apparatus.

12. A method for controlling the controller of the charging system of Claims 1 to 11, the method comprising: supplying power to the energy storage system of the vehicle (2); and,

5 cooling the energy storage system of the vehicle (2) and/or one or more components of the charging apparatus by:

pumping a cooling fluid;

controlling the cooling fluid to selectively flow through
10 the first fluid line, second fluid line, and in-vehicle cooling line in a first direction or in a second direction, opposite to the first direction, according to a cooling fluid flow programme.

13. The method of Claim 12, further comprising receiving
15 thermal data relating to the energy storage system and controlling the cooling fluid to flow according to the cooling fluid flow programme based on the thermal data relating to the energy storage system.

14. The method of Claims 12 or 13, further comprising
20 monitoring or receiving data related to atmospheric conditions and controlling the cooling fluid to flow according to the cooling fluid flow programme based on the measured or received atmospheric conditions and/or supplying power to the energy storage system based on the
25 measured or received atmospheric conditions.

15. The method of any of Claims 12 to 14, further comprising receiving data related to a previous charging cycle of the vehicle and controlling the cooling fluid to flow according to the cooling fluid flow programme based
30 on the previous charging cycle of the vehicle (2).

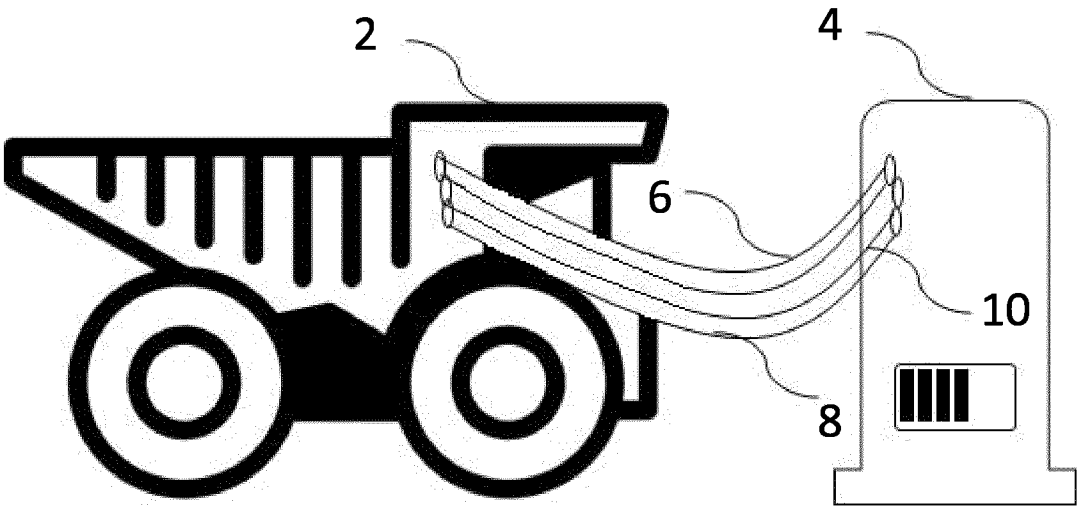


Fig. 1

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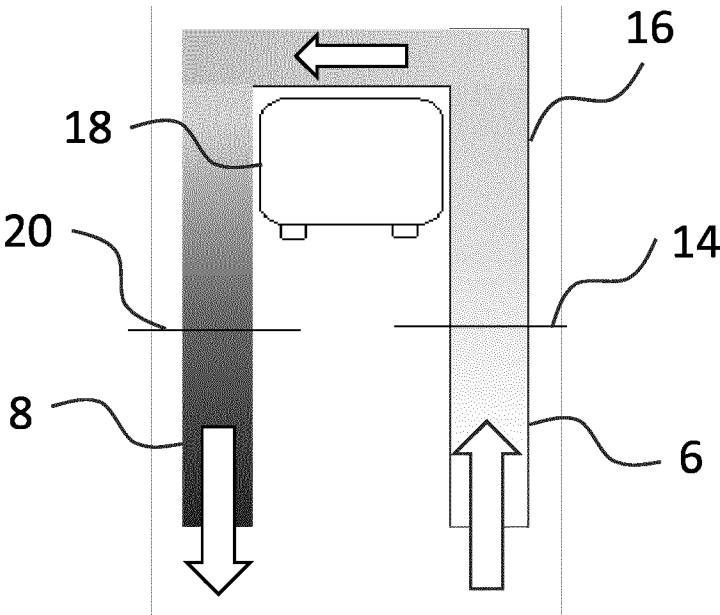


Fig. 2a

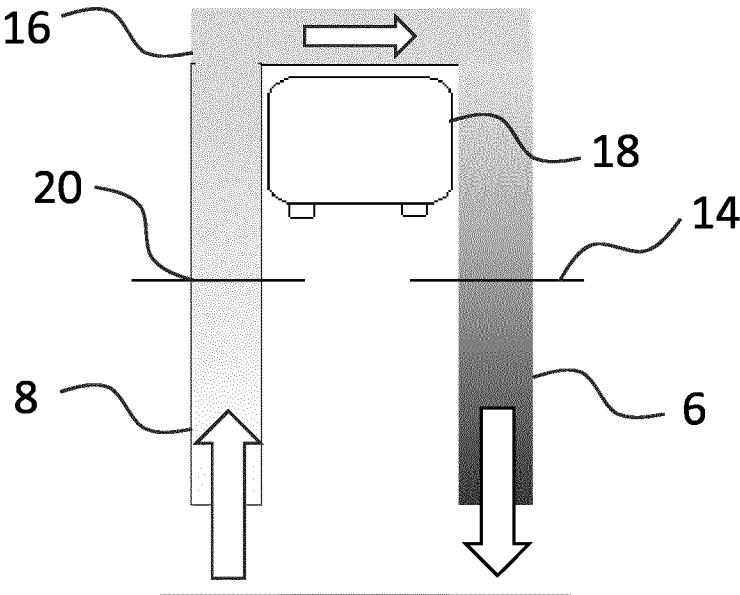
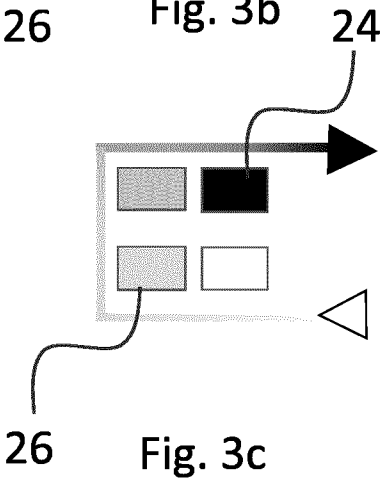
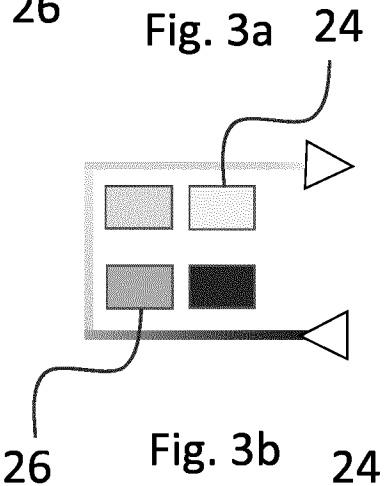
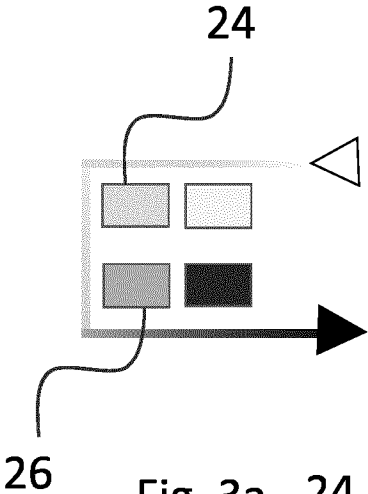


Fig. 2b

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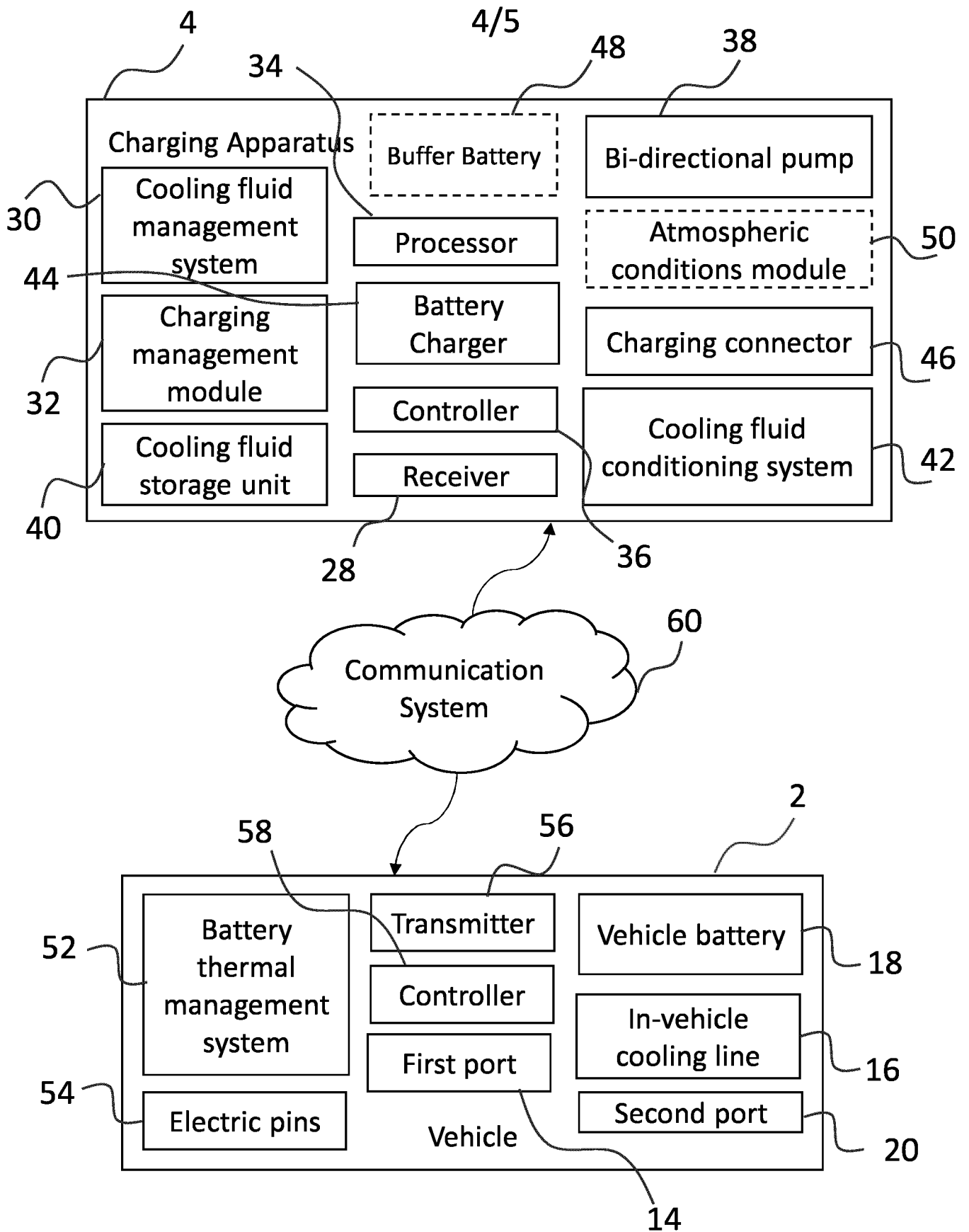


Fig. 4

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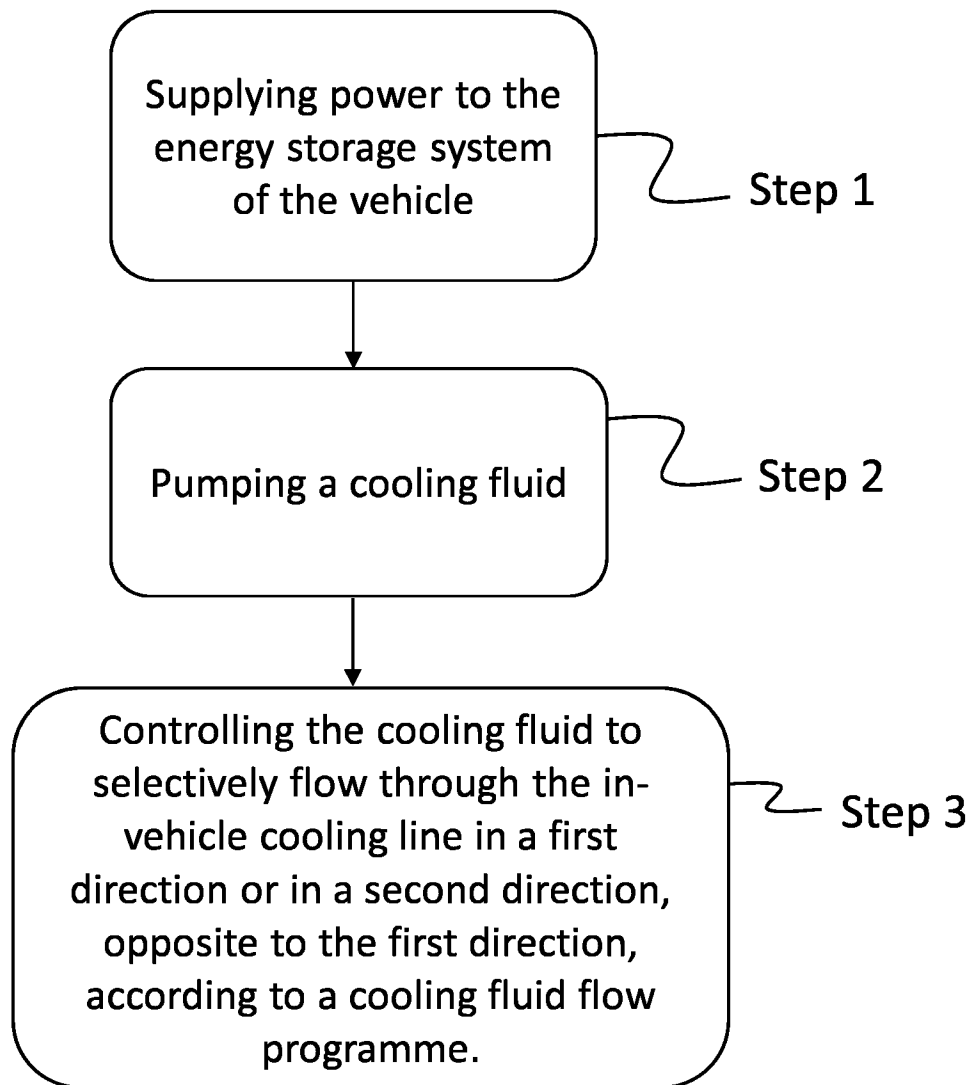


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/083584

A. CLASSIFICATION OF SUBJECT MATTER					
INV.	B60L53/14	B60L53/302	B60L58/26	H01M10/613	B60L53/16
	B60L53/18	B60L53/53	B60L53/55		
ADD.					
According to International Patent Classification (IPC) or to both national classification and IPC					
B. FIELDS SEARCHED					
Minimum documentation searched (classification system followed by classification symbols)					
B60L H01M					
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched					
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)					
EPO-Internal, WPI Data					
C. DOCUMENTS CONSIDERED TO BE RELEVANT					
Category*	Citation of document, with indication, where appropriate, of the relevant passages				Relevant to claim No.
X	US 2023/110777 A1 (NELIGAN MAURICE [DE] ET AL) 13 April 2023 (2023-04-13)				1-7,
Y	paragraphs [0001], [0019], [0021], [0030], [0038], [0043]				11-14
	-----				8-10,15
Y	US 2019/241093 A1 (SHIMAUCHI TAKAYUKI [JP] ET AL) 8 August 2019 (2019-08-08)				8,9,15
A	paragraph [0046]				1,12

Y	US 2021/188127 A1 (KLOSE ALEXANDER [DE] ET AL) 24 June 2021 (2021-06-24)				10
A	paragraph [0020]				1,12

☐ Further documents are listed in the continuation of Box C.					
☒ See patent family annex.					
* Special categories of cited documents :					
"A" document defining the general state of the art which is not considered to be of particular relevance			"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention		
"E" earlier application or patent but published on or after the international filing date			"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone		
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"O" document referring to an oral disclosure, use, exhibition or other means			"&" document member of the same patent family		
"P" document published prior to the international filing date but later than the priority date claimed					
Date of the actual completion of the international search			Date of mailing of the international search report		
10 February 2025			11/03/2025		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016			Authorized officer Wirth, Sebastian		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2024/083584

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023110777 A1	13-04-2023	CN 116018708 A	25-04-2023
		DK 4128423 T3	11-11-2024
		EP 3890098 A1	06-10-2021
		EP 4128423 A1	08-02-2023
		EP 4435928 A2	25-09-2024
		ES 2994503 T3	24-01-2025
		PT 4128423 T	30-10-2024
		US 2023110777 A1	13-04-2023
		WO 2021198287 A1	07-10-2021

US 2019241093 A1	08-08-2019	CN 110116613 A	13-08-2019
		DE 102019102814 A1	08-08-2019
		JP 7059670 B2	26-04-2022
		JP 2019140740 A	22-08-2019
		US 2019241093 A1	08-08-2019

US 2021188127 A1	24-06-2021	DE 102017221829 B3	25-04-2019
		US 2021188127 A1	24-06-2021
		WO 2019110576 A1	13-06-2019
