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Donnellan et al.

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(54) **TRANSPORT CLIMATE CONTROL SYSTEM POWER ARCHITECTURE**

(71) Applicant: **THERMO KING LLC**, Minneapolis, MN (US)

(72) Inventors: **Wayne Donnellan**, Oranmore (IE); **Sean Keaveney**, Galway (IE)

(73) Assignee: **THERMO KING LLC**, Minneapolis, MN (US)

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This patent is subject to a terminal disclaimer.

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(58) **Field of Classification Search**

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See application file for complete search history.

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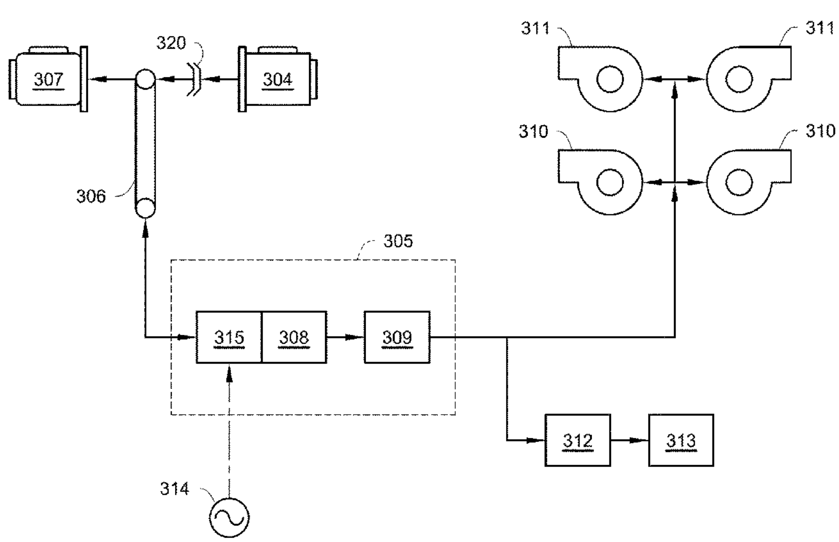
Primary Examiner — Jared Fureman
Assistant Examiner — Esayas G Yeshaw
(74) *Attorney, Agent, or Firm* — Hamre, Schumann, Mueller & Larson, P.C.

(57) **ABSTRACT**

A transport climate control system is disclosed. The system includes a compressor, a motor-generator-rectifier machine, a belt drive connected to the motor-generator-rectifier machine and the compressor, at least one condenser fan, at least one evaporator fan, and a DC to DC converter. The motor-generator-rectifier machine connects to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter. The motor-generator-rectifier machine includes a motor, a low voltage generator connected to the motor, and a rectifier connected to the low voltage generator. The motor-generator-rectifier machine can provide a first low voltage DC power to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter. The DC to DC converter can convert the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

17 Claims, 7 Drawing Sheets



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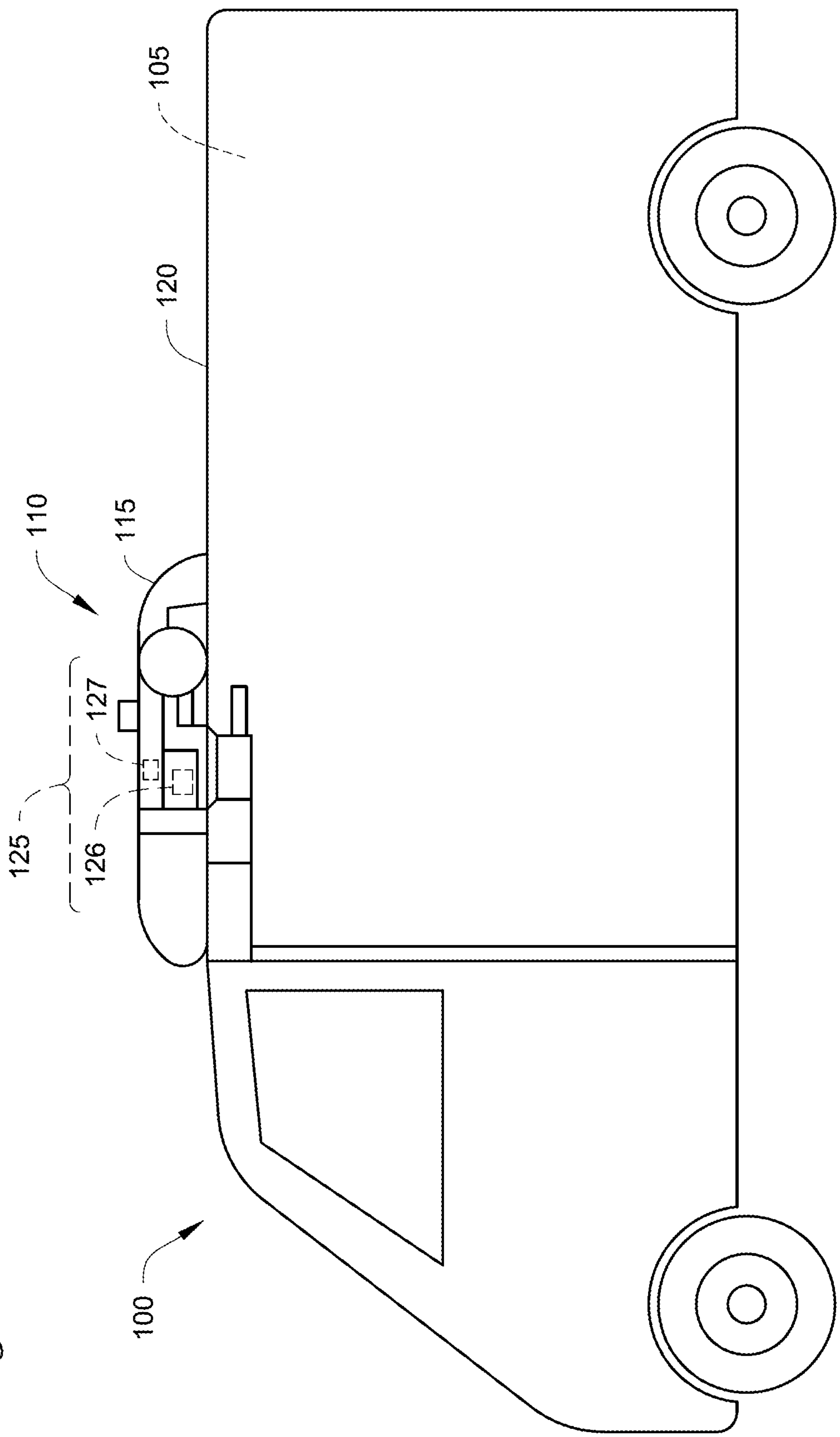


Fig. 1A

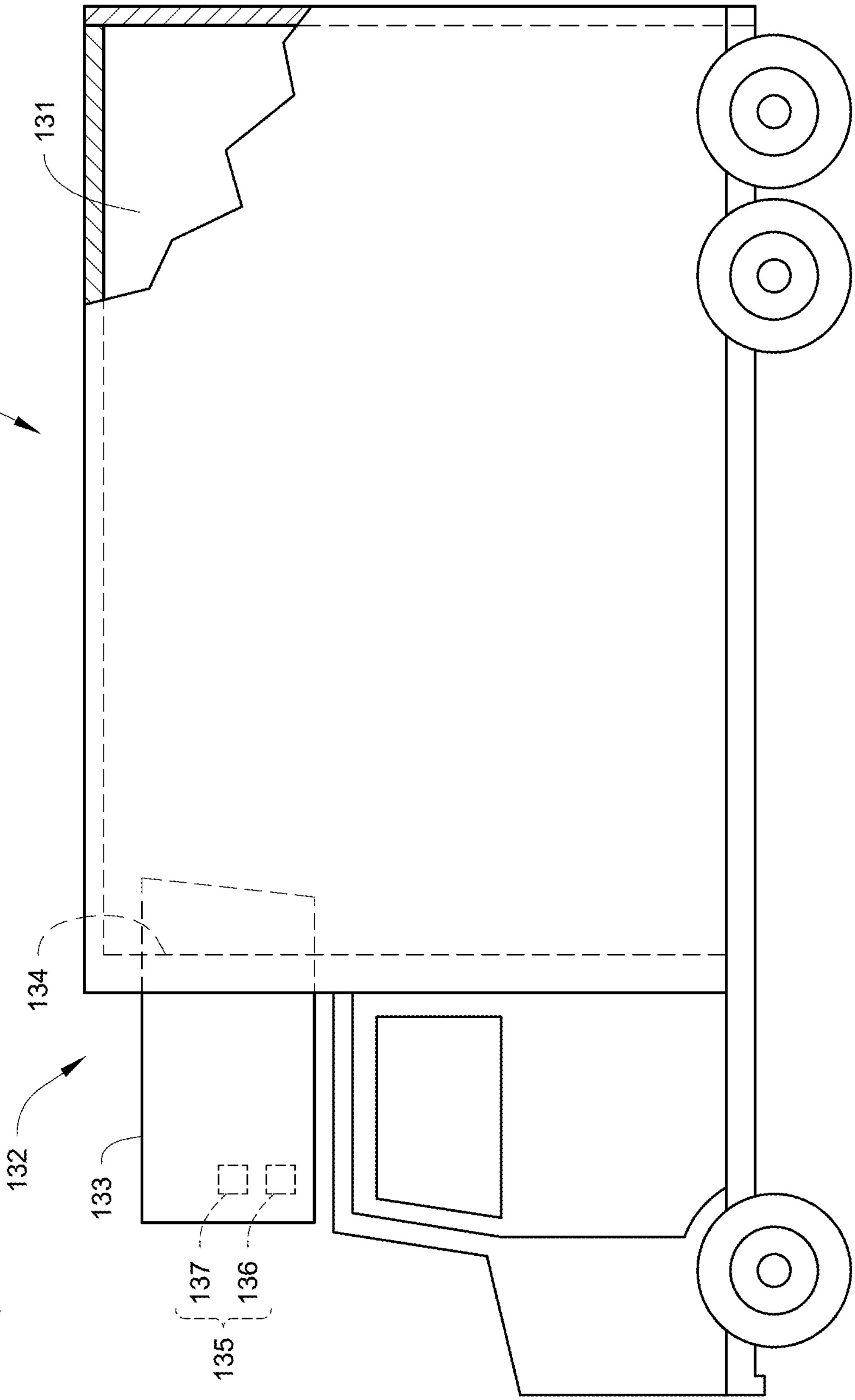


Fig. 1B

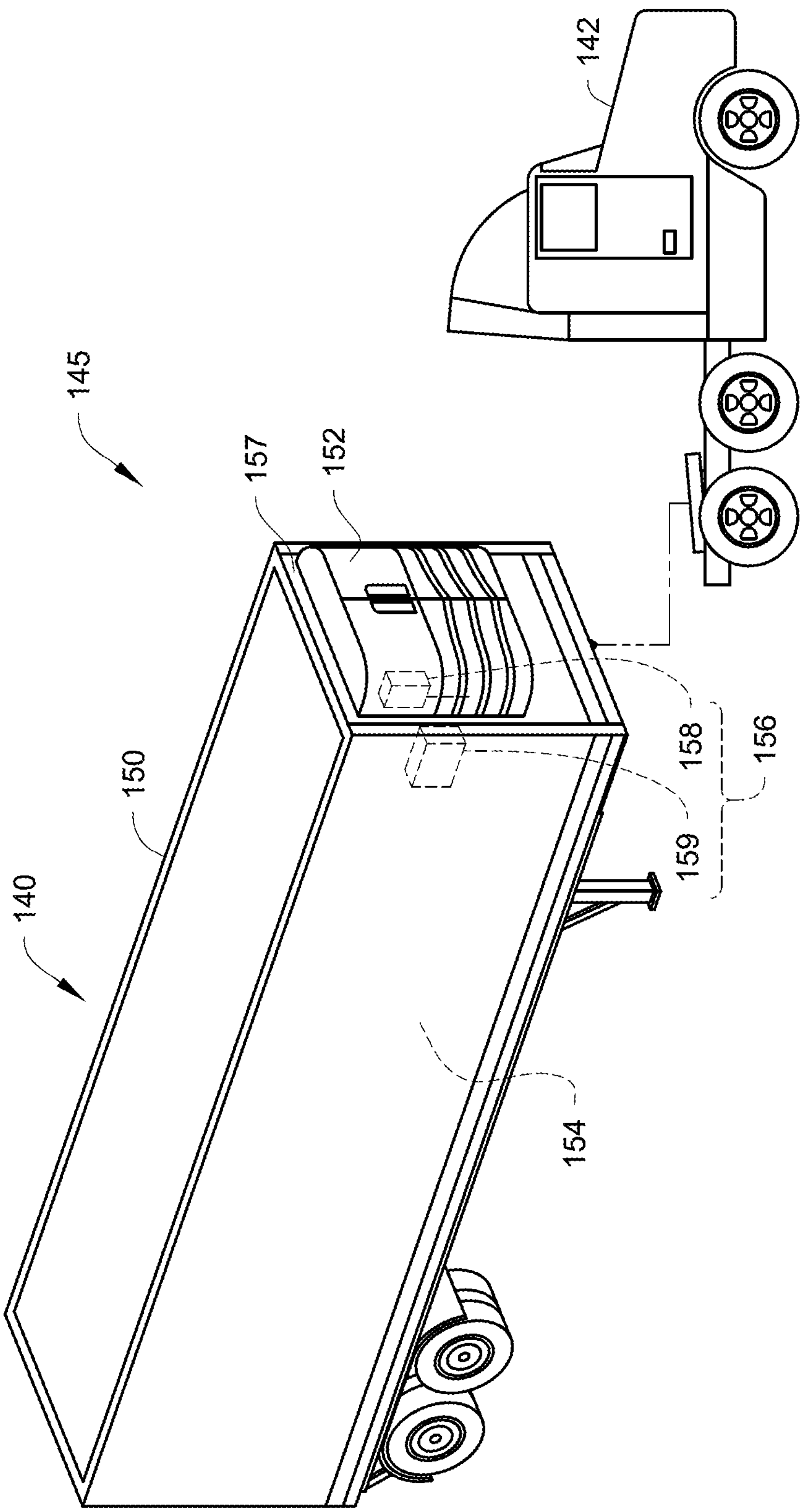
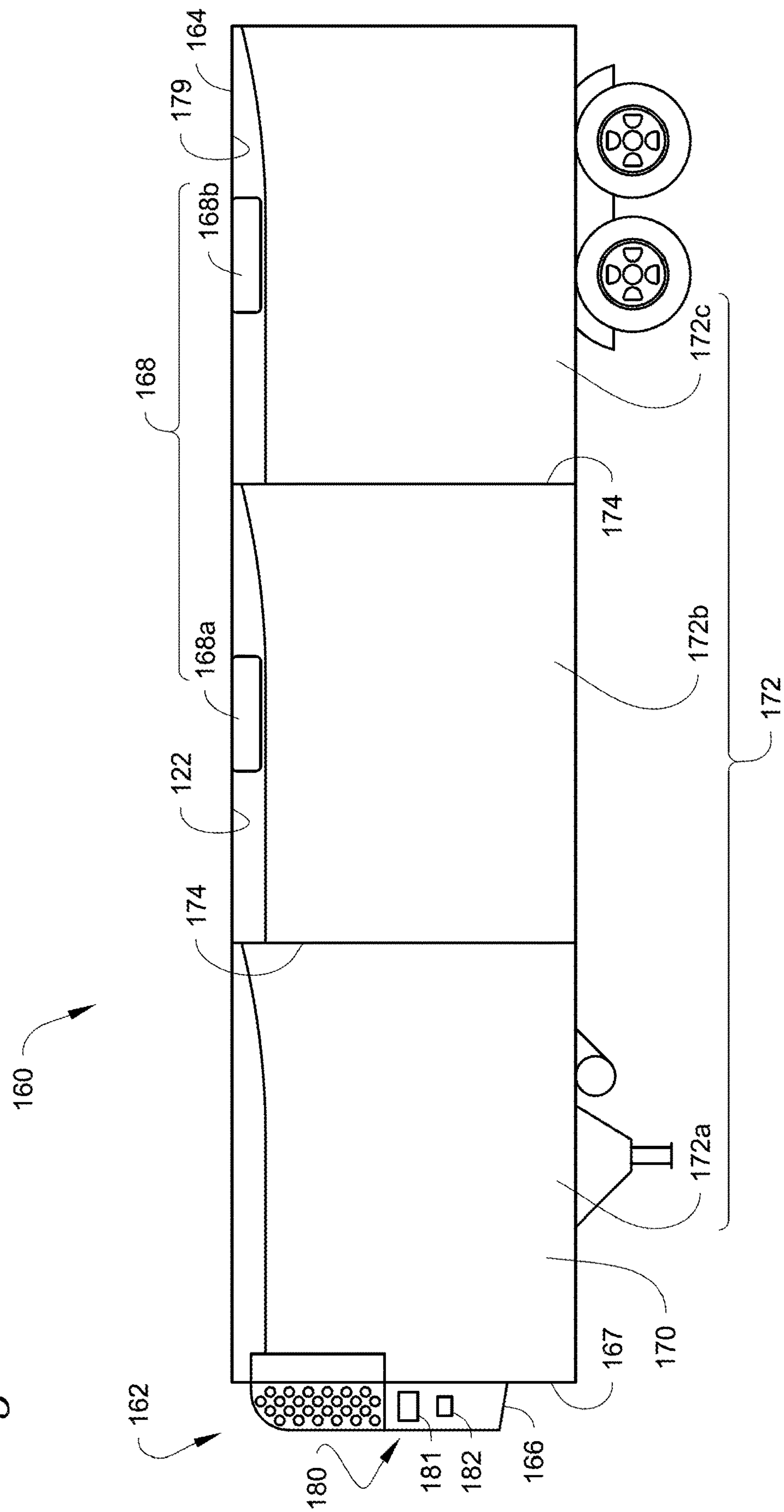


Fig. 1C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179
168b
168
168a
122
174
174
160
162
180
181
182
166
167
170
172a
172b
172c
172

Fig. 1D

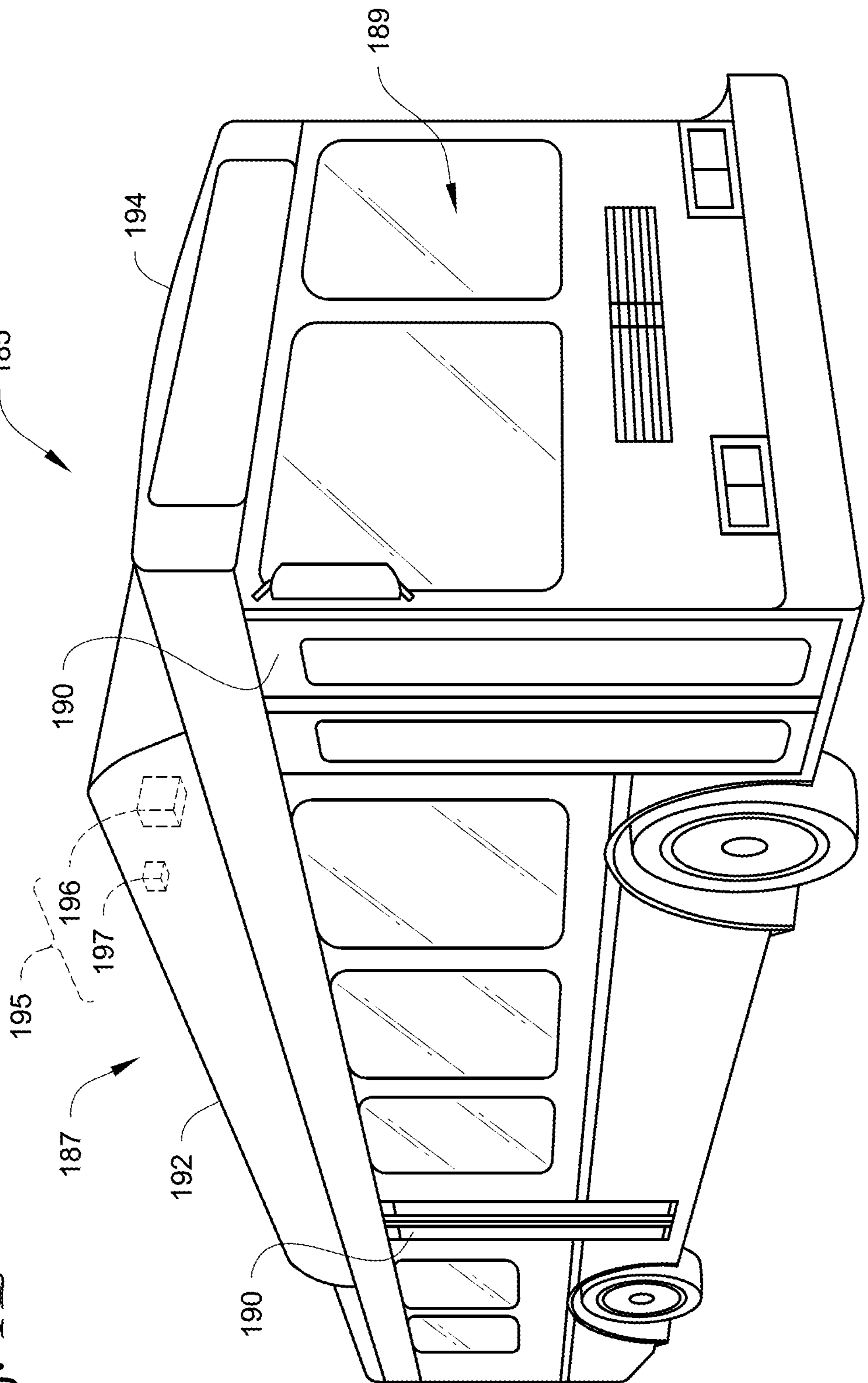
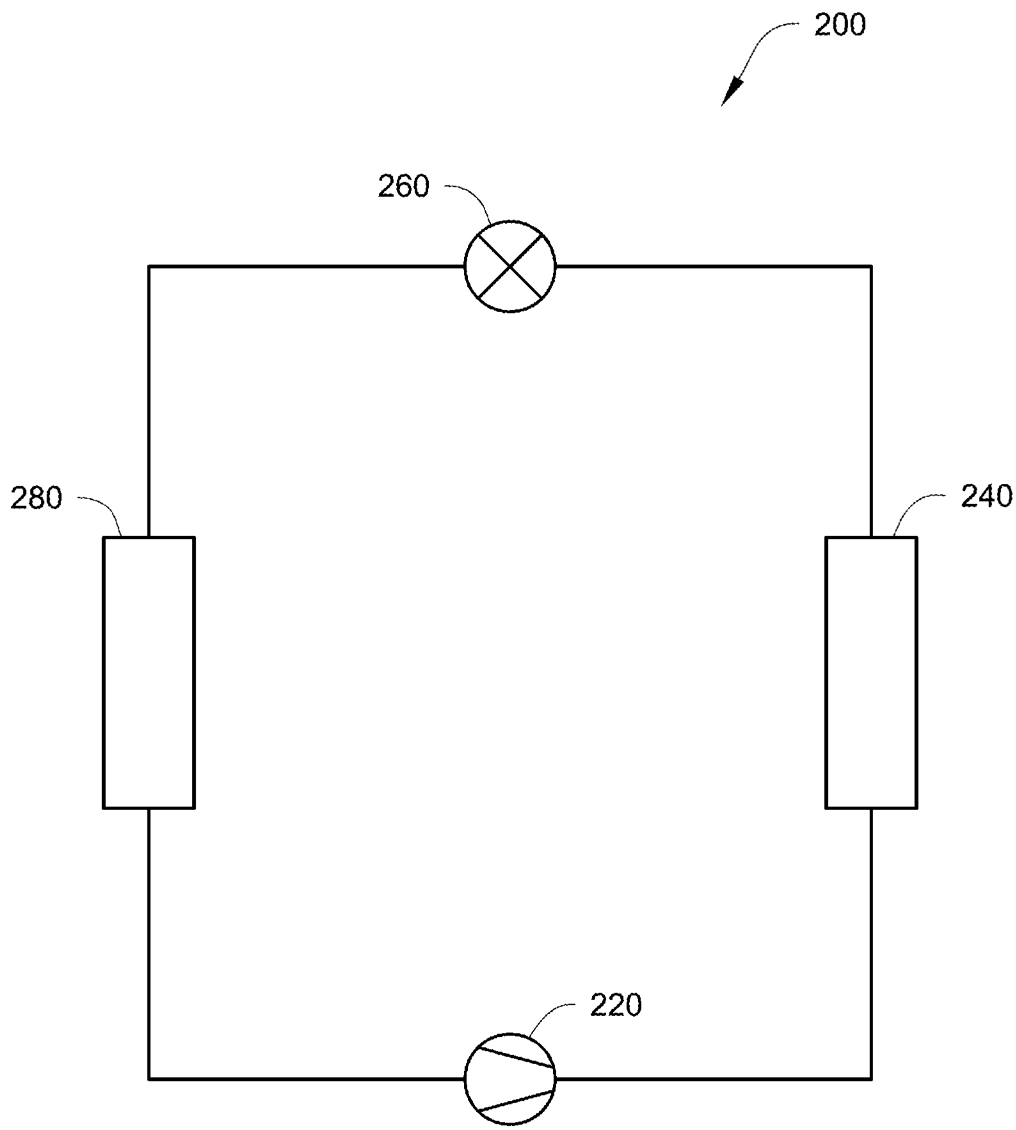


Fig. 1E

Fig. 2



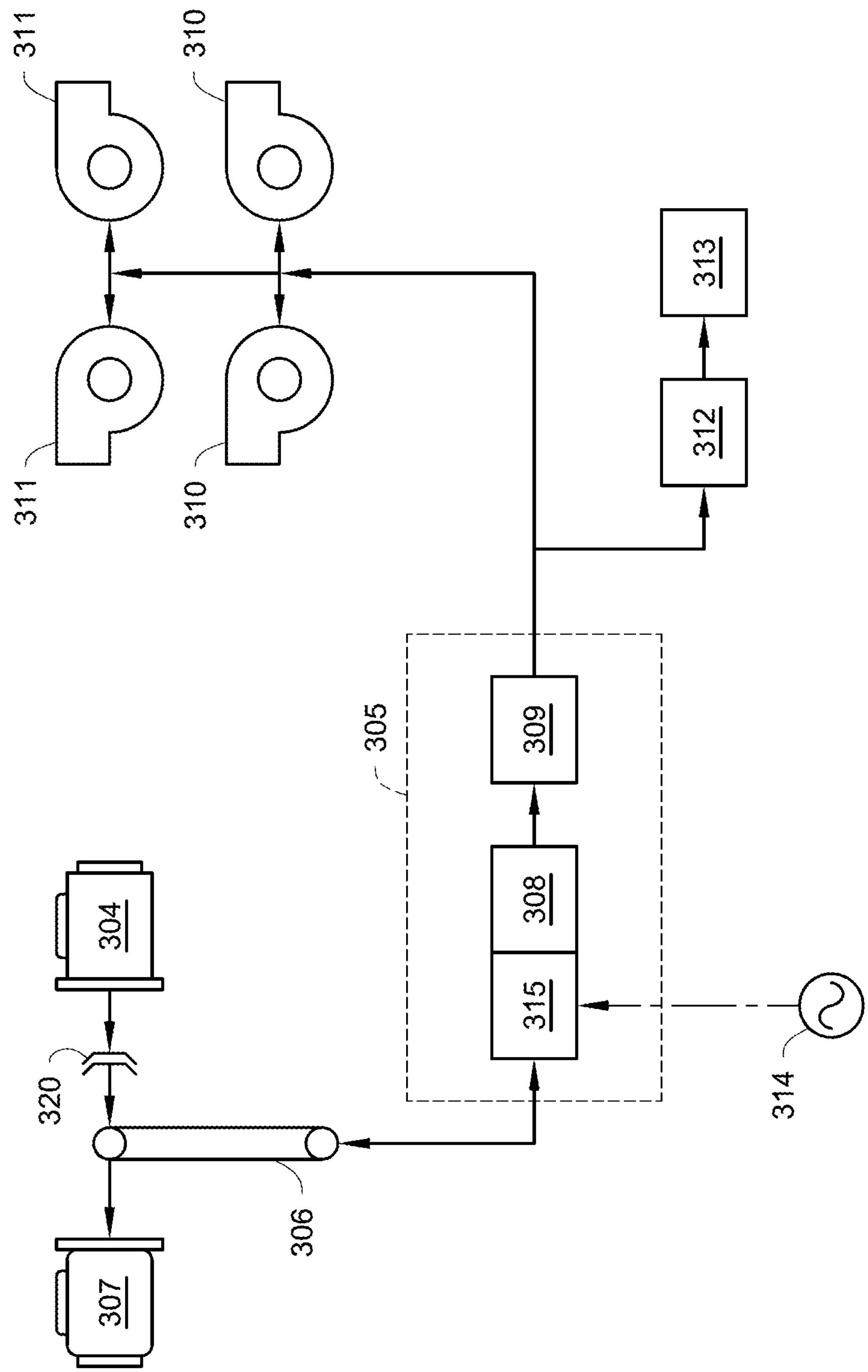


Fig. 3

TRANSPORT CLIMATE CONTROL SYSTEM POWER ARCHITECTURE

FIELD

The disclosure herein relates to a power architecture for providing energy to a transport climate control system.

BACKGROUND

A transport climate control system is generally used to control environmental condition(s) (e.g., temperature, humidity, air quality, and the like) within a climate controlled space of a transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit). The transport climate control system can include, for example, a transport refrigeration system (TRS) and/or a heating, ventilation and air conditioning (HVAC) system. The TRS can control environmental condition(s) within the climate controlled space to maintain cargo (e.g., produce, frozen foods, pharmaceuticals, etc.). The HVAC system can control environmental conditions(s) within the climate controlled space to provide passenger comfort for passengers travelling in the transport unit. In some transport units, the transport climate control system can be installed externally (e.g., on a rooftop of the transport unit, on a front wall of the transport unit, etc.).

SUMMARY

The disclosure herein relates to a power architecture for providing energy to a transport climate control system.

In some embodiments, a transport climate control system is provided with a diesel engine as a prime mover driving a motor-generator-rectifier machine via a belt drive to provide a low voltage DC power to drive low voltage DC components such as low voltage DC condenser fan(s) and/or evaporator fan(s).

The embodiments described herein are directed to a transport climate control system that includes condenser fan(s) and/or evaporator fan(s) that are electrically driven variable speed DC fan(s). Accordingly, the embodiments described herein can provide flexibility in the sizing and positioning of the condenser fan(s) and/or the evaporator fan(s). The embodiments described herein can also provide flexibility in the sizing and positioning of the condenser coil and/or the evaporator coil. The embodiments described herein can also facilitate variable condenser fan(s) and/or evaporator fan(s) which can optimize performance of the transport climate control system throughout is full operating range while also allowing a user to control a desired airflow within the climate controlled space of the transport unit. Accordingly, the embodiments described herein can reduce energy consumption and reduced total cost of ownership versus a conventional transport climate control system that has condenser fan(s) and/or evaporator fan(s) powered via a mechanical transmission (e.g. belt drive or gear drive).

In one embodiment, a transport climate control system is disclosed. The transport climate control system includes a compressor, a motor-generator-rectifier machine, a belt drive connected to the motor-generator-rectifier machine and the compressor, at least one condenser fan, at least one evaporator fan, and a DC to DC converter. The motor-generator-rectifier machine connects to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter. The motor-generator-rectifier machine includes a motor, a

low voltage generator connected to the motor, and a rectifier connected to the low voltage generator. The motor-generator-rectifier machine is configured to provide a first low voltage DC power to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter. The DC to DC converter is configured to convert the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

In one embodiment, a method for distributing power for a transport climate control system is disclosed. The method includes distributing power to a motor-generator-rectifier machine. The motor-generator-rectifier machine includes a motor, a low voltage generator, and a rectifier. The method also includes the motor-generator-rectifier machine generating a first low voltage DC power to drive at least one condenser fan, at least one evaporator fan, and a DC to DC converter. The method further includes the DC to DC converter converting the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

BRIEF DESCRIPTION OF THE DRAWINGS

References are made to the accompanying drawings that form a part of this disclosure and which illustrate embodiments in which the systems and methods described in this specification can be practiced.

FIG. **1**A illustrates a side view of a van with a transport climate control system, according to one embodiment.

FIG. **1**B illustrates a side view of a truck with a transport climate control system, according to one embodiment.

FIG. **1**C illustrates a perspective view of a climate controlled transport unit, with a transport climate control system, attached to a tractor, according to one embodiment.

FIG. **1**D illustrates a side view of a climate controlled transport unit with a multi-zone transport climate control system, according to one embodiment.

FIG. **1**E illustrates a perspective view of a mass-transit vehicle including a transport climate control system, according to one embodiment.

FIG. **2** is a schematic diagram of a climate control circuit, according to one embodiment.

FIG. **3** is a schematic diagram of a climate control power system, according to one embodiment.

Like reference numbers represent like parts throughout.

DETAILED DESCRIPTIONS

The disclosure herein relates to an electrical architecture for a transport climate control system.

In some embodiments, a transport climate control system is provided with a diesel engine as a prime mover driving a motor-generator-rectifier machine via a belt drive to provide a low voltage DC power to drive low voltage DC components such as low voltage DC condenser fan(s) and/or evaporator fan(s).

As defined herein, "low voltage" refers to Class A of the ISO 6469-3 in the automotive environment. In particular, "low voltage" refers to a maximum working voltage of between 0V and 60V DC or between 0V and 30V AC. E.g., a low voltage can be 12 VDC, 24 VDC, 48 VDC, or other suitable DC voltage.

As defined herein, "high voltage" refers to Class B of the ISO 6469-3 in the automotive environment. In particular, "high voltage" refers to a maximum working voltage of between 60V and 1500V DC or between 30V and 1000V

AC. E.g., a high voltage can be 350 VDC, 400 VDC, 700 VDC, 800 VDC or other suitable DC voltage.

FIG. **1**A depicts a climate-controlled van **100** that includes a climate controlled space **105** for carrying cargo and a transport climate control system **110** for providing climate control within the climate controlled space **105**. The transport climate control system **110** includes a climate control unit (CCU) **115** that is mounted to a rooftop **120** of the van **100**. The transport climate control system **110** can include, amongst other components, a climate control circuit (see FIG. **2**) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide climate control within the climate controlled space **105**. It will be appreciated that the embodiments described herein are not limited to climate-controlled vans, but can apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), etc.

The transport climate control system **110** also includes a programmable climate controller **125** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **110** (e.g., an ambient temperature outside of the van **100**, an ambient humidity outside of the van **100**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **115** into the climate controlled space **105**, a return air temperature of air returned from the climate controlled space **105** back to the CCU **115**, a humidity within the climate controlled space **105**, etc.) and communicate parameter data to the climate controller **125**. The climate controller **125** is configured to control operation of the transport climate control system **110** including the components of the climate control circuit. The climate controller unit **115** may comprise a single integrated control unit **126** or may comprise a distributed network of climate controller elements **126**, **127**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

FIG. **1**B depicts a climate-controlled straight truck **130** that includes a climate controlled space **131** for carrying cargo and a transport climate control system **132**. The transport climate control system **132** includes a CCU **133** that is mounted to a front wall **134** of the climate controlled space **131**. The CCU **133** can include, amongst other components, a climate control circuit (see FIG. **2**) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide climate control within the climate controlled space **131**.

The transport climate control system **132** also includes a programmable climate controller **135** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **132** (e.g., an ambient temperature outside of the truck **130**, an ambient humidity outside of the truck **130**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **133** into the climate controlled space **131**, a return air temperature of air returned from the climate controlled space **131** back to the CCU **133**, a humidity within the climate controlled space **131**, etc.) and communicate parameter data to the climate controller **135**. The climate controller **135** is configured to control operation of the transport climate control system **132** including components of the climate control circuit. The climate controller **135** may comprise a single integrated control unit **136** or may comprise a distributed network of climate controller elements **136**, **137**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

FIG. **1**C illustrates one embodiment of a climate controlled transport unit **140** attached to a tractor **142**. The climate controlled transport unit **140** includes a transport climate control system **145** for a transport unit **150**. The tractor **142** is attached to and is configured to tow the transport unit **150**. The transport unit **150** shown in FIG. **1**C is a trailer.

The transport climate control system **145** includes a CCU **152** that provides environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **154** of the transport unit **150**. The CCU **152** is disposed on a front wall **157** of the transport unit **150**. In other embodiments, it will be appreciated that the CCU **152** can be disposed, for example, on a rooftop or another wall of the transport unit **150**. The CCU **152** includes a climate control circuit (see FIG. **2**) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **154**.

The transport climate control system **145** also includes a programmable climate controller **156** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **145** (e.g., an ambient temperature outside of the transport unit **150**, an ambient humidity outside of the transport unit **150**, a compressor suction pressure, a compressor discharge pressure, a supply air temperature of air supplied by the CCU **152** into the climate controlled space **154**, a return air temperature of air returned from the climate controlled space **154** back to the CCU **152**, a humidity within the climate controlled space **154**, etc.) and communicate parameter data to the climate controller **156**. The climate controller **156** is configured to control operation of the transport climate control system **145** including components of the climate control circuit. The climate controller **156** may comprise a single integrated control unit **158** or may comprise a distributed network of climate controller elements **158**, **159**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

FIG. **1**D illustrates another embodiment of a climate controlled transport unit **160**. The climate controlled transport unit **160** includes a multi-zone transport climate control system (MTCS) **162** for a transport unit **164** that can be towed, for example, by a tractor (not shown). It will be appreciated that the embodiments described herein are not limited to tractor and trailer units, but can apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), etc.

The MTCS **162** includes a CCU **166** and a plurality of remote units **168** that provide environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **170** of the transport unit **164**. The climate controlled space **170** can be divided into a plurality of zones **172**. The term "zone" means a part of an area of the climate controlled space **170** separated by walls **174**. The CCU **166** can operate as a host unit and provide climate control within a first zone **172***a* of the climate controlled space **166**. The remote unit **168***a* can provide climate control within a second zone **172***b* of the climate controlled space **170**. The remote unit **168***b* can provide climate control within a third zone **172***c* of the climate controlled space **170**. Accordingly, the MTCS **162** can be used to separately and independently control environmental condition(s) within each of the multiple zones **172** of the climate controlled space **162**.

The CCU **166** is disposed on a front wall **167** of the transport unit **160**. In other embodiments, it will be appreciated that the CCU **166** can be disposed, for example, on a rooftop or another wall of the transport unit **160**. The CCU **166** includes a climate control circuit (see FIG. **2**) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **170**. The remote unit **168***a* is disposed on a ceiling **179** within the second zone **172***b* and the remote unit **168***b* is disposed on the ceiling **179** within the third zone **172***c*. Each of the remote units **168***a*, **168***b* include an evaporator (not shown) that connects to the rest of the climate control circuit provided in the CCU **166**.

The MTCS **162** also includes a programmable climate controller **180** and one or more sensors (not shown) that are configured to measure one or more parameters of the MTCS **162** (e.g., an ambient temperature outside of the transport unit **164**, an ambient humidity outside of the transport unit **164**, a compressor suction pressure, a compressor discharge pressure, supply air temperatures of air supplied by the CCU **166** and the remote units **168** into each of the zones **172**, return air temperatures of air returned from each of the zones **172** back to the respective CCU **166** or remote unit **168***a* or **168***b*, a humidity within each of the zones **118**, etc.) and communicate parameter data to a climate controller **180**. The climate controller **180** is configured to control operation of the MTCS **162** including components of the climate control circuit. The climate controller **180** may comprise a single integrated control unit **181** or may comprise a distributed network of climate controller elements **181**, **182**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

FIG. **1**E is a perspective view of a vehicle **185** including a transport climate control system **187**, according to one embodiment. The vehicle **185** is a mass-transit bus that can carry passenger(s) (not shown) to one or more destinations. In other embodiments, the vehicle **185** can be a school bus, railway vehicle, subway car, or other commercial vehicle that carries passengers. The vehicle **185** includes a climate controlled space (e.g., passenger compartment) **189** supported that can accommodate a plurality of passengers. The vehicle **185** includes doors **190** that are positioned on a side of the vehicle **185**. In the embodiment shown in FIG. **1**E, a first door **190** is located adjacent to a forward end of the vehicle **185**, and a second door **190** is positioned towards a rearward end of the vehicle **185**. Each door **190** is movable between an open position and a closed position to selectively allow access to the climate controlled space **189**. The transport climate control system **187** includes a CCU **192** attached to a roof **194** of the vehicle **185**.

The CCU **192** includes a climate control circuit (see FIG. **2**) that connects, for example, a compressor, a condenser, an evaporator and an expansion device to provide conditioned air within the climate controlled space **189**. The transport climate control system **187** also includes a programmable climate controller **195** and one or more sensors (not shown) that are configured to measure one or more parameters of the transport climate control system **187** (e.g., an ambient temperature outside of the vehicle **185**, a space temperature within the climate controlled space **189**, an ambient humidity outside of the vehicle **185**, a space humidity within the climate controlled space **189**, etc.) and communicate parameter data to the climate controller **195**. The climate controller **195** is configured to control operation of the transport climate control system **187** including components of the climate control circuit. The climate controller **195** may comprise a single integrated control unit **196** or may comprise a distributed network of climate controller elements **196**, **197**. The number of distributed control elements in a given network can depend upon the particular application of the principles described herein.

FIG. **2** is a schematic diagram of a climate control circuit **200**, according to one embodiment. The climate control circuit **200** can be used, for example, in the transport climate control systems **110**, **132**, **145**, **162** and **187** (shown in FIGS. **1**A-**1**E). The climate control circuit **200** generally includes a compressor **220**, a condenser **240**, an expansion device **260**, and an evaporator **280**. The climate control circuit **200** is an example and can be modified to include additional components. For example, in an embodiment, the climate control circuit **200** can include other components such as, but not limited to, an economizer heat exchanger, one or more flow control devices, a receiver tank, a dryer, a suction-liquid heat exchanger, one or more condenser blowers/fans, one or more evaporator blowers/fans, one or more sensors, a controller, or the like.

The climate control circuit **200** can generally be applied in a variety of systems used to control an environmental condition (e.g., temperature, humidity, air quality, or the like) in a space (generally referred to as a conditioned space). Examples of such systems include, but are not limited to, HVAC systems, transport climate control systems, or the like. In one embodiment, an HVAC system can be a rooftop unit or a heat pump air-conditioning unit.

The compressor **220**, condenser **240**, expansion device **260**, and evaporator **280** are fluidly connected. In one embodiment, the climate control circuit **200** can be configured to be a cooling system (e.g., an air conditioning system) capable of operating in a cooling mode. In one embodiment, the climate control circuit **200** can be configured to be a heat pump system that can operate in both a cooling mode and a heating/defrost mode.

The climate control circuit **200** can operate according to generally known principles. The climate control circuit **200** can be configured to heat or cool a liquid process fluid (e.g., a heat transfer fluid or medium (e.g., a liquid such as, but not limited to, water or the like)), in which case the climate control circuit **200** may be generally representative of a liquid chiller system. The climate control circuit **200** can alternatively be configured to heat or cool a gaseous process fluid (e.g., a heat transfer medium or fluid (e.g., a gas such as, but not limited to, air or the like)), in which case the climate control circuit **200** may be generally representative of an air conditioner or heat pump.

In operation, the compressor **220** compresses a working fluid (e.g., a heat transfer fluid (e.g., refrigerant or the like)) from a relatively lower pressure gas to a relatively higher-pressure gas. The relatively higher-pressure gas is also at a relatively higher temperature, which is discharged from the compressor **220** and flows through the condenser **240**. In accordance with generally known principles, the working fluid flows through the condenser **200** and rejects heat to the process fluid (e.g., water, air, etc.), thereby cooling the working fluid. The cooled working fluid, which is now in a liquid form, flows to the expansion device **260**. The expansion device **260** reduces the pressure of the working fluid. As a result, a portion of the working fluid is converted to a gaseous form. The working fluid, which is now in a mixed liquid and gaseous form flows to the evaporator **280**. The working fluid flows through the evaporator **280** and absorbs heat from the process fluid (e.g., a heat transfer medium (e.g., water, air, etc.)), heating the working fluid, and converting it to a gaseous form. The gaseous working fluid then returns to the compressor **220**. The above-described process continues while the heat transfer circuit is operating, for example, in a cooling mode.

FIG. **3** is a schematic diagram of a climate control power system **300**, according to one embodiment. It will be appreciated that the climate control power system **300** can be used to provide energy for powering the compressor **220** and at least one condenser fan associated with the condenser **240** and at least one evaporator fan associated with the evaporator **280** of the climate control circuit **200** of FIG. **2**. The climate control power system **300** can also power any other components (e.g., vehicle tail lift charger, auxiliary lighting systems inside the climate controlled space, etc.) of a transport climate control system (e.g., the transport climate control systems **110**, **132**, **145**, **162** and **187** shown in FIGS. **1**A-**1**E).

The climate control power system **300** includes a compressor **307** (e.g., the compressor **220** shown in FIG. **2**), a belt drive **306**, a prime mover **304** and a clutch **320**. The compressor **307** can be mechanically driven by the belt drive **306** or by the prime mover **304** via a clutch **320**. The prime mover **304** can be an internal combustion engine (e.g., a diesel engine, a compression-ignition engine, etc.). In one embodiment, the compressor **307** can be directly mounted to the prime mover **304** via the clutch **320**. In such embodiment, the prime mover **304** can be configured to, e.g., mechanically drive the compressor **307** via the clutch **320** when the clutch **320** is engaged (to the compressor **307** and the belt drive **306**). When the clutch **320** does not engage the compressor **307** to the belt drive **306**, the compressor **307** can be driven by a motor-generator-rectifier machine **305** via the belt drive **306**.

The motor-generator-rectifier machine **305** includes a motor **315** (e.g., an AC motor winding), a generator **308** (e.g., a low voltage AC generator winding to generate electrical power when a shaft of the motor-generator-rectifier machine **305** is rotating) connected to the motor **315**, and a rectifier **309** (e.g., an AC-DC rectifier) connected to the generator **308**.

In one embodiment, when the clutch **320** is engaged (and thus the prime mover **304**) with the compressor **307** and the belt drive **306**, the motor-generator-rectifier machine **305** can be powered and/or driven by the prime mover **304** via the belt drive **306**, to provide power. In such embodiment, the compressor **307** can be directly driven by the prime mover **304** via the clutch **320**.

In one embodiment, the motor-generator-rectifier machine **305** can connect to an AC power source **314**. In such embodiment, the clutch **320** (and thus the prime mover **304**) is disengaged from the compressor **307** and the belt drive **306**. The AC power source **314** can be, for example, a shore/utility power source. The AC power source **314** can be a three-phase AC power source. The AC power source **314** can provide power to the motor **315** of the motor-generator-rectifier machine **305** to energize the motor **315**. The motor **315** can be an electric motor. In such embodiment, the motor **315** is a standby motor, which serves as an alternate prime mover to provide power to the climate control power system **300**, for example, when the prime mover **304** is unavailable to provide power.

When the motor **315** is energized, the motor **315** can rotate a shaft (not shown) of the motor-generator-rectifier machine **305**. It will be appreciated that the motor **315** and the generator **308** are on the same shaft. The shaft of the motor-generator-rectifier machine **305** can propel the generator **308** so that the generator **308** can generate AC power. In one embodiment, the generator **308** is a low voltage generator. The AC power generated by the generator **308** is distributed to the rectifier **309**. In one embodiment, the rectifier **309** is an active rectifier. The rectifier **309** can convert the AC power generated by the generator **308**, to e.g., a low voltage DC power. In one embodiment, the voltage of the converted low voltage DC power is 48 volts. When the motor **315** is energized, the motor **315** can also drive the compressor **307** via the belt drive **306**.

The climate control power system **300** includes at least one condenser fan **310**, at least one evaporator fan **311**, and a DC to DC converter **312**. In some embodiments, the at least one condenser fan **310** can be a variable speed fan. In some embodiments, the at least one condenser fan **310** can be a low voltage DC fan. In some embodiments, the at least one evaporator fan **311** can be a variable speed fan. In some embodiments, the at least one evaporator fan **311** can be a low voltage DC fan.

The converted low voltage DC power from the rectifier **309** is distributed to the at least one condenser fan **310**, the at least one evaporator fan **311**, and the DC to DC converter **312**. In one embodiment, the DC to DC converter **312** is a buck converter that lowers the converted low voltage DC power from the rectifier **309**, to a second low voltage DC power.

In one embodiment, the second low voltage DC power is distributed to a control system **313** to power and/or charge the control system **313**. The control system **313** can include a controller, a rechargeable energy storage system (e.g., a battery), a battery charger, solenoid(s), and/or valve(s), etc. In one embodiment, the voltage of the second low voltage DC power is 12 volts.

In operation, in a running mode of the climate control power system **300**, the prime mover **304** is engaged with the compressor **307** and the belt drive **306**, via the clutch **320**. In such mode, the prime mover **304** directly drives the compressor **307**, which is directly mounted to the prime mover **304**. The prime mover **304** connects to and drives the motor-generator-rectifier machine **305** via the belt drive **306**, such that the generator **308** of the motor-generator-rectifier machine **305** can provide a low voltage AC power to the rectifier **309** of the motor-generator-rectifier machine **305**. The rectifier **309** can convert the low voltage AC power to a low voltage DC power to drive the low voltage DC fans (the at least one condenser fan **310** and at least one evaporator fan **311**) and to provide power to the DC to DC convertor **312**. The DC to DC convertor **312** can convert the low voltage DC power from the rectifier **309** to a second low voltage DC voltage to power and/or charge the control system **313** (e.g., charging the battery of the control system **313**, providing DC power to the solenoid(s) and valve(s) of the control system **313**, etc.).

In operation, in a standby mode of the climate control power system **300**, the prime mover **304** is disengaged with the compressor **307** and the belt drive **306**, via the clutch **320**. The AC power source **314** can provide power to the climate control circuit **300** when connected to the motor **315** to energize the motor **315**. When the motor **315** is energized, the motor **315** can rotate the shaft of the motor-generator-rectifier machine **315**, which can propel the generator **308** to provide a low voltage AC power to the rectifier **309** which in turn can convert the low voltage AC power to a low voltage DC power to drive the low voltage DC fans (the at least one condenser fan **310** and at least one evaporator fan

311) and to provide power to the DC to DC convertor **312**. The DC to DC convertor **312** can convert the low voltage DC power from the rectifier **309** to a second low voltage DC power to power and/or charge the control system **313** (e.g., charging the battery of the control system **313**, providing DC power to the solenoid(s) and valve(s) of the control system **313**, etc.). When the motor **315** is energized, the motor **315** can also drive the compressor **307** via the belt drive **306**.

Embodiments disclosed herein allow each of the at least one condenser fan **310** and the at least one evaporator fan **311** to be individually and independently powered and controlled (e.g., by the controller). As such, the speed of the at least one condenser fan **310** and/or the speed of the at least one evaporator fan **311** can be controlled independent of the speed of the prime mover **304** and/or the speed of the generator **308**.

In one embodiment, the at least one condenser fan **310** and/or the at least one evaporator fan **311** can be fully variable speed fans. In such embodiment, the at least one condenser fan **310** and/or the at least one evaporator fan **311** can have more than two speeds. It will be appreciated that a two-speed fan refers to a fan with a high speed and a low speed corresponding to a two-speed engine/generator that drives the fan. The fans (**310** and/or **311**) can be configured to run continuously and/or in a cycle-sentry mode. The speed of the fans (**310** and/or **311**) can be controlled (e.g., by the controller) to optimize at each point around fuel economy. For example, the speed of the fans (**310** and/or **311**) can be controlled based on a curve fit which is based on e.g., prime mover (e.g., engine) speed, ambient temperature, and/or box temperature (e.g., temperature of the climate controlled space), during operations such as pulldown. In one embodiment, the curve fit of the fan speed (a curve used by the controller to determine the speed of the fan) can be based on the speed of the compressor, ambient temperature, and/or box temperature. In such embodiment, the speed of the fans (**310** and/or **311**) can be controlled based on the load of the transport climate control system. In one embodiment, the curve fit of the fan speed (a curve used by the controller to determine the speed of the fan) can be used when, e.g., an AC power source (such as utility/shore power) is used and the prime mover is disengaged.

It will be appreciated that in one embodiment, to generate power for the transport climate control system, technology from automotive Hybrid Electric Vehicles can be used. For example, an automotive belt-driven-starter-generator (BSG) can be used in place of the motor-generator-rectifier machine **305** of FIG. **3** to be belt driven, or be directly coupled to the motor **315** to provide a low voltage DC power to the low voltage DC fans (e.g., the at least one condenser fan **310** and at least one evaporator fan **311**) and to the DC to DC converter **312**. It will also be appreciated that in one embodiment, to generate power for the low voltage DC fans (e.g., the at least one condenser fan **310** and at least one evaporator fan **311**) and the DC to DC converter **312**, the motor **315** can be directly coupled to a high voltage generator (to replace the low voltage generator **308**), where the generator can provide high voltage AC power (e.g., 400 VAC, 50 Hz). Alternately, the high voltage generator can be a belt driven device providing high voltage AC. The high voltage AC generated by either of the two high voltage generator configurations can then be input to an AC to DC converter, that can provide the required DC power levels for the at least one condenser fan **310**, the at least one evaporator fan **311**, and/or the control system **313**. In some embodiments, AC (e.g., high voltage AC) powered condenser and/or evaporator fans can be used in place of the at least one condenser fan **310** and the at least one evaporator fan **311**. In such embodiments, the condenser and/or evaporator fans can be powered by a high voltage generator and/or by the prime mover **304**.

ASPECTS

It is to be appreciated that any of aspects 1-11 can be combined with any of aspects 12-15.

Aspect 1. A transport climate control system, the transport climate control system comprising:
- a compressor;
- a motor-generator-rectifier machine;
- a belt drive connected to the motor-generator-rectifier machine and the compressor;
- at least one condenser fan;
- at least one evaporator fan; and
- a DC to DC converter,
- wherein the motor-generator-rectifier machine connects to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter,
- wherein the motor-generator-rectifier machine includes:
  - a motor;
  - a low voltage generator connected to the motor; and
  - a rectifier connected to the low voltage generator,
- wherein the motor-generator-rectifier machine is configured to provide a first low voltage DC power to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter, and
- the DC to DC converter is configured to convert the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

Aspect 2. The transport climate control system according to aspect 1, wherein the compressor is configured to be directly driven by a prime mover via a clutch.

Aspect 3. The transport climate control system according to aspect 1 or aspect 2, wherein the motor-generator-rectifier machine is configured to be driven by a prime mover via the belt drive.

Aspect 4. The transport climate control system according to any one of aspects 1-3, wherein the prime mover is a diesel engine.

Aspect 5. The transport climate control system according to any one of aspects 1-4, wherein the compressor is configured to be driven by the motor via the belt drive.

Aspect 6. The transport climate control system according to aspect 1, wherein the motor is configured to be driven by an AC power source.

Aspect 7. The transport climate control system according to aspect 6, wherein the motor is configured to rotate a shaft of the motor-generator-rectifier machine, and
- the shaft is configured to propel the low voltage generator to provide power.

Aspect 8. The transport climate control system according to any one of aspects 1-7, wherein the DC to DC converter is a buck converter that lowers the first low voltage DC power to the second low voltage DC power.

Aspect 9. The transport climate control system according to any one of aspects 1-8, wherein the at least one condenser fan and/or the at least one evaporator fan are variable speed fans.

Aspect 10. The transport climate control system according to any one of aspects 1-9, wherein a speed of the at least one condenser fan and/or a speed of the at least one evaporator fan are controlled independent of a speed of a prime mover and/or a speed of the low voltage generator.

Aspect 11. The transport climate control system according to any one of aspects 1-10, wherein the first low voltage DC power is 48 volts and the second low voltage DC power is 12 volts.

Aspect 12. A method for distributing power for a transport climate control system, the method comprising:

distributing power to a motor-generator-rectifier machine, the motor-generator-rectifier machine including a motor, a low voltage generator, and a rectifier,

the motor-generator-rectifier machine generating a first low voltage DC power to drive at least one condenser fan, at least one evaporator fan, and a DC to DC converter,

the DC to DC converter converting the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

Aspect 13. The method according to aspect 12, further comprising: a prime mover directly driving a compressor of the transport climate control system; and the prime mover driving the motor-generator-rectifier machine via a belt drive.

Aspect 14. The method according to aspect 12, further comprising:

an AC power source supplying power to the motor of the motor-generator-rectifier machine;

the motor rotating a shaft of the motor-generator-rectifier machine; and

the shaft propelling the low voltage generator to provide power.

Aspect 15. The method of any one of aspects 12-14, further comprising:

controlling a speed of the at least one condenser fan and a speed of the at least one evaporator fan independent of a speed of a prime mover or a speed of the low voltage generator.

The terminology used in this specification is intended to describe particular embodiments and is not intended to be limiting. The terms "a," "an," and "the" include the plural forms as well, unless clearly indicated otherwise. The terms "comprises" and/or "comprising," when used in this specification, specify the presence of the stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or components.

With regard to the preceding description, it is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement of parts without departing from the scope of the present disclosure. This specification and the embodiments described are exemplary only, with the true scope and spirit of the disclosure being indicated by the claims that follow.

What is claimed is:

1. A transport climate control system, the transport climate control system comprising:

a compressor;

a motor-generator-rectifier machine;

a belt drive connected to the motor-generator-rectifier machine and the compressor;

at least one condenser fan;

at least one evaporator fan; and

a DC to DC converter,

wherein the motor-generator-rectifier machine connects to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter,

wherein the motor-generator-rectifier machine includes:

an AC motor connected to the belt drive;

an AC low voltage generator connected to the motor, the motor and the low voltage generator being on a same shaft of the motor-generator-rectifier machine; and

a rectifier connected to the low voltage generator,

wherein the motor-generator-rectifier machine is configured to provide a first low voltage DC power to the at least one condenser fan, the at least one evaporator fan, and the DC to DC converter, and

the DC to DC converter is configured to convert the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

2. The transport climate control system according to claim **1**, wherein the compressor is configured to be directly driven by a prime mover via a clutch.

3. The transport climate control system according to claim **2**, wherein the prime mover is a diesel engine.

4. The transport climate control system according to claim **1**, wherein the motor-generator-rectifier machine is configured to be driven by a prime mover via the belt drive.

5. The transport climate control system according to claim **1**, wherein the compressor is configured to be driven by the motor via the belt drive.

6. The transport climate control system according to claim **1**, wherein the motor is configured to be driven by an AC power source.

7. The transport climate control system according to claim **6**, wherein the motor is configured to rotate the shaft of the motor-generator-rectifier machine, and

the shaft is configured to propel the low voltage generator to provide power.

8. The transport climate control system according to claim **1**, wherein the DC to DC converter is a buck converter that lowers the first low voltage DC power to the second low voltage DC power.

9. The transport climate control system according to claim **1**, wherein the at least one condenser fan and/or the at least one evaporator fan are variable speed fans.

10. The transport climate control system according to claim **1**, wherein a speed of the at least one condenser fan and/or a speed of the at least one evaporator fan are controlled independent of a speed of a prime mover and/or a speed of the low voltage generator.

11. The transport climate control system according to claim **1**, wherein the first low voltage DC power is 48 volts and the second low voltage DC power is 12 volts.

12. The transport climate control system according to claim **1**, wherein the belt drive is configured to directly connect to the motor of the motor-generator-rectifier machine and the compressor, the motor directly connects to the low voltage generator, the low voltage generator directly connects to the rectifier, and the rectifier directly connects to the at least one condenser fan and the at least one evaporator fan.

13. A method for distributing power for a transport climate control system, the method comprising:

distributing power to a motor-generator-rectifier machine, the motor-generator-rectifier machine including an AC motor connected to a belt drive, an AC low voltage generator connected to the motor, and a rectifier connected to the low voltage generator, the motor and the low voltage generator being on a same shaft of the motor-generator-rectifier machine, the motor-generator-rectifier machine generating a first low voltage DC power to drive at least one condenser fan, at least one evaporator fan, and a DC to DC converter,

the DC to DC converter converting the first low voltage DC power to a second low voltage DC power that is different from the first low voltage DC power.

14. The method according to claim **13**, further comprising:

a prime mover directly driving a compressor of the transport climate control system; and

the prime mover driving the motor-generator-rectifier machine via the belt drive.

15. The method according to claim **13**, further comprising:

an AC power source supplying power to the motor of the motor-generator-rectifier machine;

the motor rotating the shaft of the motor-generator-rectifier machine; and

the shaft propelling the low voltage generator to provide power.

16. The method of claim **13**, further comprising:

controlling a speed of the at least one condenser fan and a speed of the at least one evaporator fan independent of a speed of a prime mover or a speed of the low voltage generator.

17. The method of claim **13**, wherein the belt drive is configured to directly connect to the motor of the motor-generator-rectifier machine and the compressor, the motor directly connects to the low voltage generator, the low voltage generator directly connects to the rectifier, and the rectifier directly connects to the at least one condenser fan and the at least one evaporator fan.

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