US 20140230463A1

(19) **United States**
(12) **Patent Application Publication**
Ziehr

(10) **Pub. No.: US 2014/0230463 A1**
(43) **Pub. Date: Aug. 21, 2014**

(54) **METHOD FOR CONTROLLING A COMPRESSOR OF A THERMAL STORAGE HEAT PUMP SYSTEM**

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(21) Appl. No.: **13/767,918**

(22) Filed: **Feb. 15, 2013**

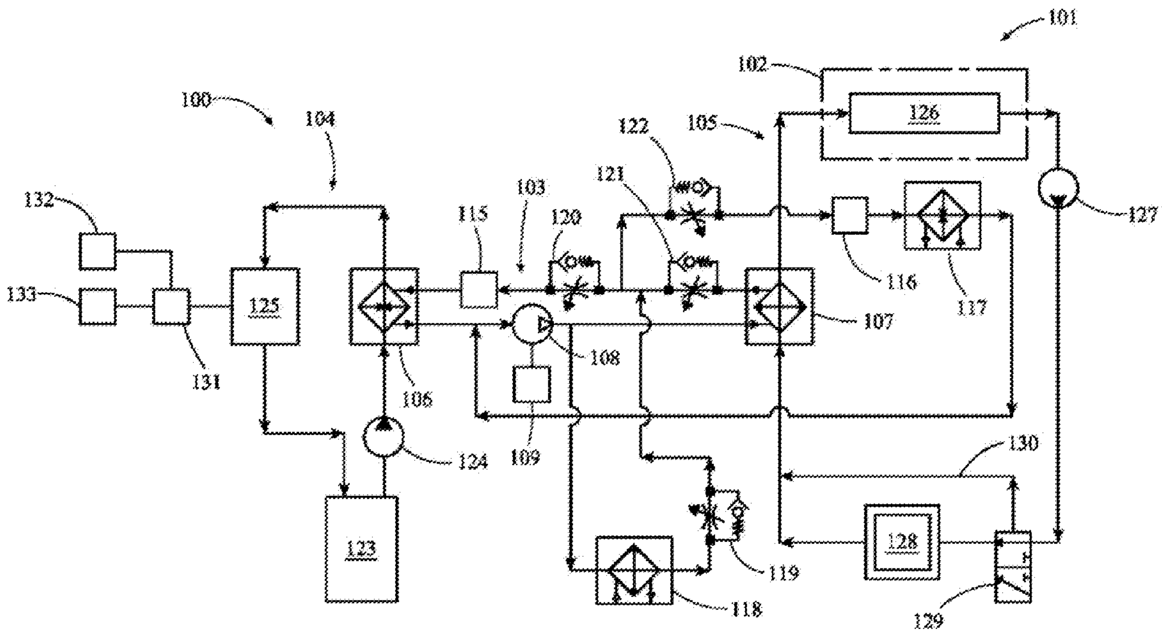
Publication Classification

(51) **Int. Cl.**
F25B 49/02 (2006.01)

(52) **U.S. Cl.**
CPC *F25B 49/022* (2013.01)
USPC **62/56**; 62/159

(57) **ABSTRACT**

A method of controlling a compressor of a thermal storage heat pump system of a vehicle is provided. The system may operate in one of a heating mode and a cooling mode, as determined by at least one system controller based on at least one parameter. The at least one parameter may be ambient air temperature. The compressor has a compressor motor and a motor controller configured to selectively operate the compressor in an unmodified state or a modified state based on the operating mode of the system. The compressor motor is operated in the unmodified state when the system is in the cooling mode, and in the modified state when the system is in the heating mode. Operating the compressor motor in the modified state may include decreasing its coefficient of performance (COP).



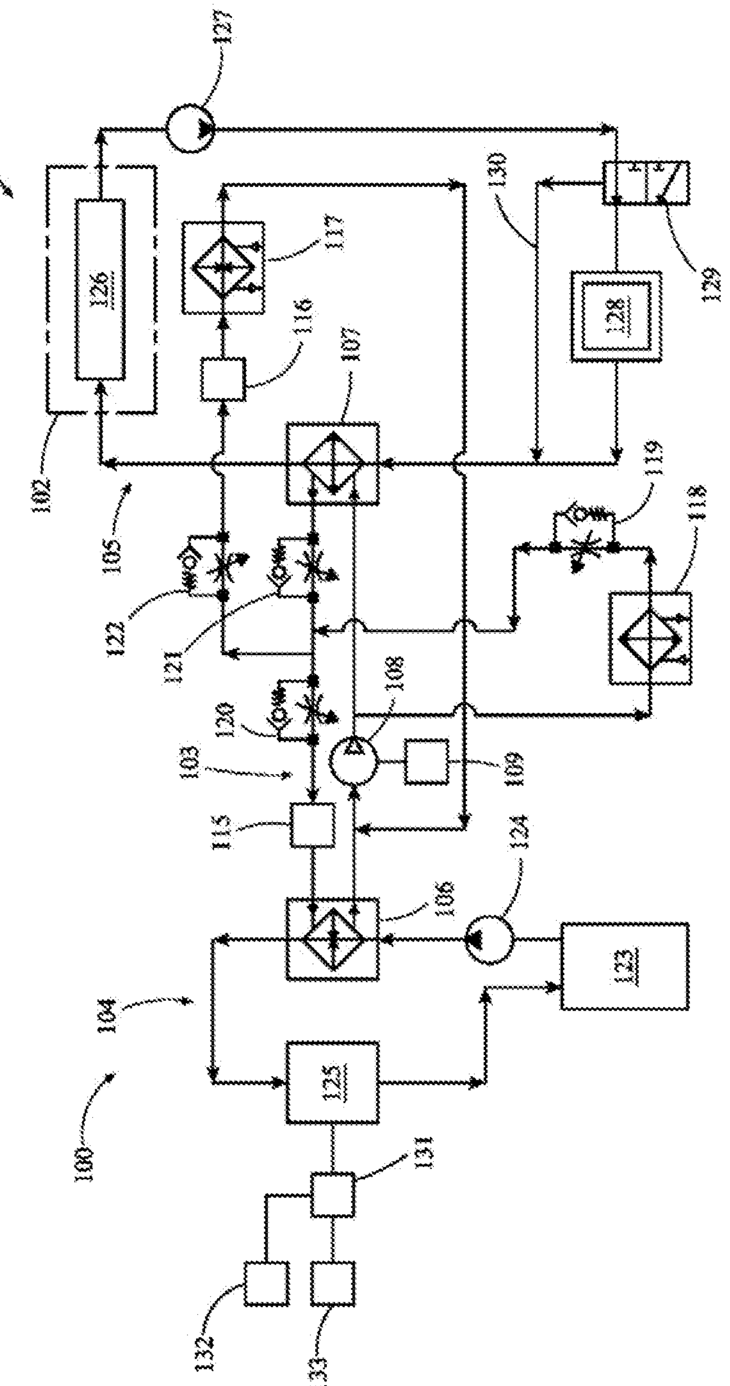

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FIG. 1

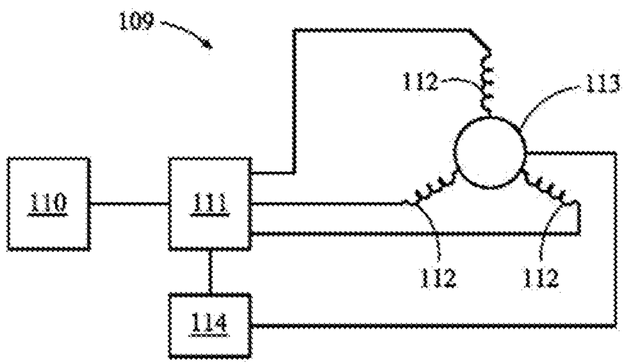

FIG. 2

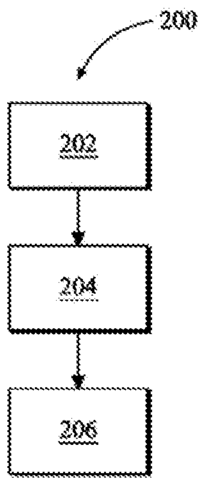

FIG. 3

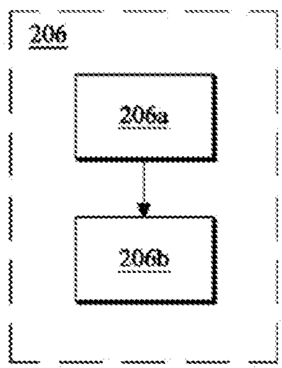

FIG. 4

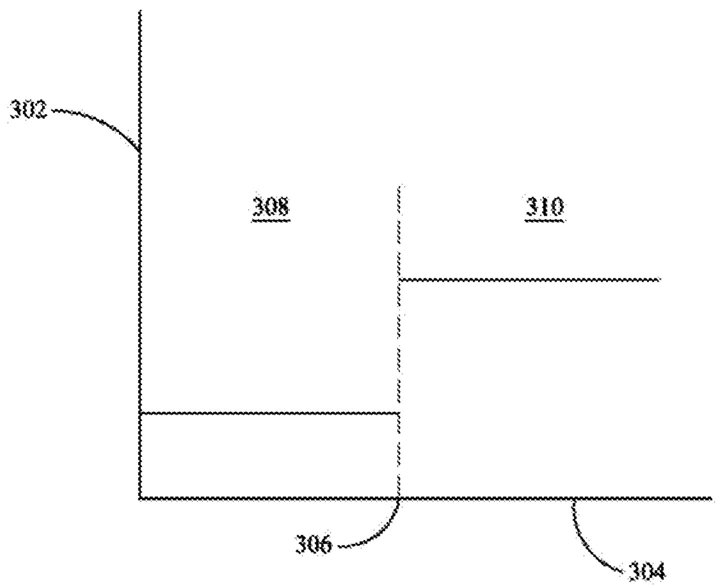

FIG. 5

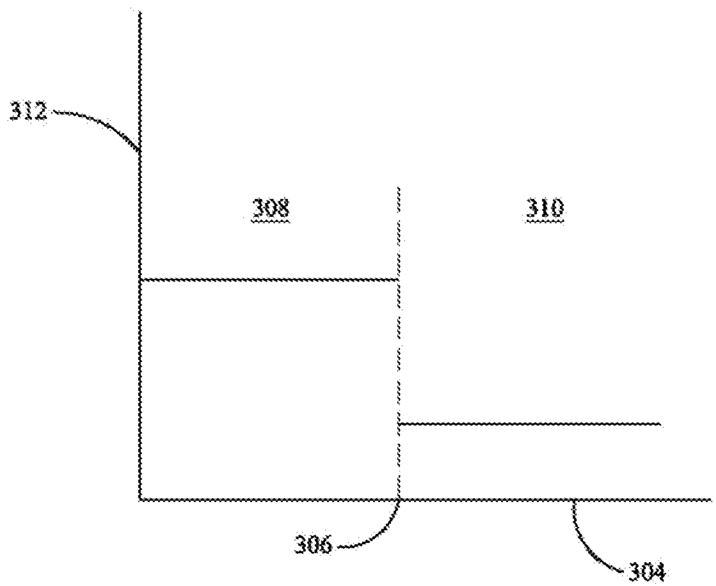

FIG. 6

METHOD FOR CONTROLLING A COMPRESSOR OF A THERMAL STORAGE HEAT PUMP SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to a method for controlling a compressor of a thermal storage heat pump system in a vehicle, such as a hybrid electric vehicle (HEV) or a plug-in hybrid electric vehicle (PHEV).

BACKGROUND

[0002] An electric vehicle, such as a hybrid electric vehicle (HEV), a plug-in hybrid electric vehicle (PHEV), or the like, generally includes an electric motor, which may alone propel the vehicle in an electric vehicle (EV), or charge-depleting, drive mode. The vehicle may also include an internal combustion engine (ICE) to serve as the primary propulsion system of the vehicle in a range extending mode, or to operate in conjunction with the electric motor in a hybrid, or charge-sustaining, mode.

[0003] The electric motor generally receives electric power from an electric power source, such as an energy storage system (ESS). The ESS may include a battery pack or other rechargeable energy storage means capable of storing large amounts of thermal energy. The ESS may store the thermal energy when the vehicle is connected to an external power source, such as an electrical grid, for charging. In colder ambient temperatures, the charge depletes faster, due to various factors.

[0004] The ESS may be used in conjunction with a thermal management system, such as a heat pump system, thereby forming a thermal storage heat pump system, to transfer the stored thermal energy to another medium for another purpose, such as to heat a passenger compartment of the vehicle.

[0005] The heat pump system (and therefore, the thermal storage heat pump system) generally includes a compressor, which compresses refrigerant serving as the heat transfer medium for the heat pump system. The compressor motor requires a certain amount of electric power, which in turn is converted to electric heat, to function in compressing the refrigerant. The electric power necessary is dependent upon the coefficient of performance (COP) of the compressor motor. As the COP increases, the compressor motor requires less electric power.

SUMMARY

[0006] A thermal storage heat pump system of a vehicle having a passenger compartment is provided. The thermal storage heat pump system generally includes a first coolant circuit, a second coolant circuit, and a refrigeration circuit that are configured to circulate a first coolant, a second coolant, and a refrigerant, respectively. The refrigeration circuit is in thermal communication with the first coolant circuit and the second coolant circuit via a first heat exchanger and a second heat exchanger, respectively.

[0007] The thermal storage heat pump system also includes a compressor located in the refrigeration circuit. The compressor is configured to compress the refrigerant in the refrigeration circuit. The compressor has a compressor motor and a motor controller configured to selectively operate the compressor motor in one of an unmodified state and a modified state. The compressor motor may be a brushless direct current (DC) electric motor that has a coefficient of performance (COP), and is a three-phase electric system in which each phase is offset by a set angle and has a defined frequency in the unmodified state. In the modified state, the COP is less than that in the unmodified state.

[0008] The thermal storage heat pump system further includes at least one system controller configured to selectively operate the thermal storage heat pump system in one of a heating mode and a cooling mode based on at least one parameter. The at least one parameter may be ambient air temperature. When the ambient air temperature is at or below a switchover temperature, the thermal storage heat pump system may operate in the heating mode. When the ambient air temperature is above the switchover temperature, the thermal storage heat pump system may operate in the cooling mode. The compressor motor is operated in the unmodified state when the thermal storage heat pump system is in the cooling mode, and in the modified state when the thermal storage heat pump system is in the heating mode.

[0009] A method for controlling the compressor of the thermal storage heat pump system described above is also provided. The method includes first receiving, by the at least one system controller, a measurement of at least one parameter. As explained above, the at least one parameter may be ambient air temperature. The method then includes determining, by the at least one system controller, the operating mode of the thermal storage heat pump system based on the measurement.

[0010] The method then includes operating, by the motor controller, the compressor motor in one of the unmodified state and the modified state. Again, the compressor motor is operated in the unmodified state when the thermal storage heat pump system is in the cooling mode, and in the modified state when the thermal storage heat pump system is in the heating mode.

[0011] Operating the compressor motor in the modified state may include reducing the COP of the compressor motor. This may further include offsetting from the set angle at least one of the three phases and/or altering the defined frequency of at least one of the three phases.

[0012] The above features and advantages, and other features and advantages, of the present invention are readily apparent from the following detailed description of some of the best modes and other embodiments for carrying out the invention, which is defined solely by the appended claims, when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a schematic diagram of a thermal storage heat pump system having a compressor with a compressor motor;

[0014] FIG. **2** is a schematic diagram of the compressor motor of FIG. **1**;

[0015] FIG. **3** is a schematic, flow diagram of a method for controlling the compressor;

[0016] FIG. **4** is a schematic flow diagram illustrating one step of the method of FIG. **3**;

[0017] FIG. **5** is a graph illustrating a relationship between the coefficient of performance (COP) of the compressor motor and the ambient air temperature; and

[0018] FIG. **6** is a graph illustrating a relationship between electrical heat produced by the compressor motor and the ambient air temperature.

DETAILED DESCRIPTION

[0019] The following description and figures refer to example embodiments and are merely illustrative in nature and not intended to limit the invention, its application, or uses. Throughout the figures, some components are illustrated with standardized or basic symbols. These symbols are representative and illustrative only, and are in no way limiting to any specific configuration shown, to combinations between the different configurations shown, or to the claims. All descriptions of componentry are open-ended and any examples of components are non-exhaustive.

[0020] Referring to the drawings, wherein like reference numbers correspond to like or similar components wherever possible throughout the several figures, a thermal storage heat pump system **100** for use in a vehicle **101**, including, but not limited to, a hybrid electric vehicle (HEV), a plug-in hybrid electric vehicle (PHEV), or the like, is shown in FIG. **1**. The vehicle **101** may selectively operate in a range extending mode, a hybrid, or charge-sustaining, mode, and an electric vehicle (EV), or charge-depleting, drive mode. In range extending mode, an internal combustion engine (ICE) **128**, described hereinafter, operates as the sole propulsion system for the vehicle **101**. In hybrid mode, the vehicle **101** operates using both electric power from an electric motor (not shown) and power from the ICE **128**. In EV drive mode, the vehicle **101** operates solely on electricity.

[0021] The thermal storage heat pump system **100** generally includes a refrigeration circuit **103** in thermal communication with a first coolant circuit **104** and a second coolant circuit **105** via a first heat exchanger **106** and a second heat exchanger **107**, respectively. The refrigeration circuit **103**, the first coolant circuit **104**, and the second coolant circuit **105** are configured to circulate a refrigerant, a first coolant, and a second coolant, respectively. The first heat exchanger **106** may be a refrigerant-to-liquid chiller heat exchanger that may function as a heat pump evaporator to dissipate heat from the first coolant in the first coolant circuit **104** to the refrigerant in the refrigeration circuit **103**. The second heat exchanger **107** may also be a refrigerant-to-liquid heat exchanger that may function as a heat pump condenser to dissipate heat from the refrigerant in the refrigeration circuit **103** to the second coolant in the second coolant circuit **105**.

[0022] The refrigeration circuit **103** includes a compressor **108** located downstream of the first heat exchanger **106** and upstream of the second heat exchanger **107**. The compressor **108** may be configured to compress the refrigerant. The compressor **108** is driven by a compressor motor **109**, which may be a brushless direct current (DC) electric motor, as depicted in the schematic diagram in FIG. **2**.

[0023] Referring now to FIG. **2**, the compressor motor **109** generally receives a DC power input signal from a power source **110**. An inverter **111** converts the DC signal into an alternating current (AC) signal to drive the compressor motor **109**. The compressor motor **109** generally is a three-phase system, and as such, has three motor windings **112** around a rotor **113** to receive the AC signal. While the motor windings **112** are shown in a wye (Y) configuration, it should be appreciated that they may be in a delta (Δ) configuration as well. In an unmodified state of the compressor motor **109**, in which the compressor motor **109** is most efficient, each phase is offset by a set angle equivalent to one third of a period, or 120 degrees. In addition, each phase runs at a defined frequency. As explained in method **200** hereinafter, these and other characteristics of the compressor motor **109** may be modified to reduce its coefficient of performance (COP), i.e., make it less efficient.

[0024] The compressor motor **109** further includes a motor controller **114** configured to control the operation of the compressor motor **109**, including, but not limited to, the speed and position of the rotor **113** of the compressor motor **109**, the frequency and offset of the three phases, commutation, and the like.

[0025] Referring back to FIG. **1**, the refrigeration circuit **103** also includes a first thermal expansion device **115**, a second thermal expansion device **116**, and a third heat exchanger **117**. The third heat exchanger **117** may be an ambient-to-refrigerant heat exchanger that may function as a cabin evaporator. It may be configured to absorb heat from the air flowing across it to cool and dehumidify the passenger compartment **102**, and to transfer the heat to the refrigerant flowing through it. The refrigerant may then be distributed to the compressor **108** and subsequently to the second heat exchanger **107**, where the heat in the refrigerant may be absorbed by the second coolant, as explained above.

[0026] The first thermal expansion device **115** and the second thermal expansion device **116** may be located downstream of the second heat exchanger **107**, and may be configured to cool and expand the refrigerant to be distributed to the first heat exchanger **106** and to the third heat exchanger **117**, respectively. The first thermal expansion device **115** and the second thermal expansion device **116** may be thermostatic or thermal expansion valves, and may be either electronically or mechanically actuated.

[0027] The refrigeration circuit **103** may also include a fourth heat exchanger **118**. The fourth heat exchanger **118** may be a refrigerant-to-ambient heat exchanger, and may function as a condenser for an air conditioning (A/C) system (not shown) in the vehicle **101**.

[0028] The refrigeration circuit **103** may further include a plurality of flow control valves **119**, **120**, **121**, and **122**. The flow control valves **119**, **120**, **121**, and **122** may be configured to control the flow to the various components in the refrigeration circuit **103**. It should be appreciated that the flow control valves **119**, **120**, **121**, and **122** may be any valve capable of restricting the flow of refrigerant in a particular line, and may be, but are not limited to, two-position, open/closed valves, or alternatively, modulating valves.

[0029] The first coolant circuit **104** includes a thermal storage device **123** and a first coolant pump **124**. The thermal storage device **123** may be any medium, device, machine, or the like, capable of generating and storing thermal energy. For example, the thermal storage device **123** may be an energy storage system (ESS) that includes at least one battery or battery pack.

[0030] The first coolant pump **124**, which may be variable speed, may be configured to circulate the first coolant through the thermal storage device **123** such that the first coolant may absorb heat generated by the thermal storage device **123**, or deposit heat within the thermal storage device **123**. The first coolant pump **124** further may be configured to circulate the first coolant through the first heat exchanger **106** such that heat may be transferred from the first coolant to the refrigerant, as explained above. While the first coolant pump **124** is shown downstream of the thermal storage device **123**, it should be appreciated that it may be located upstream of the thermal storage device **123**.

[0031] The first coolant circuit **104** also may include a heater **125**. The heater **125** may be configured to heat the first coolant in the first coolant circuit **104**, which flows to the thermal storage device **123** where the heat may be deposited and stored. The heater **125** may be, but is not limited to, a resistive heater.

[0032] The second coolant circuit **105** includes a heater core **126** and a second coolant pump **127**. The second coolant pump **127**, which may be variable speed, may be configured to circulate the second coolant through the heater core **126**. The heater core **126**, in turn, may be configured to receive the second coolant to heat air flowing across it and into the passenger compartment **102**. As explained above, the second coolant may receive heat from the thermal storage device **123** via the first heat exchanger **106**, and/or from the ambient air via the third heat exchanger **117**. While the second coolant pump **127** is shown downstream of the heater core **126**, it should be appreciated that it may be located upstream of the heater core **126**.

[0033] The second coolant circuit **105** also may include the ICE **128**, mentioned above. The ICE **128** may have heat within it from having been in operation. The heat may be deposited in the second coolant as it flows through the ICE **128**, thereby cooling the ICE **128**.

[0034] The second coolant circuit **105** further may include a bypass valve **129** and a bypass line **130**. The bypass valve **129** is configured to selectively direct the second coolant to the ICE **128** to cool it when the vehicle **101** is in range extending mode or hybrid mode, or to the bypass line **130** when the vehicle **101** is in EV drive mode. While the bypass valve **129** is shown in FIG. **1** as a two-position three-way valve, it should be appreciated that the bypass valve **129** may be any three-way valve configured to selectively direct the flow to the ICE **128** and/or to the bypass line **129**. In an alternative embodiment not shown, in lieu of a three-way valve, there may be two separate flow control valves, one each on the bypass line **130** and the second coolant circuit **105** downstream of the takeoff for the bypass line **130**.

[0035] The thermal storage heat pump system **100** may also include at least one system controller **131** that may be electrically connected to the thermal storage heat pump system **100** to control its operation. In particular, the system controller **131** may communicate with and control the operation of various devices of the thermal storage heat pump system **100**, including the motor controller **114**, based on at least one parameter, including, but not limited to, ambient air temperature, as described in method **200** hereinafter.

[0036] The system controller **131** also may be configured to communicate with and receive information from other ancillary devices, including, but not limited to, a temperature sensor **132** and an input module **133**, describer hereinafter. The system controller **131** may process the information received from these ancillary devices to determine the operating mode in which the thermal storage heat pump system **100** is to operate, and to operate the devices accordingly. As explained hereinafter, the thermal storage heat pump system **100** may operate in a heating mode or in a cooling mode. The system controller **131** may further be configured to control any other devices in the thermal storage heat pump system **100**, as well as any other subsystems in the vehicle **101**.

[0037] The temperature sensor **132** generally is any device configured to measure the ambient air temperature. The temperature sensor **132** may be configured to transmit data, such as the ambient air temperature measurement, to the system controller **131** to be stored and/or processed. The temperature sensor **132** may be external to the system controller **131**, as depicted in FIG. **1**, and may transmit the data through a wired or wireless connection. In another embodiment not shown, the temperature sensor may be internal to the system controller **131**. In yet another embodiment not shown, the system controller **131** may be configured to obtain such data as the ambient air temperature from a remote source (not shown) via the internet or other communications network.

[0038] The input module **133** may be any device configured to receive an input, such as a desired temperature or heat supply for the passenger compartment **102**, or other data from a user of the thermal storage heat pump system **100**. The input module **133** further may be configured to transmit such data to the controller **131**. The input module **133** may be, but is not limited to, an onboard computer in the vehicle **101**.

[0039] As mentioned above, the thermal storage heat pump system **100** may operate in a heating mode or a cooling mode. In the heating mode, the refrigerant in the refrigeration circuit **103** may be used to transfer heat to the second coolant in the second coolant circuit **105** via the second heat exchanger **107** to heat the passenger compartment **102** via the heater core **126**, as explained above. Conversely, in the cooling mode, the refrigerant may be used to absorb heat from the ambient air via the third heat exchanger **117** to cool the passenger compartment **102**. The thermal storage heat pump system **100** may selectively switch between the two modes based on a parameter, such as ambient air temperature.

[0040] In either mode, the refrigerant in the refrigeration circuit **103** is utilized to transfer heat, and as such, the compressor **108** and compressor motor **109** operate to compress the refrigerant. The compressor motor **109** requires a certain amount of electrical power received from the power source **110** to operate. In compressing the refrigerant, the compressor motor **109** converts the electrical power into electrical heat, which then may be transferred to the refrigerant.

[0041] In the heating mode, the electrical power necessary for the compressor motor **109**, and thus the electrical heat produced by the compressor motor **109**, is equal to the total thermal load required to heat the passenger compartment **102** divided by the COP of the compressor motor **109**. The total thermal load required may be determined by the system controller **131** based on a desired temperature or heat supply for the passenger compartment **102** as received from the input module **133**. The remaining thermal load not provided by the electrical heat produced from the compressor motor **109** may be provided from the thermal storage device **123**.

[0042] Referring now to FIGS. **5** and **6**, the effect of modifying the COP, represented by the y-axis **302** in FIG. **5**, on the electrical heat produced, represented by the y-axis **312** in FIG. **6**, when switching between the heating and cooling modes, represented by sections **308** and **310**, respectively, in FIGS. **5** and **6**, is shown. The x-axis **304** in FIGS. **5** and **6** represents the ambient air temperature. As explained above, the compressor motor **109** may be made less efficient by modifying its characteristics to reduce its COP. Generally, the compressor motor **109** is in its unmodified state in the cooling mode. However, by reducing the COP in the heating mode, the electrical heat produced increases with a fixed total thermal load required. As such, the amount of thermal load to be drawn from the thermal storage device **123** may decrease. This in turn may decrease the need to operate the heater **125** to provide the heat stored in the thermal storage device **123**.

[0043] Referring now to FIG. **3**, a method **200** for controlling the thermal storage heat pump system **100**, particularly the compressor **108** and the compressor motor **109**, is shown.

[0044] Method **200** begins at step **202** in which the system controller **131** receives a measurement of at least one parameter. The at least one parameter may be, but is not limited to, ambient air temperature. As explained above, the ambient air temperature measurement may be taken and transmitted to the system controller **131** by the temperature sensor **132**.

[0045] After step **202**, method **200** proceeds to step **204**. At step **204**, the system controller **131** determines the operating mode of the thermal storage heat pump system **100** based on the measurement of the at least one parameter. As explained above, the thermal storage heat pump system **100** may operate in either a heating mode or a cooling mode.

[0046] When the measurement of the at least one parameter meets a certain condition, the thermal storage heat pump system **100** will operate in the particular mode associated with that condition. For example, as seen in the graphs of FIGS. **5** and **6**, when the ambient air temperature (x-axis **304**) is at or below a switchover temperature **306**, the thermal storage heat pump system **100** may operate in the heating mode (section **308**). Conversely, when the ambient air temperature is above the switchover temperature **306**, the thermal storage heat pump system **100** may operate in the cooling mode (section **310**). The switchover temperature may be stored in the system controller **131**, and may be adjustable.

[0047] After step **204**, method **200** proceeds to step **206**. At step **206**, the compressor controller **114** operates the compressor motor **109** in either an unmodified state or a modified state, depending on the mode of operation. As explained above, when the thermal storage heat pump system is in the cooling mode, the compressor controller **114** operates the compressor motor **109** in the unmodified, or most efficient, state. When the thermal storage heat pump system **100** is in the heating mode, the compressor controller **114** operates the compressor motor **109** in the modified state in which its COP is decreased. This may include several sub-steps, as depicted in FIG. **4**.

[0048] Referring to FIG. **4**, at sub-step **206***a*, the compressor controller **114** may offset from the set angle at least one of the three phases of the compressor motor **109**. For example, the compressor controller **114** may offset one of the phases by 30 degrees. At sub-step **206***b*, the compressor controller **114** may alter the defined frequency of at least one of the three phases. As explained above, each phase operates at a defined frequency. Altering at least one of them may reduce the COP. It should be appreciated that step **204** may include any one of sub-steps **206***a* and **206***b*, which may be performed in any order. It should further be appreciated that step **206** may include more sub-steps in which the compressor motor **109** may be altered in other ways, such as internal motor restriction, mechanical losses internal to the compressor motor **109** (or frictional losses), mechanical braking, and the like, to reduce the COP.

[0049] The detailed description and the drawings or figures are supportive and descriptive of the invention, but the scope of the invention is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed invention have been described in detail, various alternative designs and embodiments exist for practicing the invention defined in the appended claims.

1. A method for controlling a compressor of a thermal storage heat pump system in a vehicle having a passenger compartment, the thermal storage heat pump system including a refrigeration circuit in thermal communication with a first coolant circuit and a second coolant circuit, the compressor being located in the refrigeration circuit and having a compressor motor and a motor controller, the method comprising:

receiving, by at least one system controller, a measurement of at least one parameter;

determining, by the at least one system controller, an operating mode of the thermal storage heat pump system based on the measurement of the at least one parameter; and

operating, by the motor controller, the compressor motor in one of an unmodified state and a modified state based on the operating mode of the thermal storage heat pump system;

wherein the operating mode is one of a heating mode and a cooling mode; and

wherein the compressor motor is operated in the unmodified state when the thermal storage heat pump system is in the cooling mode, and in the modified state when the thermal storage heat pump system is in the heating mode.

2. The method of claim **1** wherein the at least one parameter is ambient air temperature.

3. The method of claim **2** wherein the measurement of the ambient air temperature is taken and transmitted to the at least one system controller by a temperature sensor.

4. The method of claim **2** wherein the operating mode is the heating mode when the measurement of the ambient air temperature is at or below a switchover temperature, and is the cooling mode when the measurement of the ambient air temperature is above the switchover temperature.

5. The method of claim **1** wherein the compressor motor is a brushless direct current (DC) electric motor that has a coefficient of performance (COP), and is a three-phase system in which each phase is offset by a set angle and has a defined frequency in the unmodified state.

6. The method of claim **5** wherein the operating of the compressor motor in a modified state comprises reducing the COP of the compressor motor.

7. The method of claim **6** wherein the reducing of the COP comprises offsetting from the set angle at least one of the phases of the compressor motor.

8. The method of claim **6** wherein the reducing of the COP comprises altering the defined frequency of at least one of the phases of the compressor motor.

9. A thermal storage heat pump system of a vehicle having a passenger compartment, the system comprising:

a first coolant circuit configured to circulate a first coolant;

a second coolant circuit configured to circulate a second coolant;

a refrigeration circuit configured to circulate a refrigerant, the refrigeration circuit being in thermal communication with the first coolant circuit and the second coolant circuit via a first heat exchanger and a second heat exchanger, respectively;

a compressor located in the refrigeration circuit, the compressor being configured to compress the refrigerant, and having a compressor motor and a motor controller configured to selectively operate the compressor motor in one of an unmodified state and a modified state; and

at least one system controller configured to selectively operate the thermal storage heat pump system in one of a heating mode and a cooling mode based on a measurement of at least one parameter;

wherein the compressor motor is operated in the unmodified state when the thermal storage heat pump system is in the cooling mode, and in the modified state when the thermal storage heat pump system is in the heating mode.

10. The thermal storage heat pump system of claim **9** wherein the at least one parameter is ambient air temperature.

11. The thermal storage heat pump system of claim **10** further comprising a temperature sensor configured to measure the ambient air temperature to obtain an ambient air temperature measurement, and to transmit the ambient air temperature measurement to the at least one system controller.

12. The thermal storage heat pump system of claim **11** wherein the operating mode is the heating mode when the ambient air temperature measurement is at or below a switchover temperature, and is the cooling mode when the ambient air temperature measurement is above the switchover temperature.

13. The thermal storage heat pump system of claim **9** wherein the compressor motor is a brushless direct current (DC) electric motor that has a coefficient of performance (COP), and is a three-phase system in which each phase is offset by a set angle and has a defined frequency in the unmodified state.

14. The thermal storage heat pump system of claim **13** wherein the COP when the thermal storage heat pump system is in the heating mode is less than the COP when the thermal storage heat pump system is in the cooling mode.

15. The thermal storage heat pump system of claim **14** wherein at least one of the phases of the compressor motor is offset from the set angle.

16. The thermal storage heat pump system of claim **14** wherein at least one of the phases has an altered frequency different from the defined frequency.

17. A method for controlling a compressor of a thermal storage heat pump system having at least one system controller and a refrigeration circuit in which the compressor is located, the compressor having a compressor motor and a motor controller, the method comprising:

measuring, by a temperature sensor, ambient air temperature to obtain a temperature measurement;

transmitting, by the temperature sensor, the temperature measurement to the at least one system controller;

determining, by the at least one system controller, an operating mode of the thermal storage heat pump system based on the temperature measurement, the operating mode being one of a heating mode and a cooling mode; and

operating, by the motor controller, the compressor motor in an unmodified state when the thermal storage heat pump system is in the cooling mode, and in the modified state when the thermal storage heat pump system is in the heating mode.

18. The method of claim **17** wherein the operating mode is the heating mode when the temperature measurement is at or below a switchover temperature, and is the cooling mode when the temperature measurement is above the switchover temperature.

19. The method of claim **17** wherein the compressor motor is a brushless direct current (DC) electric motor that has a coefficient of performance (COP), and is a three-phase system in which each phase is offset by a set angle and has a defined frequency in the unmodified state.

20. The method of claim **19** wherein the operating of the compressor motor in a modified state comprises reducing the COP of the compressor motor by at least one of offsetting from the set angle at least one of the phases of the compressor motor, altering the defined frequency of at least one of the phases of the compressor motor, and adding mechanical losses internal to the compressor motor.

* * * * *