(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 505 840 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
03.07.2019 Bulletin 2019/27

(21) Application number: **17843080.7**

(22) Date of filing: **10.02.2017**

(51) Int Cl.:
F24F 11/30 *(2018.01)*

(86) International application number:
PCT/JP2017/004989

(87) International publication number:
WO 2018/037588 (01.03.2018 Gazette 2018/09)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **26.08.2016 JP 2016165760**

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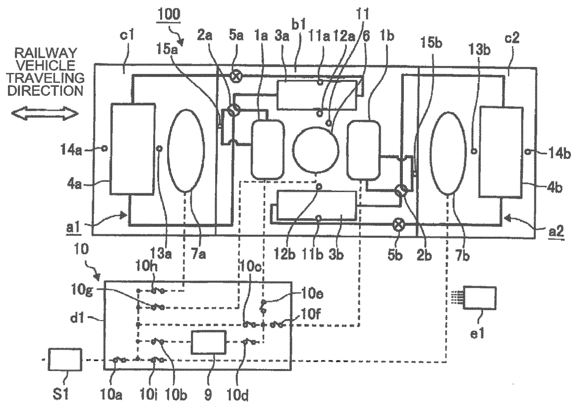
(54) RAILROAD CAR AIR-CONDITIONING APPARATUS

(57) An air-conditioning apparatus for a railway vehicle includes a plurality of refrigerant circuits each including a compressor, a first heat exchanger, an expansion device, and a second heat exchanger that are connected to each other by pipes; an inverter connected to an auxiliary power supply device of a railway vehicle and configured to control a frequency of the compressor; a switching unit configured to switch between wiring connection for supplying power to the compressor via the inverter and wiring connection for directly supplying power from the auxiliary power supply device to the compressor; and a controller configured to control a switching operation of the switching unit in such a manner that, when an air conditioning load of a boarding space of the railway vehicle is higher than a load threshold value, wiring for directly supplying power from the auxiliary power supply device to at least one of the compressors of the plurality of refrigerant circuits is established.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus for a railway vehicle that is configured to condition air in a boarding space of a railway vehicle.

Background Art

[0002] There has been known an air-conditioning apparatus for a railway vehicle that is configured to condition air in a boarding space of a railway vehicle. In Patent Literature 1, there is disclosed an air-conditioning apparatus for a vehicle that is configured to supply power from a power source to a compressor or an indoor fan via an inverter. In Patent Literature 1, the air-conditioning apparatus for a vehicle includes a circuit configured to enable switching so that power is supplied from the power source to the fan via the inverter when the compressor is not operated, and power is directly supplied from the power source to the fan when the compressor is operated.

CITATION LIST

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication JP 07-17397 A

SUMMARY OF INVENTION

Technical Problem

[0004] However, the air-conditioning apparatus for a vehicle disclosed in Patent Literature 1 includes the circuit configured to supply power from the power source to the compressor via the inverter, and is required to use an inverter having large power supply capacity that is suitable to the compressor having large power consumption. As a result, the inverter is increased in size and weight and thus the air-conditioning apparatus for a railway vehicle is caused to be narrowed in remaining space and increased in weight.

[0005] The present invention has been made to solve the above-mentioned problems, and provides an air-conditioning apparatus for a railway vehicle having sufficiently secured space and reduced weight.

Solution to Problem

[0006] According to an embodiment of the present invention, there is provided an air-conditioning apparatus for a railway vehicle, including a plurality of refrigerant circuits each including a compressor, a first heat exchanger, an expansion device, and a second heat exchanger that are connected to each other by pipes; an inverter connected to an auxiliary power supply device of a railway vehicle and configured to control a frequency of the compressor; a switching unit configured to switch between wiring connection for supplying power to the compressor via the inverter and wiring connection for directly supplying power from the auxiliary power supply device to the compressor; and a controller configured to control a switching operation of the switching unit in such a manner that, when an air conditioning load of a boarding space of the railway vehicle is higher than a load threshold value, wiring for directly supplying power from the auxiliary power supply device to at least one of the compressors of the plurality of refrigerant circuits is established.

Advantageous Effects of Invention

[0007] According to an embodiment of the present invention, when the air conditioning load is higher than the load threshold value, power is directly supplied from the auxiliary power supply device to at least one of the compressors. Thus, the inverter is only required to be designed suitably to, for example, the compressor having small power consumption, and hence its power supply capacity can be reduced. Consequently, the inverter is reduced in size and weight, and it is possible to achieve the air-conditioning apparatus for a railway vehicle having sufficiently secured space and reduced weight.

Brief Description of Drawings

[0008]

Fig. 1 is a schematic diagram for illustrating an air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 of the present invention.

Fig. 2 is a schematic view for illustrating a railway vehicle S100 in Embodiment 1 of the present invention.

Fig. 3 is a schematic view for illustrating a compressor 1a in Embodiment 1 of the present invention.

Fig. 4 is a graph for showing an example of a voltage-frequency characteristic of a motor 16a in Embodiment 1 of the present invention.

Fig. 5 is a diagram for illustrating an example of a control pattern of a controller e1 in Embodiment 1 of the present invention.

Fig. 6 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 1 of the present invention at the time when an inverter 9 is abnormal.

Fig. 7 is a flow chart for illustrating an operation of the air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 of the present invention.

Fig. 8 is a schematic diagram for illustrating an air-conditioning apparatus 200 for a railway vehicle according to Embodiment 2 of the present invention.

Fig. 9 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 2 of the present invention.

Fig. 10 is a schematic diagram for illustrating an air-conditioning apparatus 300 for a railway vehicle according to Embodiment 3 of the present invention.

Fig. 11 is a schematic view for illustrating a railway vehicle S200 in Embodiment 3 of the present invention.

Fig. 12 is a schematic diagram for illustrating an air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 of the present invention.

Fig. 13 is a schematic view for illustrating a railway vehicle S300 in Embodiment 4 of the present invention.

Fig. 14 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 4 of the present invention.

Fig. 15 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 4 of the present invention at the time when the inverter 9 is abnormal.

Fig. 16 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 4 of the present invention.

Fig. 17 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 5 of the present invention.

Fig. 18 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 5 of the present invention at the time when the inverter is abnormal.

Fig. 19 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 5 of the present invention.

Fig. 20 is a schematic view for illustrating an example of the compressor 1a in Embodiment 6 of the present invention.

Fig. 21 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 6 of the present invention.

Fig. 22 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention at the time when the inverter is abnormal.

Fig. 23 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 6 of the present invention.

Fig. 24 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention.

Fig. 25 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention.

Fig. 26 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention.

Fig. 27 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention.

Description of Embodiments

Embodiment 1

[0009] An air-conditioning apparatus for a railway vehicle according to each embodiment of the present invention is described below with reference to the drawings. Fig. 1 is a schematic diagram for illustrating an air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 of the present invention. With reference to Fig. 1, the air-conditioning apparatus 100 for a railway vehicle is described. In Fig. 1, the thick lines connecting components to each other represent refrigerant pipes, and the broken lines represent electric wires for three-phase AC. In the following description, in some cases, the refrigerant pipe is referred to as "pipe", and the electric wire is referred to as "wire". As illustrated in Fig. 1, the air-conditioning apparatus 100 for a railway vehicle includes a first refrigeration cycle a1, a second refrigeration cycle a2, an outdoor unit b1, a first indoor unit c1, a second indoor unit c2, a power supply circuit d1, and a controller e1.

[0010] The first refrigeration cycle a1 includes a compressor 1a, a refrigerant flow switching device 2a, a first heat exchanger 3a, a second heat exchanger 4a, and an expansion device 5a, which are connected to each other by pipes. The second refrigeration cycle a2 includes a compressor 1b, a refrigerant flow switching device 2b, a first heat exchanger 3b, a second heat exchanger 4b, and an expansion device 5b, which are connected to each other by pipes. The expansion device 5b is configured to decompress refrigerant.

[0011] The outdoor unit b1 accommodates the first heat exchanger 3a of the first refrigeration cycle a1, the first heat exchanger 3b of the second refrigeration cycle a2, and an outdoor fan 6. The outdoor unit b1 has an air passage formed so that, through operation of the outdoor fan 6, air present outside a vehicle flows into the first heat exchanger 3a and the first heat exchanger 3b, and thus the air can exchange heat with the refrigerant present inside the first heat exchanger 3a and the first heat exchanger 3b.

[0012] The first indoor unit c1 accommodates the second heat exchanger 4a of the first refrigeration cycle a1, and an indoor fan 7a. The first indoor unit c1 has an air passage formed so that, through operation of the indoor fan 7a, air present inside the vehicle flows into the second heat exchanger 4a, and thus the air can exchange heat with the refrigerant present inside the second heat exchanger 4a.

[0013] The second indoor unit c2 accommodates the second heat exchanger 4b of the second refrigeration cycle a2, and an indoor fan 7b. The second indoor unit c2 has an air passage formed so that, through operation of the indoor fan 7b, air present inside the vehicle flows into the second heat exchanger 4b, and thus the air can exchange heat with the refrigerant present inside the second heat exchanger 4b.

[0014] The power supply circuit d1 includes an inverter 9, contactors 10a to 10i, and three-phase wires for connecting elements to each other. The inverter 9 has an upstream port connected to the contactor 10b, and a downstream port connected to the contactor 10d.

[0015] The contactor 10a has an upstream port connected to an auxiliary power supply device S1 of a railway vehicle S100, and a downstream port connected to the contactor 10b, the contactor 10c, the contactor 10g, the contactor 10h, and the contactor 10i. The contactor 10b has an upstream port connected to the contactor 10a, and a downstream port connected to the inverter 9. The contactor 10c has an upstream port connected to the contactor 10a, and a downstream port connected to the contactor 10e and the contactor 10f. The contactor 10d has an upstream port connected to the inverter 9, and a downstream port connected to the contactor 10e and the contactor 10f. The contactor 10e has an upstream port connected to the contactor 10c and the contactor 10d, and a downstream port connected to the compressor

1a. The contactor 10f has an upstream port connected to the contactor 10c and the contactor 10d, and a downstream port connected to the compressor 1b. The contactor 10g has an upstream port connected to the contactor 10a, and a downstream port connected to the outdoor fan 6. The contactor 10h has an upstream port connected to the contactor 10a, and a downstream port connected to the indoor fan 7a. The contactor 10i has an upstream port connected to the contactor 10a, and a downstream port connected to the indoor fan 7b.

[0016] The power supply circuit d1 may be installed inside any one of the outdoor unit b1, the first indoor unit c1, and the second indoor unit c2, or outside these units. The components of the power supply circuit d1 may be separately placed in these units.

[0017] The outdoor unit b1 includes an outdoor temperature and humidity sensor 11, an outdoor temperature and humidity sensor 11a, an outdoor temperature and humidity sensor 12a, an outdoor temperature and humidity sensor 11b, and an outdoor temperature and humidity sensor 12b. The outdoor temperature and humidity sensor 11 is provided to a portion in the vicinity of an air inlet of the outdoor unit b1. The outdoor temperature and humidity sensor 11a is provided to an air inflow portion of the first heat exchanger 3a. The outdoor temperature and humidity sensor 12a is provided to a portion in the vicinity of an air outlet of the outdoor unit b1 or an air outflow portion of the first heat exchanger 3a. The outdoor temperature and humidity sensor 11b is provided to an air inflow portion of the first heat exchanger 3b. The outdoor temperature and humidity sensor 12b is provided to a portion in the vicinity of an air outlet of the outdoor unit b1 or an air outflow portion of the first heat exchanger 3a. The outdoor temperature and humidity sensor 11a and the outdoor temperature and humidity sensor 11b may be omitted as long as the outdoor temperature and humidity sensor 11 is provided. The outdoor temperature and humidity sensor 12a may be omitted as long as the outdoor temperature and humidity sensor 11 or the outdoor temperature and humidity sensor 11a is provided. The outdoor temperature and humidity sensor 12b may be omitted as long as the outdoor temperature and humidity sensor 11 or the outdoor temperature and humidity sensor 11b is provided.

[0018] The first indoor unit c1 includes an indoor temperature and humidity sensor 13a and an indoor temperature and humidity sensor 14a. The indoor temperature and humidity sensor 13a is provided to an air inflow portion of the second heat exchanger 4a or a portion in the vicinity of an air inlet of the first indoor unit c1. The indoor temperature and humidity sensor 14a is provided to an air outflow portion of the second heat exchanger 4a or a portion in the vicinity of an air outlet of the first indoor unit c1. Any one of the indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 14a may be omitted as long as the other of the indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 14a is provided.

[0019] The second indoor unit c2 includes an indoor temperature and humidity sensor 13b and an indoor temperature and humidity sensor 14b. The indoor temperature and humidity sensor 13b is provided to an air inflow portion of the second heat exchanger 4b or a portion in the vicinity of an air inlet of the second indoor unit c2. The indoor temperature and humidity sensor 14b is provided to an air outflow portion of the second heat exchanger 4b or a portion in the vicinity of an air outlet of the second indoor unit c2. Any one of the indoor temperature and humidity sensor 13b and the indoor temperature and humidity sensor 14b may be omitted as long as the other of the indoor temperature and humidity sensor 13b and the indoor temperature and humidity sensor 14b is provided.

[0020] The outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 13b, the indoor temperature and humidity sensor 14a, and the indoor temperature and humidity sensor 14b are each configured to measure temperature or both of temperature and humidity. The outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 13b, the indoor temperature and humidity sensor 14a, and the indoor temperature and humidity sensor 14b may each be a temperature sensor configured to measure only temperature.

[0021] A plurality of refrigerant sensors 15a are mounted to components of the first refrigeration cycle a1 or refrigerant pipes connecting the components to each other, such as a refrigerant pipe of a suction portion of the compressor 1a and a refrigerant pipe of a discharge portion of the compressor 1a. The refrigerant sensors 15a are each configured to measure temperature and pressure of refrigerant in the first refrigeration cycle a1. A plurality of refrigerant sensors 15b are mounted to components of the second refrigeration cycle a2 or refrigerant pipes connecting the components to each other, such as a refrigerant pipe of a suction portion of the compressor 1b and a refrigerant pipe of a discharge portion of the compressor 1b. The refrigerant sensors 15b are each configured to measure temperature and pressure of refrigerant in the second refrigeration cycle a2.

[0022] The controller e1 of the air-conditioning apparatus 100 for a railway vehicle acquires a measurement value of the temperature or measurement values of both of the temperature and the humidity measured by each of the outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 13b, the indoor temperature and humidity sensor 14a, and the indoor temperature and humidity sensor 14b. Further, the controller e1 acquires measurement values of the temperature and the pressure of the refrigerant measured by each of the refrigerant sensors 15a and the refrigerant sensors 15b. The controller e1 executes, on the basis of these acquired results, control of opening degrees of the expansion device 5a and the expansion device 5b, switching control of the refrigerant flow switching device 2a and the refrigerant flow switching device 2b, control of an output voltage and an output frequency of the inverter 9, and control of switching between energization and disconnection of the contactors 10a to 10i. The controller e1 may be mounted inside any one of the outdoor unit b1, the first indoor unit c1, and the second indoor unit c2, or outside these units.

[0023] Fig. 2 is a schematic view for illustrating the railway vehicle S100 in Embodiment 1 of the present invention. As illustrated in Fig. 2, in the railway vehicle S100, one air-conditioning apparatus 100 for a railway vehicle is installed on a roof of the railway vehicle S100. The railway vehicle S100 has a configuration in which a stream of air subjected to heat exchange by the second heat exchanger 4a of the first indoor unit c1 passes through an air outlet duct S2 to be blown out to a boarding space S4 inside the railway vehicle S100, and a stream of air subjected to heat exchange by the second heat exchanger 4b of the second indoor unit c2 passes through an air outlet duct S3 to be blown out to a boarding space S5 inside the railway vehicle S100. In Embodiment 1, the air outlet duct S2 and the air outlet duct S3 are each provided as a separate component.

[0024] In some cases, as in the above-mentioned configuration, the railway vehicle S100 has a configuration in which the boarding space S4 to which the stream of air subjected to heat exchange in the first indoor unit c1 is blown out does not match the boarding space S5 to which the stream of air subjected to heat exchange in the second indoor unit c2 is blown out, and, for example, the boarding spaces S4 and S5 are distributed in a front and rear of a traveling direction of the railway vehicle S100. The railway vehicle S100 includes a vehicle outside temperature and humidity sensor S6, a vehicle inside temperature and humidity sensor S7, a vehicle inside temperature and humidity sensor S8, and a vehicle occupancy sensor S9. The vehicle outside temperature and humidity sensor S6 is mounted outside the railway vehicle S100. The vehicle inside temperature and humidity sensor S7 is mounted in the boarding space S4. The vehicle inside temperature and humidity sensor S8 is mounted in the boarding space S5. The vehicle occupancy sensor S9 is mounted, for example, below the boarding space S4 or the boarding space S5 of the railway vehicle S100. The vehicle outside temperature and humidity sensor S6, the vehicle inside temperature and humidity sensor S7, and the vehicle inside temperature and humidity sensor S8 are each configured to measure temperature or both of temperature and humidity. The vehicle occupancy sensor S9 is configured to measure the number of passengers inside the railway vehicle S100 on the basis of, for example, a measurement value of a load.

[0025] Further, the railway vehicle S100 shares an integrated information system X1 with other connected railway vehicles. The controller e1 of the air-conditioning apparatus 100 for a railway vehicle can acquire information on the temperature or both of the temperature and the humidity measured by each of the vehicle outside temperature and humidity sensor S6, the vehicle inside temperature and humidity sensor S7, and the vehicle inside temperature and humidity sensor S8. The controller e1 can acquire information on the number of passengers on the basis of a measurement result of the vehicle occupancy sensor S9 of the railway vehicle S100. The controller e1 can acquire, from the integrated information system X1, information on the position of the railway vehicle, information on an opening-closing status of a door, a running schedule, and information on a driver's operation signal or other signals. The controller e1 can execute control of components of the air-conditioning apparatus 100 for a railway vehicle with further use of information acquired from the components of the air-conditioning apparatus 100 for a railway vehicle.

[0026] The outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, and the outdoor temperature and humidity sensor 12b of the air-conditioning apparatus 100 for a railway vehicle may be omitted as long as the controller e1 can acquire information on the temperature or both of the temperature and the humidity from the vehicle outside temperature and humidity sensor S6. The indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 14a may be omitted as long as the controller e1 can acquire information on the temperature or both of the temperature and the humidity from the vehicle inside temperature and humidity sensor S7. The indoor temperature and humidity sensor 13b and the indoor temperature and humidity sensor 14b may be omitted as long as the controller e1 can acquire information on the temperature or both of the temperature and the humidity from the vehicle inside temperature and humidity sensor S8.

[0027] The auxiliary power supply device S1 of the railway vehicle S100 is configured to convert power supplied from a railway overhead line to supply three-phase AC power to devices in the railway vehicle S100. The voltage to be supplied by the auxiliary power supply device S1 is, for example, 200 V or 440 V, and the frequency is, for example, 60 Hz or 50 Hz.

[0028] In the air-conditioning apparatus 100 for a railway vehicle to be installed on the roof of the railway vehicle S100 as illustrated in Fig. 2, to prevent the railway vehicle S100 from excessively inclining and shaking in a direction perpendicular to a traveling-direction axis, the components are arranged so that the center of gravity is located at a center in the direction perpendicular to the traveling-direction axis. For example, as in the arrangement of the first refrigeration cycle a1 and the second refrigeration cycle a2 illustrated in Fig. 1, components having similar functions may be arranged symmetrically about the traveling-direction axis of the railway vehicle S100.

[0029] Fig. 3 is a schematic view for illustrating the compressor 1a in Embodiment 1 of the present invention. As illustrated in Fig. 3, the compressor 1a is, for example, an inverter compressor capable of adjusting a refrigeration capacity by changing input power. In the compressor 1a, rotational power is transmitted from a motor 16a to a compression chamber 18a via a rotary shaft 17a connected to the motor 16a, so that refrigerant is compressed. As described above, the motor 16a is configured to drive the compressor 1a. In the compressor 1a, for example, when the inflow refrigerant has the same temperature and pressure conditions, the flow rate output by the compression chamber 18a is increased as the rotation frequency is increased, and the motive power required for the refrigeration capacity and the compression is increased.

[0030] Fig. 4 is a graph for showing an example of a voltage-frequency characteristic of the motor 16a in Embodiment 1 of the present invention. The motor 16a is, for example, a three-phase AC induction motor, and is structured to be easily operable even when power is directly supplied from the auxiliary power supply device S1 to the compressor 1a or when power output from the auxiliary power supply device S1 and converted by the inverter 9 is supplied. For example, as shown in Fig. 4, the compressor 1a including the motor 16a is configured so that, at the same frequency as the frequency of the three-phase AC power output from the auxiliary power supply device S1, a voltage equal to or lower than the voltage of the three-phase AC power output from the auxiliary power supply device S1 is appropriate. With this configuration, even when power is directly supplied from the auxiliary power supply device S1 to the compressor 1a, it is possible to prevent the motor 16a of the compressor 1a from failing in operation due to insufficiency of torque required for compression. In a case in which the compressor 1a including the motor 16a is configured to have, at the same frequency as the frequency of the three-phase AC power output from the auxiliary power supply device S1, the same voltage as the voltage of the three-phase AC power output from the auxiliary power supply device S1, when power is directly supplied from the auxiliary power supply device S1 to the compressor 1a, an operation is enabled with high motor efficiency and small extra power loss. The compressor 1b has a configuration similar to that of the compressor 1a, and hence description of the compressor 1b is omitted herein.

[0031] The above-mentioned appropriate voltage is described in further detail. For example, in a case in which the motor 16a is designed so that a compression operation is enabled by applying appropriate torque to the compression chamber 18a with input of 200 V and 50 Hz, when the inverter 9 inputs a low voltage of 100 V and 50 Hz to the motor 16a, the compression operation may be disabled due to torque insufficiency (current insufficiency). When the inverter 9 inputs a high voltage of 400 V and 50 Hz to the motor 16a, the compression operation is enabled, but extra power (excessive current) may be converted into heat to cause temperature increase and operation failure of the motor 16a. Regarding the high-voltage input, although the compression efficiency is decreased, an operation is possible without a problem as long as the motor 16a can be appropriately cooled. Consequently, a voltage equal to or lower than that of the auxiliary power supply device S1 is the appropriate voltage. Even an inexpensive inverter 9 without an expensive boosting function can easily convert, for example, the input of 200 V and 50 Hz into the output of 200 V and 25 Hz. Consequently, in a case in which a compressor designed so that the motor can produce the torque required for compression with 200 V and 25 Hz or 400 V and 50 Hz, the compression operation may be disabled due to torque insufficiency when power is directly input from the auxiliary power supply device to the compressor.

[0032] Next, an operation mode of the air-conditioning apparatus 100 for a railway vehicle is described. First, a case of a cooling operation is described. Description is given of a behavior of the refrigerant in the first refrigeration cycle a1 when the compressor 1a, the outdoor fan 6, and the indoor fan 7a of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the cooling operation. The refrigerant compressed by the compressor 1a of the first refrigeration cycle a1 passes through the refrigerant pipe to flow into the first heat exchanger 3a via the refrigerant flow switching device 2a. In the first heat exchanger 3a, the refrigerant is cooled by heat exchange with air having flowed into the first heat exchanger 3a of the outdoor unit b1 from the outside by the outdoor fan 6, and then passes through the refrigerant pipe to flow into the expansion device 5a. In the expansion device 5a, the refrigerant is decompressed, and then passes through the refrigerant pipe to flow into the second heat exchanger 4a. In the second heat exchanger 4a, the refrigerant is heated by heat exchange with air having flowed into the second heat exchanger 4a of the first indoor unit c1 from the boarding space S4 or the boarding space S5 by the indoor fan 7a, and then passes through the refrigerant pipe to flow into the compressor 1a via the refrigerant flow switching device 2a. In the compressor 1a, the refrigerant is compressed again, and then is circulated in the same manner.

[0033] Description is given of a behavior of air flowing into and out from the first indoor unit c1 when the compressor 1a, the outdoor fan 6, and the indoor fan 7a of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the cooling operation. Air having flowed into the first indoor unit c1 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows into the second heat exchanger 4a. In the second heat exchanger 4a, the air is cooled by heat exchange with the refrigerant flowing inside the second heat exchanger 4a, and then flows to the indoor fan 7a. In the indoor fan 7a, the air is forced out to pass through the air outlet duct S2 and flow into the boarding space S4. Thus, the boarding space S4 is cooled. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the first indoor unit c1 flows in the order of the indoor fan 7a, the second heat exchanger 4a, the air outlet duct S2, and the boarding space S4.

[0034] Description is given of a behavior of the refrigerant in the second refrigeration cycle a2 when the compressor 1b, the outdoor fan 6, and the indoor fan 7b of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the cooling operation. The refrigerant compressed by the compressor 1b of the second refrigeration cycle a2 passes through the refrigerant pipe to flow into the second heat exchanger 4b via the refrigerant flow switching device 2b. In the second heat exchanger 4b, the refrigerant is cooled by heat exchange with air having flowed into the first heat exchanger 3b of the outdoor unit b1 from the outside by the outdoor fan 6, and then passes through the refrigerant pipe to flow into the expansion device 5b. In the expansion device 5b, the refrigerant is decompressed, and then passes through the refrigerant pipe to flow into the second heat exchanger 4b. In the second heat exchanger 4b, the refrigerant is heated by heat exchange with air having flowed into the second heat exchanger 4b of the second indoor unit c2 from the boarding space S4 or the boarding space S5 by the indoor fan 7b, and then passes through the refrigerant pipe to flow into the compressor 1b via the refrigerant flow switching device 2b. In the compressor 1b, the refrigerant is compressed again, and then is circulated in the same manner.

[0035] Description is given of a behavior of air flowing into and out from the second indoor unit c2 when the compressor 1b, the outdoor fan 6, and the indoor fan 7b of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the cooling operation. Air having flowed into the second indoor unit c2 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows into the second heat exchanger 4b. In the second heat exchanger 4b, the air is cooled by heat exchange with the refrigerant flowing inside the second heat exchanger 4b, and then flows to the indoor fan 7b. In the indoor fan 7b, the air is forced out to pass through the air outlet duct S3 and flow into the boarding space S5. Thus, the boarding space S5 is cooled. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the second indoor unit c2 flows in the order of the indoor fan 7b, the second heat exchanger 4b, the air outlet duct S3, and the boarding space S5.

[0036] Description is given of a behavior of air flowing into and out from the outdoor unit b1 when the first refrigeration cycle a1 or the second refrigeration cycle a2 of the air-conditioning apparatus 100 for a railway vehicle performs the cooling operation. Air having flowed into the outdoor unit b1 from the outside of the railway vehicle S100 flows into the first heat exchanger 3a or the first heat exchanger 3b. In the first heat exchanger 3a or the first heat exchanger 3b, the air is heated by heat exchange with the refrigerant inside each heat exchanger, and then flows to the outdoor fan 6. In the outdoor fan 6, the air is forced out to flow to the outside of the railway vehicle S100. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the outdoor unit b1 flows in the order of the outdoor fan 6, the first heat exchanger 3a or the first heat exchanger 3b, and the outside of the railway vehicle S100.

[0037] Next, a heating operation is described. Description is given of a behavior of the refrigerant in the first refrigeration cycle a1 when the compressor 1a, the outdoor fan 6, and the indoor fan 7a of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the heating operation. In the heating operation, the refrigerant flow switching device 2a is switched to have a refrigerant flow passage different from that in the case of the cooling operation. The refrigerant compressed by the compressor 1a of the first refrigeration cycle a1 passes through the refrigerant pipe to flow into the second heat exchanger 4a via the refrigerant flow switching device 2a. In the second heat exchanger 4a, the refrigerant is cooled by heat exchange with air having flowed into the second heat exchanger 4a of the first indoor unit c1 from the boarding space S4 or the boarding space S5 by the indoor fan 7a, and then passes through the refrigerant pipe to flow into the expansion device 5a. In the expansion device 5a, the refrigerant is decompressed, and then passes through the refrigerant pipe to flow into the first heat exchanger 3a. In the first heat exchanger 3a, the refrigerant is heated by heat exchange with air having flowed into the first heat exchanger 3a of the outdoor unit b1 from the outside by the outdoor fan 6, and then passes through the refrigerant pipe to flow into the compressor 1a via the refrigerant flow switching device 2a. In the compressor 1a, the refrigerant is compressed again, and then is circulated in the same manner.

[0038] Description is given of a behavior of air flowing into and out from the first indoor unit c1 when the compressor 1a, the outdoor fan 6, and the indoor fan 7a of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the heating operation. Air having flowed into the first indoor unit c1 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows into the second heat exchanger 4a. In the second heat exchanger 4a, the air is heated by heat exchange with the refrigerant flowing inside the second heat exchanger 4a, and then flows to the indoor fan 7a. In the indoor fan 7a, the air is forced out to pass through the air outlet duct S2 and flow into the boarding space S4. Thus, the boarding space S4 is heated. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the first indoor unit c1 flows in the order of the indoor fan 7a, the second heat exchanger 4a, the air outlet duct S2, and the boarding space S4.

[0039] Description is given of a behavior of the refrigerant in the second refrigeration cycle a2 when the compressor 1b, the outdoor fan 6, and the indoor fan 7b of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the heating operation. In the heating operation, the refrigerant flow switching device 2b is switched to have a refrigerant flow passage different from that in the case of the cooling operation. The refrigerant compressed by the compressor 1b of the second refrigeration cycle a2 passes through the refrigerant pipe to flow into the second heat exchanger 4b via the refrigerant flow switching device 2b. In the second heat exchanger 4b, the refrigerant is cooled by heat exchange with air having flowed into the second heat exchanger 4b of the second indoor unit c2 from the boarding space S4 or the boarding space S5 by the indoor fan 7b, and then passes through the refrigerant pipe to flow into the expansion device 5b. In the expansion device 5b, the refrigerant is decompressed, and then passes through the refrigerant pipe to flow into the first heat exchanger 3b. In the first heat exchanger 3b, the refrigerant is heated by heat exchange with air having flowed into the second heat exchanger 4b of the outdoor unit b1 from the outside by the outdoor fan 6, and then passes through the refrigerant pipe to flow into the compressor 1b via the refrigerant flow switching device 2b. In the compressor 1b, the refrigerant is compressed again, and then is circulated in the same manner.

[0040] Description is given of a behavior of air flowing into and out from the second indoor unit c2 when the compressor 1b, the outdoor fan 6, and the indoor fan 7b of the air-conditioning apparatus 100 for a railway vehicle are activated in the case of the heating operation. Air having flowed into the second indoor unit c2 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows into the second heat exchanger 4b. In the second heat exchanger 4b, the air is heated by heat exchange with the refrigerant flowing inside the second heat exchanger 4b, and then flows to the indoor fan 7b. In the indoor fan 7b, the air is forced out to pass through the air outlet duct S3 and flow into the boarding space S5. Thus, the boarding space S5 is heated. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the second indoor unit c2 flows in the order of the indoor fan 7b, the second heat exchanger 4b, the air outlet duct S3, and the boarding space S5.

[0041] Description is given of a behavior of air flowing into and out from the outdoor unit b1 when the first refrigeration cycle a1 or the second refrigeration cycle a2 of the air-conditioning apparatus 100 for a railway vehicle performs the heating operation. Air having flowed into the outdoor unit b1 from the outside of the railway vehicle S100 flows into the first heat exchanger 3a or the first heat exchanger 3a. In the first heat exchanger 3a or the first heat exchanger 3b, the air is cooled by heat exchange with the refrigerant inside each heat exchanger, and then flows to the outdoor fan 6. In the outdoor fan 6, the air is forced out to flow to the outside of the railway vehicle S100. Alternatively, the air-conditioning apparatus 100 for a railway vehicle may be configured so that the air having flowed into the outdoor unit b1 flows in the order of the outdoor fan 6, the first heat exchanger 3a or the first heat exchanger 3b, and the outside of the railway vehicle S100.

[0042] Next, an air-sending operation is described. When only air sending is performed to the boarding space S4, the indoor fan 7a of the first indoor unit c1 is activated without activation of the compressor 1a of the first refrigeration cycle a1. In this case, air having flowed into the first indoor unit c1 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows through the second heat exchanger 4a but does not exchange heat with the refrigerant flowing inside the second heat exchanger 4a. Then, the air flows out from the first indoor unit c1 without heat exchange, and passes through the air outlet duct S2 to be sent to the boarding space S4.

[0043] When only air sending is performed to the boarding space S5, the indoor fan 7b of the second indoor unit c2 is activated without activation of the compressor 1b of the second refrigeration cycle a2. In this case, air having flowed into the second indoor unit c2 from the boarding space S4 or the boarding space S5 of the railway vehicle S100 flows through the second heat exchanger 4b but does not exchange heat with the refrigerant flowing inside the second heat exchanger 4b. Then, the air flows out from the second indoor unit c2 without heat exchange, and passes through the air outlet duct S3 to be sent to the boarding space S4.

[0044] Next, the operation of the power supply circuit d1 is described. When the contactor 10a of the power supply circuit d1 of the air-conditioning apparatus 100 for a railway vehicle is disconnected, supply of power from the auxiliary power supply device S1 of the railway vehicle S100 is cut off, and the contactors 10b to 10i connected to the downstream port of the contactor 10a are not energized. A case is described below in which the contactor 10a is energized when the contactors 10b to 10i are energized.

[0045] In a case in which the compressor 1a is to be activated and the compressor 1b is to be stopped, when the compressor 1a is to be activated by directly supplying power from the auxiliary power supply device S1, operations of disconnecting the contactor 10b, energizing the contactor 10c, disconnecting the contactor 10d, energizing the contactor 10e, and disconnecting the contactor 10f are performed. In the case in which the compressor 1a is to be activated and the compressor 1b is to be stopped, when the compressor 1a is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, disconnecting the contactor 10c, energizing the contactor 10d, energizing the contactor 10e, and disconnecting the contactor 10f are performed. In a case in which the compressor 1a is to be stopped and the compressor 1b is to be activated, when the compressor 1b is to be activated by directly supplying power from the auxiliary power supply device S1, operations of disconnecting the contactor 10b, energizing the contactor 10c, disconnecting the contactor 10d, disconnecting the contactor 10e, and energizing the contactor 10f are performed.

[0046] In the case in which the compressor 1a is to be stopped and the compressor 1b is to be activated, when the compressor 1b is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, disconnecting the contactor 10c, energizing the contactor 10d, disconnecting the contactor 10e, and energizing the contactor 10f are performed. In a case in which the compressor

1a and the compressor 1b are to be stopped, operations of disconnecting the contactor 10b, disconnecting the contactor 10c, and disconnecting the contactor 10d are performed. When the outdoor fan 6 is activated, the contactor 10g is energized. When the outdoor fan 6 is to be stopped, the contactor 10g is disconnected. When the indoor fan 7a is to be activated, the contactor 10h is energized. When the indoor fan 7a is to be stopped, the contactor 10h is disconnected. When the indoor fan 7b is to be activated, the contactor 10i is energized. When the indoor fan 7b is to be stopped, the contactor 10i is disconnected. In this case, the contactors 10a and 10i are collectively referred to as "switching unit 10". That is, the switching unit 10 is configured to switch between wiring connection for supplying power to the compressor 1a or 1b via the inverter 9 and wiring connection for directly supplying power from the auxiliary power supply device S1 to the compressor 1a or 1b.

[0047] Next, the operation of the inverter 9 is described. The inverter 9 changes the voltage and the frequency of the power to be supplied to the compressor 1a or the compressor 1b to change the rotation frequency of the motor 16a, to thereby change the output of the compressor 1a or the compressor 1b. In a case in which the power output from the auxiliary power supply device S1 and converted by the inverter 9 is to be supplied to the compressor 1a or the compressor 1b, when the voltage and the frequency of the three-phase AC power to be supplied from the auxiliary power supply device S1 are converted by the inverter 9 to follow the relationship of the voltage-frequency characteristic shown in Fig. 4, the compressor 1a or the compressor 1b can be efficiently operated.

[0048] Next, the operation of the controller e1 is described. The controller e1 acquires information from components of the air-conditioning apparatus 100 for a railway vehicle, components of the railway vehicle S100, and the integrated information system X1. The controller e1 calculates, on the basis of the information, a thermal load required for conditioning air in each of the boarding space S4 and the boarding space S5, and determines the operation mode of the air-conditioning apparatus 100 for a railway vehicle that is suitable to the load. Then, the controller e1 executes control of the opening degrees of the expansion device 5a and the expansion device 5b, switching control of the refrigerant flow switching device 2a and the refrigerant flow switching device 2b, control of the output voltage and output frequency of the inverter 9, and switching control between energization and disconnection of each of the contactors 10a to 10i.

[0049] For example, with regard to a thermal load required for conditioning air in the boarding space S4 at the time of the cooling operation, the higher the temperature measured by the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, or the vehicle inside temperature and humidity sensor S7 is than a setting temperature, the larger the load is calculated to be. Further, the higher the temperature measured by any one of the outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, and the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. Further, the larger the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be. Moreover, for example, with regard to a thermal load required for conditioning air in the boarding space S4 at the time of the heating operation, the lower the temperature measured by the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, or the vehicle inside temperature and humidity sensor S7 is than the setting temperature, the larger the load is calculated to be. Further, the lower the temperature measured by the outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 12, or the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. Further, the smaller the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be.

[0050] When simplified control is to be performed, a difference between target temperature and room temperature may be used without calculation of the load. This control is particularly effective when only PI control is to be executed. In Embodiment 1 in which the modes are switched, current air-conditioning output (mode, compressor rotation frequency, and motor valve opening degree) is grasped, and in a case in which the target temperature is not reached even when a limit condition of the mode is achieved, the mode is shifted. In the railway vehicle S100 having drastic change in load due to entry and exit of people or other reasons, responsiveness is required to be considered. For example, between a case in which a large number of people are present and a case in which almost nobody is present, or between a dry day and a rainy day, a load significantly differs even when a temperature difference is the same, and hence it may require time to reach the target temperature. In some of the related-art air-conditioning apparatus for a railway vehicle, the load is calculated on the basis of whether air conditioning is activated or deactivated. In typical stationary air conditioning, PI control is performed on the basis of a difference in temperature or temperature and humidity with inverter air conditioning. In Embodiment 1, the air-conditioning apparatus for a railway vehicle performs both of these two types of air conditioning, and the case of load calculation is exemplified.

[0051] Fig. 5 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 1 of the present invention. In Fig. 5, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. For example, when the load and the load distribution presumed to be required for conditioning air in the railway vehicle S100 fall within a range surrounded by the thick line, the horizontal axis, and the vertical axis in Fig. 5, the controller e1 executes operation control in any one of modes M1 to M6 for a corresponding one of regions divided by the dotted lines. In a case in which the boarding spaces S4 and S5 are not partitioned from each other by a wall, for example, even when a heat source having a high load is provided in any one of the boarding spaces S4 and S5 in such a manner that biased distribution is caused, the heat flows from the space in which the heat source is present to the space in which the heat source is absent due to the increase in temperature difference and humidity difference between the boarding spaces. Further, the refrigeration cycle in the space in which the heat source is absent is required to be operated to obtain air-conditioning output. Consequently, the thick line is a line descending toward the right.

[0052] As illustrated in Fig. 5, the mode M1 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M1, while power having a constant voltage and a constant frequency is supplied to the compressor 1a and the compressor 1b, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 1, the mode M1 corresponds to a control method of a case in which a load that can be covered by a refrigeration capacity close to the maximum refrigeration capacity of the air-conditioning apparatus 100 for a railway vehicle is generated.

[0053] The mode M2 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M2, when the boarding space S4 has a higher load, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the compressor 1b is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air-conditioning output is adjusted. When the boarding space S5 has a higher load, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the compressor 1a is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air-conditioning output is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 1, the mode M2 corresponds to a control method of a case in which a load that can be covered by a refrigeration capacity close to the maximum refrigeration capacity is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0054] The mode M3 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M3, the compressor 1a is controlled to be repeatedly activated and stopped, and the opening degree of the expansion device 5a is controlled so that output required for conditioning air in the boarding space S4 is adjusted. Further, the compressor 1b is controlled to be repeatedly activated and stopped, and the opening degree of the expansion device 5b is controlled so that output required for conditioning air in the boarding space S5 is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 1, the mode M3 corresponds to a control method of a case in which a relatively high load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0055] The mode M4 is a mode in which both of the compressor 1a and the compressor 1b are activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. In the mode M4, while the voltage and the frequency of the power to be supplied to both of the compressor 1a and the compressor 1b are changed, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 1, the mode M4 corresponds to a control method of a case in which a middle-level or relatively low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0056] The mode M5 is the following mode. When the boarding space S4 has a higher load, the compressor 1a is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the compressor 1b is stopped. Further, while the voltage and the frequency of the power to be supplied to the compressor 1a are changed, the opening degree of the expansion device 5a is controlled so that output required for conditioning air is adjusted. When the boarding space S5 has a higher load, the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the compressor 1a is stopped. Further, while the voltage and the frequency of the power to be supplied to the compressor 1b are changed, the opening degree of the expansion device 5b is controlled so that output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 1, the mode M5 corresponds to a control method of a case in which a low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2 or a case in which a low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 and almost no load or a low reverse load is generated in the other of the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0057] The mode M6 is a mode in which the compressor 1a and the compressor 1b are stopped, and the air-sending operation is executed with the indoor fan 7a being switched to be activated and stopped and the indoor fan 7b being switched to be activated and stopped. The mode M6 corresponds to a control method of a case in which the first refrigeration cycle a1 and the second refrigeration cycle a2 have almost no load.

[0058] In the modes M1 to M6, the controller e1 uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the opening degree of the expansion device 5a or the expansion device 5b. In the modes M1 to M3, the controller e1 uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a to execute, for example, control for regions obtained by further finely dividing the regions of the modes M1 to M3 in Fig. 5, to thereby determine a repetition frequency and timing to activate and stop the compressor 1a or the compressor 1b. In the modes M4 to M6, the controller e1 uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the voltage and the frequency to be output by the inverter 9 to the compressor 1a or the compressor 1b.

[0059] In the compressor 1a, when the rotation frequency of the motor 16a is increased as the load is increased, and the rotation frequency of the motor 16a is decreased as the load is decreased, the air conditioner efficiency of the first refrigeration cycle a1 is increased. Consequently, an operation mode having high efficiency that is suitable to each load and load distribution can be selected in the control pattern of Fig. 5. In the regions of the modes M2 and M3, as the load is decreased, the output adjustment due to the compressor 1a and the compressor 1b being activated and stopped is increased, and hence the air conditioner efficiency is relatively reduced as compared to a case in which the rotation frequencies of the compressor 1a and the compressor 1b are controlled. However, when an amount of power convertible by the inverter 9 is increased, the regions of the modes M4 and M5 can be extended toward the regions of the modes M2 and M3 in Fig. 5. As a result, the air conditioner efficiency is increased in these regions. In contrast, when the amount of power convertible by the inverter 9 is decreased, the regions of the modes M2 and M3 are extended toward the regions of the modes M4 and M5, but the capacity of the inverter 9 can be reduced, and the inverter 9 reduced in size and weight can be mounted. As described above, the controller e1 controls the switching operation of the switching unit 10 so that, when the air conditioning load of a corresponding one of the boarding space S4 and S5 of the railway vehicle S100 is higher than a load threshold value, wiring for directly supplying power from the auxiliary power supply device S1 to at least one of the compressors 1a and 1b is established.

[0060] Fig. 6 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 1 of the present invention at the time when the inverter 9 is abnormal. In Fig. 6, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. For example, when the load and the load distribution presumed in the railway vehicle S100 fall within a range surrounded by the thick line, the horizontal axis, and the vertical axis in Fig. 6, the controller e1 executes operation control in any one of the modes M1 to M3 and the mode M6 for a corresponding one of regions divided by the dotted lines. In this case, the region of the mode M3 covers the regions of the modes M4 and M5 in Fig. 5. With this control, even when the inverter 9 cannot be used due to occurrence of abnormality in the inverter 9, the air-conditioning apparatus 100 for a railway vehicle can condition air suitably to the load of each of the boarding space S4 and the boarding space S5. As described above, the controller e1 controls the switching operation of the switching unit 10, when the inverter 9 is abnormal, to either directly supply power from the auxiliary power supply device S1 individually to the plurality of compressors 1a and 1b or cut off the power.

[0061] Fig. 7 is a flow chart for illustrating the operation of the air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 of the present invention. As illustrated in Fig. 7, the controller e1 acquires information from each device to calculate a thermal load required for conditioning air in each of the boarding space S4 and the boarding space S5 (Step ST1). The controller e1 determines the control mode corresponding to the calculated load from the modes M1 to M6 at the time of the normal operation illustrated in Fig. 5, and determines the control mode corresponding to the load from the modes M1 to M3 and the mode M6 at the time when the inverter is abnormal as illustrated in Fig. 6 (Step ST2). The controller e1 acquires information from each device, such as abnormality detection information from the inverter 9 and operation continuation information of the air-conditioning apparatus 100 for a railway vehicle from the integrated information system X1 (Step ST3).

[0062] The controller e1 determines whether to continue or stop the operation of the air-conditioning apparatus 100 for a railway vehicle (Step ST4). When the operation of the air-conditioning apparatus 100 for a railway vehicle is to be continued, the controller e1 proceeds to Step ST5. When the operation of the air-conditioning apparatus 100 for a railway vehicle is to be stopped, the controller e1 proceeds to Step ST10. The controller e1 determines whether the inverter 9 is normal or abnormal (Step ST5). When the inverter 9 is normal, the controller e1 proceeds to Step ST6. When the inverter 9 is abnormal, the controller e1 proceeds to Step ST11.

[0063] Next, description is given of a case in which the controller e1 proceeds to Step ST6 as a result of the determination in Step ST5 that the inverter 9 is normal. The controller e1 acquires, from each constituent device, information required for the control mode to be executed at the time of the normal operation that is determined in Step ST2 to calculate the load (Step ST6). The controller e1 instructs each device to operate suitably to the load in the control mode to be executed at the time of the normal operation that is determined in Step ST2, and proceeds to Step ST8 (Step ST7). The controller e1 determines whether a predetermined time period has elapsed from passage of Step ST2, whether Step ST3 has been passed a predetermined number of times, or whether none of them have occurred (Step ST8). When the predetermined time period has elapsed from the passage of Step ST2, or Step ST3 has been passed the predetermined number of times, the controller e1 proceeds to Step ST9. When the predetermined time period has not elapsed from the passage of Step ST2, or Step ST3 has not been passed the predetermined number of times, the controller e1 returns to Step ST3 to repeat the processing.

[0064] The controller e1 determines whether or not a critical error that causes difficulty in operation of the air-conditioning apparatus 100 for a railway vehicle has occurred (Step ST9). The critical error refers to a case in which it is determined that both of the compressor 1a and the compressor 1b cannot be operated, such as a case in which a current detection value, values included in information acquired from the integrated information system X1, or both pressure values acquired from any one of the refrigerant sensors 15a and a corresponding one of the refrigerant sensors 15b indicate abnormal values. When the critical error has occurred, the controller e1 proceeds to Step ST10. When the critical error has not occurred, the controller e1 returns to Step ST1 to repeat the processing.

[0065] Next, description is given of a case in which the controller e1 proceeds to Step ST11 as a result of the determination in Step ST5 that the inverter 9 is abnormal. The controller e1 acquires, from each constituent device, information required for the control mode at the time when the inverter 9 is abnormal that is determined in Step ST2 to calculate the load (Step ST12). The controller e1 instructs each device to operate suitably to the load in the control mode at the time when the inverter 9 is abnormal that is determined in Step ST2, and proceeds to Step ST8 (Step ST12). The subsequent steps are performed as described above.

[0066] The controller e1 returns to Step ST1 after the predetermined time period has elapsed from the passage of Step ST2 or Step ST3 has been passed the predetermined number of times in Step ST8 to prevent failure due to reduction in product lifetime of each device when the determination of the control mode in Step ST2 is frequently repeated and thus the compressor 1a, the compressor 1b, the contactors 10a to 10i, or the inverter 9 is increased in frequency of switching between energization and disconnection. For example, the region of each mode in the control pattern of Fig. 5 may be extended to overlap the adjacent region so that the predetermined time period to be elapsed in Step ST8 may be 0 seconds or the predetermined number of times of the passage of Step ST3 may be 1. In this case, when a load corresponding to the overlapping region is calculated in Step ST1, it may be determined in Step ST2 to prioritize the operation in the control mode determined in previous Step ST2 so that frequent change of the control mode is less likely to occur.

[0067] According to Embodiment 1, even when there is employed a configuration in which the compressors 1a and 1b are brought to have variable speeds with use of the inverter 9 so that operation with low power consumption is enabled, the power supply capacity of the inverter is not required to be increased, and hence the increase in size and weight is not caused. Further, the air-conditioning apparatus 100 for a railway vehicle can operate the compressor 1a and the compressor 1b to condition air even when abnormality occurs in the inverter 9. Further, air conditioning with high level of comfort is enabled without biasing the cooling output or the heating output to any one of the boarding space S4 and the boarding space S5. Further, in Embodiment 1, a plurality of refrigerant circuits are controlled by one inverter 9, and hence the number of components can be reduced.

[0068] Further, the air-conditioning apparatus 100 for a railway vehicle has a two-refrigeration-cycle configuration including the first refrigeration cycle a1 and the second refrigeration cycle a2. Consequently, in a case in which the boarding space S4 and the boarding space S5 of the air-conditioning apparatus 100 for a railway vehicle are not partitioned from each other by a wall, even when any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 is stopped due to occurrence of abnormality during the operation, the air-conditioning output biased to any one of the boarding space S4 and the boarding space S5 covers the air-conditioning output to the other of the boarding space S4 and the boarding space S5 so that air can be conditioned in the boarding space S4 and the boarding space S5. Further, at the time of a high load, the power is directly supplied from the auxiliary power supply device S1 to the compressor 1a or the compressor 1b without passage through the inverter 9. Thus, the loss due to the passage through the inverter 9 is eliminated, and the air can be conditioned with high efficiency. Then, the controller e1 switches between directly supplying power from the auxiliary power supply device S1 individually to the plurality of compressors 1a and 1b and supplying power from the auxiliary power supply device S1 via the inverter 9 on the basis of the load distribution measured and obtained by each sensor, and hence the air in the boarding spaces S4 and S5 can be uniformly conditioned. Further, as the voltage-frequency characteristic of the motor 16a, the compressors 1a and 1b are driven at a voltage that is equal to or lower than the voltage of the power to be output from the auxiliary power supply device S1 at the frequency of the power to be output from the auxiliary power supply device S1. Consequently, when power output from the auxiliary power supply device S1 is directly input to the compressors 1a and 1b, torque insufficiency can be prevented. Further, when power converted and output by the inverter 9 is input to the compressors 1a and 1b, the operation is enabled at a frequency that is higher than the frequency of the power output from the auxiliary power supply device S1. Consequently, power converted in a wider range and output by the inverter 9 is input to the compressors 1a and 1b, and hence operation with low power consumption is enabled.

Embodiment 2

[0069] Fig. 8 is a schematic diagram for illustrating an air-conditioning apparatus 200 for a railway vehicle according to Embodiment 2 of the present invention. Embodiment 2 differs from Embodiment 1 in that any one of the compressor 1a and the compressor 1b is activated by supplying power converted by the inverter 9, and the other of the compressor 1a and the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1. In Embodiment 2, parts in common with Embodiment 1 are denoted by the same reference signs to omit the description of the parts, and differences from Embodiment 1 are mainly described.

[0070] As illustrated in Fig. 8, in the air-conditioning apparatus 200 for a railway vehicle according to Embodiment 2, the power supply circuit d1 includes contactors 10j to 10m having different wiring connections in place of the contactors 10c to 10f of Embodiment 1. The contactor 10j has an upstream port connected to the contactor 10a, and a downstream port connected to the compressor 1a. The contactor 10k has an upstream port connected to the inverter 9, and a downstream port connected to the compressor 1a. The contactor 101 has an upstream port connected to the contactor 10a, and a downstream port connected to the compressor 1b. The contactor 10m has an upstream port connected to the inverter 9, and a downstream port connected to the compressor 1b. In this configuration, any one of the compressor 1a and the compressor 1b can be activated by supplying power converted by the inverter 9, and the other of the compressor 1a and the compressor 1b can be activated by directly supplying power from the auxiliary power supply device S1.

[0071] Next, the operation of the power supply circuit d1 of the air-conditioning apparatus 200 for a railway vehicle is described. When the contactor 10a of the power supply circuit d1 of the air-conditioning apparatus 200 for a railway vehicle is disconnected, supply of power from the auxiliary power supply device S1 of the railway vehicle S100 is cut off, and the contactor 10b and the contactors 10g to 10m connected to the downstream port of the contactor 10a are not energized. A case is described below in which the contactor 10a is energized when the contactor 10b and the contactors 10g to 10m are energized.

[0072] In a case in which the compressor 1a and the compressor 1b are to be activated, when both of the compressor 1a and the compressor 1b are to be activated by directly supplying power from the auxiliary power supply device S1, operations of disconnecting the contactor 10b, energizing the contactor 10j, disconnecting the contactor 10k, energizing the contactor 101, and disconnecting the contactor 10m are performed. In the case in which the compressor 1a and the compressor 1b are to be activated, when both of the compressor 1a and the compressor 1b are to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, disconnecting the contactor 10j, energizing the contactor 10k, disconnecting the contactor 101, and energizing the contactor 10m are performed. In the case in which the compressor 1a and the compressor 1b are to be activated, when the compressor 1a is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9 while the compressor 1b is to be activated by directly supplying power from the auxiliary power supply device S1, operations of energizing the contactor 10b, disconnecting the contactor 10j, energizing the contactor 10k, energizing the contactor 101, and disconnecting the contactor 10m are performed.

[0073] In the case in which the compressor 1a and the compressor 1b are to be activated, when the compressor 1a is to be activated by directly supplying power from the auxiliary power supply device S1 while the compressor 1b is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, energizing the contactor 10j, disconnecting the contactor 10k, disconnecting the contactor 101, and energizing the contactor 10m are performed. In a case in which the compressor 1a is to be activated and the compressor 1b is to be stopped, when the compressor 1a is to be activated by directly supplying power from the auxiliary power supply device S1, operations of disconnecting the contactor 10b, energizing the contactor 10j, disconnecting the contactor 10k, disconnecting the contactor 101, and disconnecting the contactor 10m are performed.

[0074] In the case in which the compressor 1a is to be activated and the compressor 1b is to be stopped, when the compressor 1a is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, disconnecting the contactor 10j, energizing the contactor 10k, disconnecting the contactor 101, and disconnecting the contactor 10m are performed. In a case in which the compressor 1a is to be stopped and the compressor 1b is to be activated, when the compressor 1b is to be activated by directly supplying power from the auxiliary power supply device S1, operations of disconnecting the contactor 10b, disconnecting the contactor 10j, disconnecting the contactor 10k, energizing the contactor 101, and disconnecting the contactor 10m are performed. In the case in which the compressor 1a is to be stopped and the compressor 1b is to be activated, when the compressor 1b is to be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, operations of energizing the contactor 10b, disconnecting the contactor 10j, disconnecting the contactor 10k, disconnecting the contactor 101, and energizing the contactor 10m are performed. In a case in which the compressor 1a and the compressor 1b are to be stopped, operations of disconnecting the contactor 10b, disconnecting the contactor 10j, disconnecting the contactor 10k, disconnecting the contactor 101, and disconnecting the contactor 10m are performed.

[0075] Next, the operation of the controller e1 is described. The controller e1 acquires information from components of the air-conditioning apparatus 200 for a railway vehicle, components of the railway vehicle S100, and the integrated information system X1. The controller e1 calculates, on the basis of the information, a thermal load required for conditioning air in each of the boarding space S4 and the boarding space S5, and determines the operation mode of the air-conditioning apparatus 300 for a railway vehicle that is suitable to the load. The controller e1 executes, on the basis of the operation mode, control of the opening degrees of the expansion device 5a and the expansion device 5b, switching control of the refrigerant flow switching device 2a and the refrigerant flow switching device 2b, control of the output voltage and the output frequency of the inverter 9, and switching control between energization and disconnection of each of the contactor 10a, the contactor 10b, and the contactors 10g to 10m.

[0076] Fig. 9 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 2 of the present invention. In Fig. 9, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. For example, when the load and the load distribution presumed to be required for conditioning air in the railway vehicle S100 fall within a range surrounded by the thick line, the horizontal axis, and the vertical axis in Fig. 9, the controller e1 executes operation control in any one of the mode M1 and modes M4 to M8 for a corresponding one of regions divided by the dotted lines. The controller e1 of the air-conditioning apparatus 200 for a railway vehicle executes operation control in the mode M7 and the mode M8 in place of the mode M2 and the mode M3 executed by the controller e1 of the air-conditioning apparatus 100 for a railway vehicle in Embodiment 1.

[0077] In the mode M7, any one of the compressor 1a and the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a and the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. When the boarding space S4 has a higher load, while the compressor 1a is activated by directly supplying power from the auxiliary power supply device S1 so that the compressor 1a receives power having a constant voltage and a constant frequency, the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. When the boarding space S5 has a higher load, the compressor 1a is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and while the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1 so that the compressor 1b receives power having a constant voltage and a constant frequency, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. The mode M7 corresponds to a control method of a case in which the high load for the air-conditioning apparatus 100 for a railway vehicle is generated. The air conditioning output is adjusted by controlling the rotation frequency of the compressor 1a or the compressor 1a by the inverter 9 instead of repeatedly activating and stopping the compressor 1a or the compressor 1a. Consequently, at an equivalent load and load distribution, the power consumption can be further reduced as compared to the mode M2 or the mode M3, and the level of comfort can be increased due to finer temperature adjustment.

[0078] In the mode M8, any one of the compressor 1a and the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a and the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. When the boarding space S4 has a higher load, the compressor 1a is repeatedly activated and stopped by directly supplying power from the auxiliary power supply device S1, the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. When the boarding space S5 has a higher load, the compressor 1a is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, the compressor 1b is repeatedly activated and stopped by directly supplying power from the auxiliary power supply device S1, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. The mode M3 corresponds to a control method of a case in which a relatively high load is generated at the same level in the first refrigeration cycle a1 and the second refrigeration cycle a2. Although any one of the compressor 1a and the compressor 1a is required to be repeatedly activated and stopped, the rotation frequency of the other of the compressor 1a and the compressor 1a is controlled by the inverter 9 so that the air conditioning output is adjusted. Thus, at an equivalent load and load distribution, the power consumption can be further reduced as compared to the mode M2, and the level of comfort can be increased due to finer temperature adjustment.

[0079] In the mode M1 and the modes M4 to M8, the controller e1 of the air-conditioning apparatus 200 for a railway vehicle uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the opening degree of the expansion device 5a or the expansion device 5b. In the mode M1 and the modes M4 to M8, the controller e1 of the air-conditioning apparatus 200 for a railway vehicle uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a to execute, for example, control for regions obtained by further finely dividing the regions of the modes M1 to M3 in Fig. 9, to thereby determine the repetition frequency and timing to activate and stop the compressor 1a or the compressor 1b to directly receive power from the auxiliary power supply device S1. In the modes M4 to M8, the controller e1 uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the voltage and the frequency to be output by the inverter 9 to the compressor 1a or the compressor 1b to receive power output from the auxiliary power supply device S1 and converted by the inverter 9. As described above, the controller e1 controls the switching operation of the switching unit 10 so that, when the air conditioning load of a corresponding one of the boarding space S4 and S5 of the railway vehicle S100 is higher than the load threshold value, the wiring for directly supplying power from the auxiliary power supply device S1 to at least one of the compressors 1a and 1b and for supplying power to a remainder of the compressors 1a and 1b from the auxiliary power supply device S1 via the inverter 9 is established.

[0080] In a case in which the maximum output of the voltage and the frequency of the inverter 9 is equivalent to the voltage and the frequency output from the auxiliary power supply device S1, when the voltage and the frequency of the inverter 9 are brought to the maximum output in the mode M7, output equivalent to the air conditioning output in the mode M1 is obtained. However, the inverter 9 has an energy loss due to power conversion, and hence the operation in the mode M1 can have a smaller amount of power consumption. When the amount of power convertible by the inverter 9 is increased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be higher than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the regions of the mode M4 and the mode M5 can be extended toward the region of the mode M8 in Fig. 9, and the air conditioner efficiency in these regions can be increased.

[0081] Further, the region of the mode M7 can be enlarged to be a region having a load larger than that of the mode M1. In contrast, when the amount of power convertible by the inverter 9 is decreased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be lower than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the region of the mode M8 is extended toward the regions of the mode M4 and the mode M5, and the region of the mode M1 is extended toward the region of the mode M7. However, the capacity of the inverter 9 can be reduced, and the inverter 9 reduced in size and weight can be mounted. The control pattern to be executed by the controller e1 of the air-conditioning apparatus 200 for a railway vehicle at the time when the inverter 9 is abnormal may be similar to the control pattern to be executed by the controller e1 of the air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 illustrated in Fig. 6.

[0082] According to Embodiment 2, an operation similar to that of Embodiment 1 is enabled, and an effect similar to that of Embodiment 1 can be obtained. Further, any one of the compressor 1a and the compressor 1b can be activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a and the compressor 1b can be activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. Consequently, in the load and the load distribution in the regions of the mode M2 and the mode M3 in Fig. 5 of Embodiment 1, an operation further reduced in power consumption and air conditioning having higher level of comfort as compared to the configuration of Embodiment 1 can be performed.

Embodiment 3

[0083] Fig. 10 is a schematic diagram for illustrating an air-conditioning apparatus 300 for a railway vehicle according to Embodiment 3 of the present invention. Embodiment 3 differs from Embodiment 1 in that the air-conditioning apparatus 300 for a railway vehicle includes a first outdoor unit b2 and a second outdoor unit b3. In Embodiment 3, parts in common with Embodiment 1 are denoted by the same reference signs to omit the description of the parts, and differences from Embodiment 1 are mainly described.

[0084] The air-conditioning apparatus 300 for a railway vehicle according to Embodiment 3 includes the first outdoor unit b2 and the second outdoor unit b3 in place of the outdoor unit b1 in Embodiment 1, and includes, in the configuration, a unit f1 obtained by combining the first outdoor unit b2 and the first indoor unit c1 to be adjacent to each other and a unit f2 obtained by combining the first outdoor unit b2 and the second indoor unit c2 to be adjacent to each other. The first outdoor unit b2 accommodates the first heat exchanger 3a of the first refrigeration cycle a1 and an outdoor fan 6a. The first outdoor unit b2 has an air passage formed so that air present outside the vehicle flows into the first heat exchanger 3a when the outdoor fan 6a is operated, and thus the air can exchange heat with the refrigerant present inside the first heat exchanger 3a. The second outdoor unit b3 accommodates the first heat exchanger 3b of the second refrigeration cycle a2 and an outdoor fan 6b. The second outdoor unit b3 has an air passage formed so that air present outside the vehicle flows into the first heat exchanger 3b when the outdoor fan 6b is operated, and thus the air can exchange heat with the refrigerant present inside the first heat exchanger 3b.

[0085] In the air-conditioning apparatus 300 for a railway vehicle according to Embodiment 3, the power supply circuit d1 includes a contactor 10p and a contactor 10q in place of the contactor 10g. The contactor 10p has an upstream port connected to the contactor 10a, and a downstream port connected to the outdoor fan 6a. The contactor 10q has an upstream port connected to the contactor 10a, and a downstream port connected to the outdoor fan 6b. The power supply circuit d1 in Fig. 10 has a configuration using the contactors 10j to 10m in Embodiment 2, but may have a configuration using the contactors 10c to 10f in Embodiment 1.

[0086] The first outdoor unit b2 includes the outdoor temperature and humidity sensor 11a and the outdoor temperature and humidity sensor 12a. The outdoor temperature and humidity sensor 11a is provided to a portion in the vicinity of the air inlet of the first outdoor unit b2 or the air inflow portion of the first heat exchanger 3a. The outdoor temperature and humidity sensor 12a is provided to a portion in the vicinity of the air outlet of the first outdoor unit b2 or the air outflow portion of the first heat exchanger 3a. The outdoor temperature and humidity sensor 12a may be omitted as long as the outdoor temperature and humidity sensor 11a is provided. The second outdoor unit b3 includes the outdoor temperature and humidity sensor 11b and the outdoor temperature and humidity sensor 12b. The outdoor temperature and humidity sensor 11b is provided to a portion in the vicinity of the air inlet of the second outdoor unit b3 or the air inflow portion of the first heat exchanger 3b. The outdoor temperature and humidity sensor 12b is provided to a portion in the vicinity of the air outlet of the second outdoor unit b3 or the air outflow portion of the first heat exchanger 3b. The outdoor temperature and humidity sensor 12b may be omitted as long as the outdoor temperature and humidity sensor 11b is provided. The outdoor temperature and humidity sensor 11a and the outdoor temperature and humidity sensor 11b are each configured to measure the temperature or both of the temperature and the humidity.

[0087] Fig. 11 is a schematic view for illustrating a railway vehicle S200 in Embodiment 3 of the present invention. As illustrated in Fig. 11, in the railway vehicle S200, the unit f1 and the unit f2 of the air-conditioning apparatus 300 for a railway vehicle are separately installed on the roof of the railway vehicle S200. The railway vehicle S200 has a configuration in which a stream of air subjected to heat exchange by the second heat exchanger 4a of the first indoor unit c1 of the unit f1 passes through the air outlet duct S2 to be blown out to the boarding space S4 inside the railway vehicle S200, and a stream of air subjected to heat exchange by the second heat exchanger 4b of the second indoor unit c2 of the unit f2 passes through the air outlet duct S3 to be blown out to the boarding space S5 inside the railway vehicle S200.

[0088] Next, the operation mode of the air-conditioning apparatus 300 for a railway vehicle is described. First, the case of the cooling operation is described. Description is given of a behavior of air flowing into and out from the first outdoor unit b2 when the first refrigeration cycle a1 of the air-conditioning apparatus 300 for a railway vehicle performs the cooling operation. Air having flowed into the first outdoor unit b2 from the outside of the railway vehicle S200 flows into the first heat exchanger 3a. In the first heat exchanger 3a, the air is heated by heat exchange with the refrigerant inside the first heat exchanger 3a, and flows to the outdoor fan 6a. In the outdoor fan 6a, the air is forced out to flow to the outside of the railway vehicle S300. Alternatively, the air-conditioning apparatus 300 for a railway vehicle may be configured so that the air having flowed into the first outdoor unit b2 flows in the order of the outdoor fan 6b, the first heat exchanger 3b, and the outside of the railway vehicle S300.

[0089] Description is given of a behavior of air flowing into and out from the second outdoor unit b3 when the second refrigeration cycle a2 of the air-conditioning apparatus 300 for a railway vehicle performs the cooling operation. Air having flowed into the second outdoor unit b3 from the outside of the railway vehicle S200 flows into the first heat exchanger 3b. In the first heat exchanger 3b, the air is heated by heat exchange with the refrigerant inside the first heat exchanger 3b, and then flows to the outdoor fan 6b. In the outdoor fan 6b, the air is forced out to flow to the outside of the railway vehicle S300. Alternatively, the air-conditioning apparatus 300 for a railway vehicle may be configured so that the air having flowed into the second outdoor unit b3 flows in the order of the outdoor fan 6b, the first heat exchanger 3b, and the outside of the railway vehicle S300.

[0090] Next, the case of the heating operation is described. Description is given of a behavior of air flowing into and out from the first outdoor unit b2 when the first refrigeration cycle a1 of the air-conditioning apparatus 300 for a railway vehicle performs the cooling operation. Air having flowed into the first outdoor unit b2 from the outside of the railway vehicle S200 flows into the first heat exchanger 3a. In the first heat exchanger 3a, the air is cooled by heat exchange with the refrigerant inside the first heat exchanger 3a, and flows to the outdoor fan 6a. In the outdoor fan 6a, the air is forced out to flow to the outside of the railway vehicle S300. Alternatively, the air-conditioning apparatus 300 for a railway vehicle may be configured so that the air having flowed into the first outdoor unit b2 flows in the order of the outdoor fan

6b, the first heat exchanger 3b, and the outside of the railway vehicle S300.

[0091] Description is given of a behavior of air flowing into and out from the second outdoor unit b3 when the second refrigeration cycle a2 of the air-conditioning apparatus 300 for a railway vehicle performs the cooling operation. Air having flowed into the second outdoor unit b3 from the outside of the railway vehicle S200 flows into the first heat exchanger 3b. In the first heat exchanger 3b, the air is cooled by heat exchange with the refrigerant inside the first heat exchanger 3b, and then flows to the outdoor fan 6b. In the outdoor fan 6b, the air is forced out to flow to the outside of the railway vehicle S300. Alternatively, the air-conditioning apparatus 300 for a railway vehicle may be configured so that the air having flowed into the second outdoor unit b3 flows in the order of the outdoor fan 6b, the first heat exchanger 3b, and the outside of the railway vehicle S300.

[0092] Next, the operation of the power supply circuit d1 is described. When the contactor 10a of the power supply circuit d1 of the air-conditioning apparatus 300 for a railway vehicle is disconnected, supply of power from the auxiliary power supply device S1 of the railway vehicle S200 is cut off, and the contactor 10b, the contactors 10h to 10m, the contactor 10p, and the contactor 10q connected to the downstream port of the contactor 10a are not energized. A case is described below in which the contactor 10a is energized when the contactors 10b to 10f, the contactors 10h to 10m, the contactor 10p, and the contactor 10q are energized. When the outdoor fan 6a is activated, the contactor 10p is energized. When the outdoor fan 6a is stopped, the contactor 10p is disconnected. When the outdoor fan 6a is activated, the contactor 10q is energized. When the outdoor fan 6a is stopped, the contactor 10q is disconnected.

[0093] Next, the operation of the controller e1 is described. The controller e1 acquires information from components of the air-conditioning apparatus 300 for a railway vehicle, components of the railway vehicle S200, and the integrated information system X1. The controller e1 calculates, on the basis of the information, a thermal load required for conditioning air in each of the boarding space S4 and the boarding space S5, and determines the operation mode of the air-conditioning apparatus 300 for a railway vehicle that is suitable to the load. The controller e1 executes, on the basis of the operation mode, control of the opening degrees of the expansion device 5a and the expansion device 5b, switching control of the refrigerant flow switching device 2a and the refrigerant flow switching device 2b, control of the output voltage and the output frequency of the inverter 9, and switching control between energization and disconnection of each of the contactor 10a, the contactor 10b, the contactors 10h to 10m, the contactor 10p, and the contactor 10q.

[0094] For example, with regard to a thermal load required for conditioning air in the boarding space S4 at the time of the cooling operation, the higher the temperature measured by the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, or the vehicle inside temperature and humidity sensor S7 is than a setting temperature, the larger the load is calculated to be. Further, the higher the temperature measured by the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, or the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. Further, the larger the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be. For example, with regard to a thermal load required for conditioning air in the boarding space S4 at the time of the heating operation, the lower the temperature measured by the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, or the vehicle inside temperature and humidity sensor S7 is than the setting temperature, the larger the load is calculated to be. Further, the lower the temperature measured by the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, or the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. Further, the smaller the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be.

[0095] The control operation of the air-conditioning apparatus 300 for a railway vehicle is described below. When the air-conditioning apparatus 300 for a railway vehicle uses the contactors 10c to 10f in the power supply circuit d1 as described in Embodiment 1 to energize and disconnect the compressor 1a and the compressor 1b and to achieve connection to the inverter 9, the controller e1 of the air-conditioning apparatus 300 for a railway vehicle may execute control similar to one in the control pattern in Embodiment 1 illustrated in Fig. 5. When the air-conditioning apparatus 300 for a railway vehicle uses the contactors 10j to 10m in the power supply circuit d1 as described in Embodiment 2 to energize and disconnect the compressor 1a and the compressor 1b and to achieve connection to the inverter 9, the controller e1 of the air-conditioning apparatus 300 for a railway vehicle may execute control similar to one in the control pattern in Embodiment 2 illustrated in Fig. 9.

[0096] According to Embodiment 3, even when a large-sized apparatus cannot be installed on the vehicle roof of the railway vehicle S200 due to arrangement restrictions, the air-conditioning apparatus 300 for a railway vehicle can be placed by dividing the air-conditioning apparatus 300 for a railway vehicle into the small-sized units f1 and f2. Moreover, an operation similar to that of Embodiment 1 or Embodiment 2 is enabled, and an effect similar to that of Embodiment 1 or Embodiment 2 can be obtained. Further, the first refrigeration cycle a1 and the second refrigeration cycle a2 do not share the outdoor unit b1 and the outdoor fan 6 accommodated in the outdoor unit b1 unlike Embodiment 1 or Embodiment 2, and hence there is eliminated needless power loss of the outdoor fan 6 due to the stream of air flowing into the first heat exchanger 3a or 3b of the stopped cycle when any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 is operated. That is, according to Embodiment 3, when the operation of the first refrigeration cycle a1 is stopped, the outdoor fan 6a can be stopped to prevent a stream of air from flowing to the first heat exchanger 3a, and when the operation of the second refrigeration cycle a2 is stopped, the outdoor fan 6b can be stopped to prevent a stream of air from flowing to the first heat exchanger 3b. Consequently, an operation further reduced in power consumption as compared to the configuration of Embodiment 1 or Embodiment 2 is enabled.

Embodiment 4

[0097] Fig. 12 is a schematic diagram for illustrating an air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 of the present invention. Embodiment 4 differs from Embodiment 1 in that the air-conditioning apparatus 400 for a railway vehicle includes an indoor unit c3. In Embodiment 4, parts in common with Embodiment 1 are denoted by the same reference signs to omit the description of the parts, and differences from Embodiment 1 are mainly described.

[0098] The air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 has a configuration including the indoor unit c3 in place of the first indoor unit c1 and the second indoor unit c2 in Embodiment 1. The indoor unit c3 accommodates the second heat exchanger 4a of the first refrigeration cycle a1, the second heat exchanger 4b of the second refrigeration cycle a2, and an indoor fan 7. The indoor unit c3 has an air passage formed so that air inside the vehicle flows into the second heat exchanger 4a and the second heat exchanger 4b when the indoor fan 7 is operated, and thus the air can exchange heat with the refrigerant inside the second heat exchanger 4a and the second heat exchanger 4b.

[0099] In the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4, the power supply circuit d1 includes a contactor 10r in place of the contactor 10h and the contactor 10i. The contactor 10r has an upstream port connected to the contactor 10a, and a downstream port connected to the indoor fan 7. The power supply circuit d1 in Fig. 12 has a configuration using the contactors 10j to 10m in Embodiment 2, but may have a configuration using the contactors 10c to 10f in Embodiment 1.

[0100] The indoor unit c3 includes an indoor temperature and humidity sensor 13 (not shown) provided to a portion in the vicinity of the air inlet of the indoor unit c3, the indoor temperature and humidity sensor 13a provided to a portion in the vicinity of the air inlet of the indoor unit c3 or the air inflow portion of the second heat exchanger 4a, the indoor temperature and humidity sensor 14a provided to a portion in the vicinity of the air outlet of the indoor unit c3 or the air outflow portion of the second heat exchanger 4a, the indoor temperature and humidity sensor 13b provided to a portion in the vicinity of the air inlet of the indoor unit c3 or the air inflow portion of the second heat exchanger 4b, and the indoor temperature and humidity sensor 14b provided to a portion in the vicinity of the air outlet of the indoor unit c3 or the air outflow portion of the second heat exchanger 4b. The indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 13b may be omitted as long as the indoor temperature and humidity sensor 13 is provided. Any one of the indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 14a may be omitted as long as the other of the indoor temperature and humidity sensor 13a and the indoor temperature and humidity sensor 14a is provided. Any one of the indoor temperature and humidity sensor 13b and the indoor temperature and humidity sensor 14b may be omitted as long as the other of the indoor temperature and humidity sensor 13b and the indoor temperature and humidity sensor 14b is provided. The indoor temperature and humidity sensor 13 is configured to measure the temperature or both of the temperature and the humidity.

[0101] Fig. 13 is a schematic view for illustrating a railway vehicle S300 in Embodiment 4 of the present invention. As illustrated in Fig. 13, in the railway vehicle S300, one air-conditioning apparatus 400 for a railway vehicle is installed on the roof of the railway vehicle S300. The railway vehicle S300 has a configuration in which a stream of air subjected to heat exchange by the second heat exchanger 4a and the second heat exchanger 4b of the indoor unit c3 passes through an air outlet duct S10 to be blown out to a boarding space S11 inside the railway vehicle S300. As in the configuration of the railway vehicle S300, in some cases, the stream of air subjected to heat exchange in the indoor unit c3 flows through the air outlet duct S10 to flow to one boarding space S11. The railway vehicle S300 includes a vehicle inside temperature and humidity sensor S12 mounted in the boarding space S11. The vehicle inside temperature and humidity sensor S12 is configured to measure the temperature or both of the temperature and the humidity.

[0102] Next, the operation mode of the air-conditioning apparatus 400 for a railway vehicle is described. First, the case of the cooling operation is described. Description is given of a behavior of air flowing into and out from the indoor unit c3 when the compressor 1a or 1b, the outdoor fan 6, and the indoor fan 7 of the air-conditioning apparatus 400 for a railway vehicle are activated in the case of the cooling operation. Air having flowed into the indoor unit c3 from the boarding space S11 of the railway vehicle S300 flows to the second heat exchanger 4a and the second heat exchanger 4b. In the second heat exchanger 4a and the second heat exchanger 4b, the air is cooled by heat exchange with the refrigerant inside each heat exchanger, and flows to the indoor fan 7. In the indoor fan 7, the air is forced out to pass through the air outlet duct S10 and flow to the boarding space S11. Thus, the boarding space S11 is cooled. Alternatively, the air-conditioning apparatus 400 for a railway vehicle may be configured so that the air having flowed into the indoor unit c3 flows in the order of the indoor fan 7a, the second heat exchanger 4a or 4b, the air outlet duct S10, and the boarding space S11.

[0103] Next, the case of the heating operation is described. Description is given of a behavior of air flowing into and out from the indoor unit c3 when the compressor 1a or 1b, the outdoor fan 6, and the indoor fan 7 of the air-conditioning apparatus 400 for a railway vehicle are activated in the case of the heating operation. Air having flowed into the indoor unit c3 from the boarding space S11 of the railway vehicle S300 flows to the second heat exchanger 4a and the second heat exchanger 4b. In the second heat exchanger 4a and the second heat exchanger 4b, the air is heated by heat exchange with the refrigerant inside each heat exchanger, and flows to the indoor fan 7. In the indoor fan 7, the air is forced out to pass through the air outlet duct S10 and flow to the boarding space S11. Thus, the boarding space S11 is heated. Alternatively, the air-conditioning apparatus 400 for a railway vehicle may be configured so that the air having flowed into the indoor unit c3 flows in the order of the indoor fan 7a, the second heat exchanger 4a or 4b, the air outlet duct S10, and the boarding space S11.

[0104] Next, the case of the air-sending operation is described. When only air sending is performed to the boarding space S11, the indoor fan 7 of the indoor unit c3 is activated without activation of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2. In this case, air having flowed into the indoor unit c3 from the boarding space S11 of the railway vehicle S100 flows through the second heat exchanger 4a and the second heat exchanger 4b but does not exchange heat with the refrigerant flowing inside each heat exchanger. Then, the air flows out from the indoor unit c3, and passes through the air outlet duct S10 to be sent to the boarding space S11.

[0105] Next, the operation of the power supply circuit d1 is described. When the contactor 10a of the power supply circuit d1 of the air-conditioning apparatus 400 for a railway vehicle is disconnected, supply of power from the auxiliary power supply device S1 of the railway vehicle S300 is cut off, and the contactor 10b, the contactor 10g, the contactors 10j to 10m, and the contactor 10r connected to the downstream port of the contactor 10a are not energized. A case is described below in which the contactor 10a is energized when the contactors 10b to 10f, the contactors 10h to 10m, the contactor 10p, and the contactor 10q are energized. When the indoor fan 7 is activated, the contactor 10r is energized. When the indoor fan 7 is stopped, the contactor 10r is disconnected.

[0106] Next, the operation of the controller e1 is described. The controller e1 acquires information from components of the air-conditioning apparatus 400 for a railway vehicle, components of the railway vehicle S300, and the integrated information system X1. The controller e1 calculates, on the basis of the information, a thermal load required for conditioning air in the boarding space S11, and determines the operation mode of the air-conditioning apparatus 400 for a railway vehicle that is suitable to the load. The controller e1 executes, on the basis of the operation mode, control of the opening degrees of the expansion device 5a and the expansion device 5b, switching control of the refrigerant flow switching device 2a and the refrigerant flow switching device 2b, control of the output voltage and the output frequency of the inverter 9, and switching control between energization and disconnection of each of the contactor 10a, the contactor 10b, the contactor 10g, the contactors 10j to 10m, and the contactor 10r.

[0107] For example, with regard to a thermal load required for conditioning air in the boarding space S11 at the time of the cooling operation, the higher the temperature measured by any one of the indoor temperature and humidity sensor 13, the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, the indoor temperature and humidity sensor 13b, the indoor temperature and humidity sensor 14b, and the vehicle inside temperature and humidity sensor S12 is than a setting temperature, the larger the load is calculated to be. The higher the temperature measured by any one of the outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, and the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. Further, the larger the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be.

[0108] For example, with regard to a thermal load required for conditioning air in the boarding space S11 at the time of the heating operation, the higher the temperature measured by any one of the indoor temperature and humidity sensor 13, the indoor temperature and humidity sensor 13a, the indoor temperature and humidity sensor 14a, the indoor temperature and humidity sensor 13b, the indoor temperature and humidity sensor 14b, and the vehicle inside temperature and humidity sensor S12 is than a setting temperature, the larger the load is calculated to be. The lower the temperature measured by any one of the outdoor temperature and humidity sensor 11, the outdoor temperature and humidity sensor 11a, the outdoor temperature and humidity sensor 12a, the outdoor temperature and humidity sensor 11b, the outdoor temperature and humidity sensor 12b, and the vehicle outside temperature and humidity sensor S6 is, the larger the load is calculated to be. The smaller the number of passengers acquired as information from the vehicle occupancy sensor S9 is, the larger the load is calculated to be.

[0109] Fig. 14 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 4 of the present invention. In Fig. 14, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. The controller e1 executes operation control in any one of the mode M1 and the modes M4 to M7 for a corresponding one of regions divided by the dotted lines. Fig. 14 is not required to have the load distribution in the vertical axis unlike Fig. 5, Fig. 6, and Fig. 9. For example, when there is a region vertically sectioned by a dotted line that is parallel to the horizontal axis at a specific load as in the mode M4 and the mode M5, the operation control may be executed in any one of the mode M4 and the mode M5 at the load in the corresponding region. For example, when the thermal load required for conditioning air in the boarding space S11 is concentrated to the region around the dotted line serving as the boundary between the mode M5 and the mode M7 due to the use environment of the railway vehicle S300, the switching between the mode M5 and the mode M7 frequently occurs, and hence the control is preferred to be executed in the mode M4.

[0110] When the amount of power convertible by the inverter 9 is increased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be higher than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the regions of the mode M4 and the mode M5 in Fig. 14 are moved toward the region of the mode M7 having a high load, and the region of the mode M7 can be enlarged to be a region having a load larger than that of the mode M1. In contrast, when the amount of power convertible by the inverter 9 is decreased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be lower than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the region of the mode M4 is moved toward the region of the mode M5 having a low load, and the region of the mode M1 is extended toward the region of the mode M7. However, the capacity of the inverter 9 can be reduced, and the inverter 9 reduced in size and weight can be mounted.

[0111] Fig. 15 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 4 of the present invention at the time when the inverter 9 is abnormal. In Fig. 15, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. As illustrated in Fig. 15, the controller e1 executes the operation control in any one of the modes M1 to M3 and the mode M6 for a corresponding one of regions divided by the dotted lines. In this case, the regions of the mode M2 and the mode M3 cover the regions of the mode M4, the mode M5, and the mode M7 in Fig. 14. With this control, even when the inverter 9 cannot be used due to occurrence of abnormality in the inverter 9, the air-conditioning apparatus 400 for a railway vehicle can condition air suitably to the load of the boarding space S11.

[0112] Fig. 16 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 4 of the present invention. In Fig. 16, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. The power supply circuit d1 of the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 may have a configuration using the contactors 10c to 10f as in Embodiment 1 in place of the configuration using the contactors 10j to 10m as in Embodiment 2. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M2, and the modes M4 to M6 for a corresponding one of regions divided by the dotted lines.

[0113] According to Embodiment 4, the air-conditioning apparatus 400 for a railway vehicle is installed on the railway vehicle S300 having such duct structure and arrangement that the stream of air blown out from the indoor unit c3 is spread to the entire boarding space of the railway vehicle S300. Thus, unlike Embodiment 1 to Embodiment 3, without the need to execute control for each of the first refrigeration cycle a1 and the second refrigeration cycle a2 in consideration of the load distribution in the vehicle front-rear direction, highly-efficient operation control with use of the inverter 9 is enabled. As a result, the operation is enabled with further reduced power consumption as compared to the configurations of Embodiments 1 to 3. Further, the number of sensors in the air-conditioning apparatus 400 for a railway vehicle and the number of sensors in the railway vehicle S300 can be reduced to reduce the capacity of the controller e1. As only one indoor unit is required, the size can be reduced.

Embodiment 5

[0114] Fig. 17 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 5 of the present invention. An air-conditioning apparatus for a railway vehicle according to Embodiment 5 includes the same components as those of the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 illustrated in Fig. 12, but Embodiment 5 differs from Embodiment 1 in that, when the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1, the first refrigeration cycle a1 has a larger or smaller refrigeration capacity than that of the second refrigeration cycle a2. In Embodiment 5, parts in common with Embodiment 1 are denoted by the same reference signs to omit the description of the parts, and differences from Embodiment 1 are mainly described.

[0115] For example, the displacement of the compression chamber 18a of the compressor 1a is set to be larger than the displacement of the compression chamber 18b of the compressor 1b, and the shapes of the first heat exchanger 3a and the first heat exchanger 3b are adjusted. Thus, the first refrigeration cycle a1 can have a larger refrigeration capacity than that of the second refrigeration cycle a2. In an air-conditioning apparatus 500 for a railway vehicle, to prevent the railway vehicle S300 from excessively inclining and shaking in the direction perpendicular to the traveling-direction axis, the components are arranged, for example, to be substantially bilaterally symmetrical about the traveling-direction axis from the center so that the center of gravity is located at the center in the direction perpendicular to the traveling-direction axis.

[0116] In Fig. 17, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. The controller e1 executes the operation control in any one of the mode M1, the mode M6, and modes M9 to M12 for a corresponding one of regions divided by the dotted lines. As illustrated in Fig. 17, in the mode M9, when the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1, one of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the higher refrigeration capacity is activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the lower refrigeration capacity is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. The voltage and the frequency output from the inverter 9 are controlled, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted suitably to the load. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0117] In the mode M10, when the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1, one of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the lower refrigeration capacity is activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the higher refrigeration capacity is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. The voltage and the frequency output from the inverter 9 are controlled, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted suitably to the load. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0118] In the mode M11, when the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1, one of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the higher refrigeration capacity is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the other of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the lower refrigeration capacity is stopped. The voltage and the frequency output from the inverter 9 are controlled, and the opening degree of the expansion device 5a or the expansion device 5b is controlled so that the air conditioning output is adjusted suitably to the load. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0119] In the mode M12, when the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1, one of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the lower refrigeration capacity is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the other of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 having the higher refrigeration capacity is stopped. The voltage and the frequency output from the inverter 9 are controlled, and the opening degree of the expansion device 5a or the expansion device 5b is controlled so that the air conditioning output is adjusted suitably to the load. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0120] In the mode M1, the mode M6, and the modes M9 to M12, the controller e1 of the air-conditioning apparatus 200 for a railway vehicle uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the opening degree of the expansion device 5a or the expansion device 5b. In the modes M9 to M12, the controller e1 uses the information on the calculated thermal load required for conditioning air and the information on the temperatures and the pressures measured by the refrigerant sensors 15a and the refrigerant sensors 15b to execute, for example, PID control, to thereby determine the voltage and the frequency to be output by the inverter 9 to the compressor 1a or the compressor 1b to receive power output from the auxiliary power supply device S1 and converted by the inverter 9.

[0121] As an example in which the controller e1 executes the control pattern of Fig. 17, there is given a case in which the maximum amount of power converted by the inverter 9 reaches the maximum amount of power in the mode M1. For example, when the maximum amount of power converted by the inverter 9 is increased up to the maximum amount of power in the mode M4, the region of the mode M9 or the mode M10 having a low load in Fig. 17 may be replaced with the mode M4.

[0122] When the amount of power convertible by the inverter 9 is increased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be higher than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the regions of the mode M9 and the mode M10 can be enlarged to be a region having a load larger than that of the mode M1. In contrast, when the amount of power convertible by the inverter 9 is decreased, and the maximum output of the voltage and the frequency of the inverter 9 is brought to be lower than the maximum output of the voltage and the frequency output from the auxiliary power supply device S1, the regions of the modes M9 to M12 having the maximum load are moved to a low-load region, and the region of the mode M1 is extended toward the low-load region, or the region of the mode M2 is provided. However, the capacity of the inverter 9 can be reduced, and the inverter 9 reduced in size and weight can be mounted.

[0123] Fig. 18 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 5 of the present invention at the time when the inverter 9 is abnormal. In Fig. 18, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. The controller e1 executes the operation control in any one of the mode M1, the mode M3, the mode M6, the mode M13, and the mode M14 for a corresponding one of regions divided by the dotted lines. With this control, even when the inverter 9 cannot be used due to occurrence of abnormality in the inverter 9, the air-conditioning apparatus 500 for a railway vehicle can condition air suitably to the load of the boarding space S11.

[0124] As illustrated in Fig. 18, in the mode M13, when both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1, and the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the compressor 1b is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. When the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the compressor 1a is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0125] In the mode M14, when both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1, and the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the compressor 1a is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. When the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the compressor 1b is controlled to be repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0126] Fig. 19 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 5 of the present invention. In Fig. 19, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation. The power supply circuit d1 of the air-conditioning apparatus 500 for a railway vehicle according to Embodiment 5 may have a configuration using the contactors 10c to 10f as in Embodiment 1 in place of the configuration using the contactors 10j to 10m as in Embodiment 2. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M4, the mode M6, and the modes M11 to M14 for a corresponding one of regions divided by the dotted lines.

[0127] According to Embodiment 5, when any one of the compressor 1a and the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1, the compressor having a higher refrigeration capacity is activated at the time of a high load by directly supplying power from the auxiliary power supply device S1, and the compressor having a lower refrigeration capacity is activated at the time of a low load by directly supplying power from the auxiliary power supply device S1. Consequently, the output of the compressor does not become excessive relative to the load, and an efficient operation is enabled with a small difference between a condensing temperature and an evaporating temperature of the refrigeration cycle, for example. Thus, the operation is enabled with further reduced power consumption as compared to Embodiment 4.

Embodiment 6

[0128] Fig. 20 is a schematic view for illustrating an example of the compressor 1a in Embodiment 6 of the present invention. Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes a capacity control mechanism 19a, and the compressor 1b includes a capacity control mechanism 19b. In Embodiment 6, parts in common with Embodiments 1 to 5 are denoted by the same reference signs to omit the description of the parts, and differences from Embodiments 1 to 5 are mainly described.

[0129] As illustrated in Fig. 20, the compressor 1a of an air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 of the present invention includes the capacity control mechanism 19a. The capacity control mechanism 19a is configured so that a refrigerant inlet of the compression chamber 18a is connected to a refrigerant flow passage, in which compression is being performed, inside the compression chamber 18a with use of a capacity control pipe 20a, and the capacity control pipe 20a includes a capacity control valve 21a. That is, the refrigerant inlet of the compression chamber 18a and the refrigerant flow passage, in which compression is being performed, inside the compression chamber

18a are connected to each other under a state in which the capacity control valve 21a is interposed between the refrigerant inlet of the compression chamber 18a and the refrigerant flow passage inside the compression chamber 18a.

[0130] The capacity control valve 21a is connected to the controller e1, and is configured to be opened and closed in response to the command from the controller e1. With this configuration, when the capacity control valve 21a is opened while the compressor 1a is operated, part of refrigerant present in the refrigerant flow passage, in which compression is being performed, inside the compression chamber 18a passes through the capacity control pipe 20a to return to the refrigerant inlet of the compression chamber 18a. In this manner, the rise of pressure from the refrigerant inlet of the compression chamber 18a to the refrigerant flow passage, in which compression is being performed, inside the compression chamber 18a is significantly reduced, and thus the volume is almost not used for the compression process. Consequently, although the compression efficiency of the compressor 1a is reduced, the refrigeration capacity can be reduced. With this action, even when power is directly supplied from the auxiliary power supply device S1 to the compressor 1a, the air conditioning output can be adjusted without repeatedly activating and stopping the compressor frequently. The illustration of the compressor 1b is omitted in the drawings, but similarly, the compressor 1b includes the capacity control mechanism 19b as illustrated in Fig. 20, and can adjust the air conditioning output with an action similar to that of the compressor 1a.

[0131] Fig. 21 is a diagram for illustrating an example of a control pattern of the controller e1 in Embodiment 6 of the present invention. Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a, and the compressor 1b includes the capacity control mechanism 19b. When the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 includes substantially the same components as those of the air-conditioning apparatus 100 for a railway vehicle according to Embodiment 1 illustrated in Fig. 1, the operation control is executed in the control pattern as illustrated in Fig. 21. The operation modes having common reference signs with those of Embodiments 1 to 5 are described as operation modes in which the capacity control valve 21a and the capacity control valve 21b are closed.

[0132] In Fig. 21, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. The controller e1 executes the operation control in any one of the mode M1, the modes M4 to M6, and modes M15 to M19 for a corresponding one of regions divided by the dotted lines.

[0133] As illustrated in Fig. 21, the mode M15 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M15, when the boarding space S4 has a higher load, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. Further, when the boarding space S5 has a higher load, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M15 corresponds to a control method of a case in which a load that can be covered by a refrigeration capacity close to the maximum refrigeration capacity is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0134] The mode M16 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M16, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5a is controlled so that output required for conditioning air in the boarding space S4 is adjusted. Further, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5b is controlled so that output required for conditioning air in the boarding space S5 is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M16 corresponds to a control method of a case in which a relatively high load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0135] The mode M17 is a mode in which both of the compressor 1a and the compressor 1b are activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. In the mode M17, when the boarding space S4 has a higher load, while the voltage and the frequency of power to be supplied to both of the compressor 1a and the compressor 1b are changed, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. Further, when the boarding space S5 has a higher load, while the voltage and the frequency of power to be supplied to both of the compressor 1a and the compressor 1b are changed, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. The output required for conditioning air is adjusted by controlling the opening degrees of the expansion device 5a and the expansion device 5b while the voltage and the frequency of power to be supplied to both of the compressor 1a and the compressor 1b are changed. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M17 corresponds to a control method of a case in which a middle-level or relatively low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 in such a manner that biased distribution is caused.

[0136] The mode M18 is a mode in which both of the compressor 1a and the compressor 1b are activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. In the mode M18, while the voltage and the frequency of power to be supplied to both of the compressor 1a and the compressor 1b are changed, the capacity control valve 21a and the capacity control valve 21b are controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M18 corresponds to a control method of a case in which a relatively low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0137] The mode M19 is a mode in which, when the boarding space S4 has a higher load, the compressor 1a is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the compressor 1b is stopped. In the mode M19, while the voltage and the frequency of power to be supplied to the compressor 1a are changed, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5a is controlled so that the output required for conditioning air is adjusted. Further, when the boarding space S5 has a higher load, the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9, and the compressor 1a is stopped. While the voltage and the frequency of power to be supplied to the compressor 1b are changed, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5b is controlled so that the output required for conditioning air is adjusted. The mode M19 is a mode in which, while the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M19 corresponds to a control method of a case in which a low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2 or a case in which a low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 and almost no load or a low reverse load is generated in the other of the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0138] Fig. 22 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention at the time when the inverter is abnormal. In Fig. 22, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. The controller e1 executes the operation control in any one of the mode M1, the mode M6, the mode M15, the mode M16, and modes M20 to M23 for a corresponding one of regions divided by the dotted lines. With this control, even when the inverter 9 cannot be used due to occurrence of abnormality in the inverter 9, the air-conditioning apparatus 600 for a railway vehicle can condition air suitably to the load in each of the boarding space S4 and the boarding space S5.

[0139] As illustrated in Fig. 22, the mode M20 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M20, when the boarding space S4 has a higher load, while the capacity control valve 21b is opened, the compressor 1b is repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the output required for conditioning air is adjusted. Further, when the boarding space S5 has a higher load, while the capacity control valve 21a is opened, the compressor 1a is repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M20 corresponds to a control method of a case in which a middle-level or relatively low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 in such a manner that significant biased distribution is caused.

[0140] The mode M21 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M21, when the boarding space S4 has a higher load, while the capacity control valve 21a and the capacity control valve 21b are opened, the compressor 1b is repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the output required for conditioning air is adjusted. Further, when the boarding space S5 has a higher load, while the capacity control valve 21a and the capacity control valve 21b are opened, the compressor 1a is repeatedly activated and stopped, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M21 corresponds to a control method of a case in which a relatively low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 in such a manner that biased distribution is caused.

[0141] The mode M22 is a mode in which both of the compressor 1a and the compressor 1b are activated by directly supplying power from the auxiliary power supply device S1. In the mode M22, while the capacity control valve 21a is opened, the compressor 1a is repeatedly activated and stopped, and while the capacity control valve 21b is opened, the compressor 1b is repeatedly activated and stopped. Further, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M20 corresponds to a control method of a case in which a relatively low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0142] The mode M23 is a mode in which, when the boarding space S4 has a higher load, the compressor 1a is activated by directly supplying power from the auxiliary power supply device S1, and the compressor 1b is stopped. In the mode M23, while the capacity control valve 21a is opened, the compressor 1a is repeatedly activated and stopped, and the opening degree of the expansion device 5a is controlled so that the output required for conditioning air is adjusted. Further, when the boarding space S5 has a higher load, the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1, and the compressor 1a is stopped. While the capacity control valve 21b is opened, the compressor 1b is repeatedly activated and stopped, and the opening degree of the expansion device 5b is controlled so that the output required for conditioning air is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. In Embodiment 6, the mode M23 corresponds to a control method of a case in which a low load is generated in the first refrigeration cycle a1 and the second refrigeration cycle a2 or a case in which a low load is generated in any one of the first refrigeration cycle a1 and the second refrigeration cycle a2 and almost no load or a low reverse load is generated in the other of the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0143] Fig. 23 is a diagram for illustrating another example of the control pattern of the controller e1 in Embodiment 6 of the present invention. In Fig. 23, the horizontal axis represents a thermal load required for conditioning air at the time of the cooling operation or the heating operation, and the vertical axis represents a load distribution representing a difference in thermal load required for conditioning air in the boarding space S4 and the boarding space S5. The power supply circuit d1 of the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 may have a configuration using the contactors 10j to 10m as in Embodiment 2 in place of the configuration using the contactors 10c to 10f as in Embodiment 1. In this case, the controller e1 executes the operation control in any one of the mode M1, the modes M4 to M7, the modes M17 to M19, and a mode M24 for a corresponding one of regions divided by the dotted lines.

[0144] As illustrated in Fig. 23, the mode M24 is a mode in which any one of the compressor 1a and the compressor 1b is activated by directly supplying power from the auxiliary power supply device S1, and the other of the compressor 1a and the compressor 1b is activated by supplying power output from the auxiliary power supply device S1 and converted by the inverter 9. In the mode M24, when the boarding space S4 has a higher load, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and while the voltage and the frequency of power to be supplied to the compressor 1b are changed, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. Further, when the boarding space S5 has a higher load, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and while the voltage and the frequency of power to be supplied to the compressor 1a are changed, the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a is activated, the outdoor fan 6 and the indoor fan 7a are activated. While the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7b are activated. The mode M24 corresponds to a control method of a case in which a relatively high load is generated at the same level in the first refrigeration cycle a1 and the second refrigeration cycle a2.

[0145] Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a and the compressor 1b includes the capacity control mechanism 19b. However, when the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 includes substantially the same components as those of the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 illustrated in Fig. 12, the operation control is executed in the control pattern as illustrated in Fig. 14. In this case, the controller e1 executes the operation control in any one of the mode M1 and the modes M4 to M7 for a corresponding one of regions divided by the dotted lines.

[0146] Fig. 24 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention. Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a and the compressor 1b includes the capacity control mechanism 19b. However, when the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 includes substantially the same components as those of the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 illustrated in Fig. 12, and the inverter is abnormal, the operation control is executed in the control pattern as illustrated in Fig. 24. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M6, the mode M16, and the mode M22 for a corresponding one of regions divided by the dotted lines.

[0147] Fig. 25 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention. The air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 may have components in common with the air-conditioning apparatus 400 for a railway vehicle according to Embodiment 4 illustrated in Fig. 12, and the power supply circuit d1 may have the configuration using the contactors 10c to 10f as described in Embodiment 1 in place of the configuration using the contactors 10j to 10m as described in Embodiment 2. In this case, as illustrated in Fig. 25, the controller e1 executes the operation control in any one of the mode M1, the modes M4 to M6, and the mode M16 for a corresponding one of regions divided by the dotted lines.

[0148] Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a and the compressor 1b includes the capacity control mechanism 19b. However, when the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 is configured so that, similarly to the air-conditioning apparatus 500 for a railway vehicle according to Embodiment 5, the first refrigeration cycle a1 has a larger or smaller refrigeration capacity than that of the second refrigeration cycle a2, the operation control is executed in the control pattern as illustrated in Fig. 17. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M6, and the modes M9 to M12 for a corresponding one of regions divided by the dotted lines.

[0149] Fig. 26 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention. Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a and the compressor 1b includes the capacity control mechanism 19b. However, when the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 is configured so that, similarly to the air-conditioning apparatus 500 for a railway vehicle according to Embodiment 5, the first refrigeration cycle a1 has a larger or smaller refrigeration capacity than that of the second refrigeration cycle a2, and the inverter is abnormal, the operation control is executed in the control pattern as illustrated in Fig. 26. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M6, the mode M16, and modes M25 to M28 for a corresponding one of regions divided by the dotted lines.

[0150] As illustrated in Fig. 26, the mode M25 is a mode in which both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1. In the mode M25, when the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a and the compressor 1b, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. Further, when the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a and the compressor 1b, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0151] The mode M26 is a mode in which both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1. In the mode M26, when the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a and the compressor 1b, the capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. Further, when the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a and the compressor 1b, the capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degrees of the expansion device 5a and the expansion device 5b are controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0152] The mode M27 is a mode in which both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1. In the mode M27, when the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the compressor 1b is stopped. The capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5a is controlled so that the air conditioning output is adjusted. Further, when the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the compressor 1a is stopped. The capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5b is controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0153] The mode M28 is a mode in which both of the compressor 1a of the first refrigeration cycle a1 and the compressor 1b of the second refrigeration cycle a2 are activated by directly supplying power from the auxiliary power supply device S1. In the mode M28, when the first refrigeration cycle a1 has a higher refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1b, the compressor 1a is stopped. The capacity control valve 21b of the compressor 1b is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5b is controlled so that the air conditioning output is adjusted. Further, when the first refrigeration cycle a1 has a lower refrigeration capacity, while power having a constant voltage and a constant frequency is supplied to the compressor 1a, the compressor 1b is stopped. The capacity control valve 21a of the compressor 1a is controlled to be repeatedly opened and closed, and the opening degree of the expansion device 5a is controlled so that the air conditioning output is adjusted. While the compressor 1a or the compressor 1b is activated, the outdoor fan 6 and the indoor fan 7 are activated.

[0154] Fig. 27 is a diagram for illustrating an example of the control pattern of the controller e1 in Embodiment 6 of the present invention. Embodiment 6 differs from Embodiments 1 to 5 in that the compressor 1a includes the capacity control mechanism 19a and the compressor 1b includes the capacity control mechanism 19b. However, the air-conditioning apparatus 600 for a railway vehicle according to Embodiment 6 may be configured so that, similarly to the air-conditioning apparatus 500 for a railway vehicle according to Embodiment 5, the first refrigeration cycle a1 has a larger or smaller refrigeration capacity than that of the second refrigeration cycle a2, and the power supply circuit d1 may have the configuration using the contactors 10c to 10f as described in Embodiment 1 in place of the configuration using the contactors 10j to 10m as described in Embodiment 2. In this case, the operation control is executed in the control pattern as illustrated in Fig. 26. In this case, the controller e1 executes the operation control in any one of the mode M1, the mode M4, the mode M6, the mode M11, the mode M12, the mode M15, and the mode M16 for a corresponding one of regions divided by the dotted lines.

[0155] According to Embodiment 6, with use of the capacity control mechanism 19a and the capacity control mechanism 19a, the refrigeration capacity can be adjusted without repeatedly activating and stopping the compressor frequently. Consequently, it is possible to prevent reduction in air-conditioning efficiency due to the repeated activation and stop of the compressor, and the operation is enabled with further reduced power consumption. The variation in air conditioning output can be reduced, and hence comfortable air conditioning is enabled in the boarding space S4 and the boarding space S5. Further, the frequency to repeatedly activate and stop the compressor is reduced, and hence it is possible to reduce failure due to cyclic fatigue of the compressor and each switch.

[0156] In Embodiment 6, as illustrated in Fig. 20, the capacity control mechanism 19a is configured by connecting the refrigerant inlet of the compression chamber 18a to the refrigerant flow passage, in which compression is being performed, inside the compression chamber 18a with use of the capacity control pipe 20a, but the connection destination of the capacity control pipe 20a may be a pipe of the suction portion of the compressor 1a in place of the refrigerant inlet of the compression chamber 18a.

Reference Signs List

[0157]

1a, 1b	compressor
2a, 2b	refrigerant flow switching device
3a, 3b	first heat exchanger
4a, 4b	second heat exchanger
5a, 5b	expansion device
6, 6a, 6b	outdoor fan
7, 7a, 7b	indoor fan
9	inverter
10	switching unit
10a, 10b, 10c, 10d, 10e, 10f, 10g, 10h, 10i 10j, 10k, 101, 10m, 10p, 10q	contactor
11, 11a, 11b, 12a, 12b	outdoor temperature and humidity sensor
13, 13a, 13b, 14a, 14b	indoor temperature and humidity sensor
15a, 15b	refrigerant sensor

16a	motor
17a	rotary shaf
18a	compression chamber
19a, 19b	capacity control mechanism
20a, 20b	capacity control pipe
21a, 21b	capacity control valve
100, 200, 300, 400, 500, 600	air-conditioning apparatus for railway vehicle
a1	first refrigeration cycle
a2	second refrigeration cycle
b1	outdoor unit
b2	first outdoor unit
b3	second outdoor unit
c1	first indoor unit
c2	second indoor unit
c3	indoor unit
d1	power supply circuit
e1	controller
f1, f2	unit
S1	auxiliary power supply device
S2, S3	air outlet duct
S4, S5	boarding space
S6	vehicle outside temperature and humidity sensor
S7, S8	vehicle inside temperature and humidity sensor
S9	vehicle occupancy sensor
S10	duct
S11	boarding space
S12	vehicle inside temperature and humidity sensor
S100, S200, S300	railway vehicle
X1	integrated information system

Claims

1. An air-conditioning apparatus for a railway vehicle, comprising:

- a plurality of refrigerant circuits each including a compressor, a first heat exchanger, an expansion device, and a second heat exchanger that are connected to each other by pipes;
- an inverter connected to an auxiliary power supply device of a railway vehicle and configured to control a frequency of the compressor;
- a switching unit configured to switch between wiring connection for supplying power to the compressor via the inverter and wiring connection for directly supplying power from the auxiliary power supply device to the compressor; and
- a controller configured to control a switching operation of the switching unit in such a manner that, when an air conditioning load of a boarding space of the railway vehicle is higher than a load threshold value, wiring for directly supplying power from the auxiliary power supply device to at least one of the compressors of the plurality of refrigerant circuits is established.

2. The air-conditioning apparatus for a railway vehicle of claim 1,
wherein the controller is configured to control the switching operation of the switching unit, when the inverter is abnormal, to either directly supply power from the auxiliary power supply device individually to a plurality of the compressors or cut off the power.

3. The air-conditioning apparatus for a railway vehicle of claim 1 or 2,
wherein the controller is configured to control the switching operation of the switching unit in such a manner that

wiring for directly supplying power from the auxiliary power supply device to at least one of the compressors and for supplying power from the auxiliary power supply device via the inverter to a remainder of the compressors is established.

4. The air-conditioning apparatus for a railway vehicle of any one of claims 1 to 3, further comprising:

- a plurality of indoor units each including the second heat exchanger and configured to blow out air subjected to heat exchange by the second heat exchanger and passing through a corresponding one of air outlet ducts to a corresponding one of different positions in the boarding space; and
- a plurality of temperature sensors each provided at a corresponding one of different positions in the boarding space and each configured to measure a temperature of the corresponding one of the different positions in the boarding space,

wherein the controller is configured to

- calculate a load distribution in the boarding space on a basis of the temperatures measured by the plurality of temperature sensors, and
- control the switching operation of the switching unit, on a basis of the load distribution, to either directly supply power from the auxiliary power supply device individually to a plurality of the compressors or supply power from the auxiliary power supply device via the inverter to the plurality of the compressors.

5. The air-conditioning apparatus for a railway vehicle of any one of claims 1 to 4,
wherein at least one of the compressors has a displacement that is different from a displacement of an other of the compressors, and
wherein the controller is configured to control the switching operation of the switching unit in such a manner that, when the air conditioning load is higher than the load threshold value, wiring for directly supplying power from the auxiliary power supply device to the compressor having a high displacement is established, and, when the air conditioning load is equal to or lower than the load threshold value, wiring for directly supplying power from the auxiliary power supply device to the compressor having a small displacement is established.

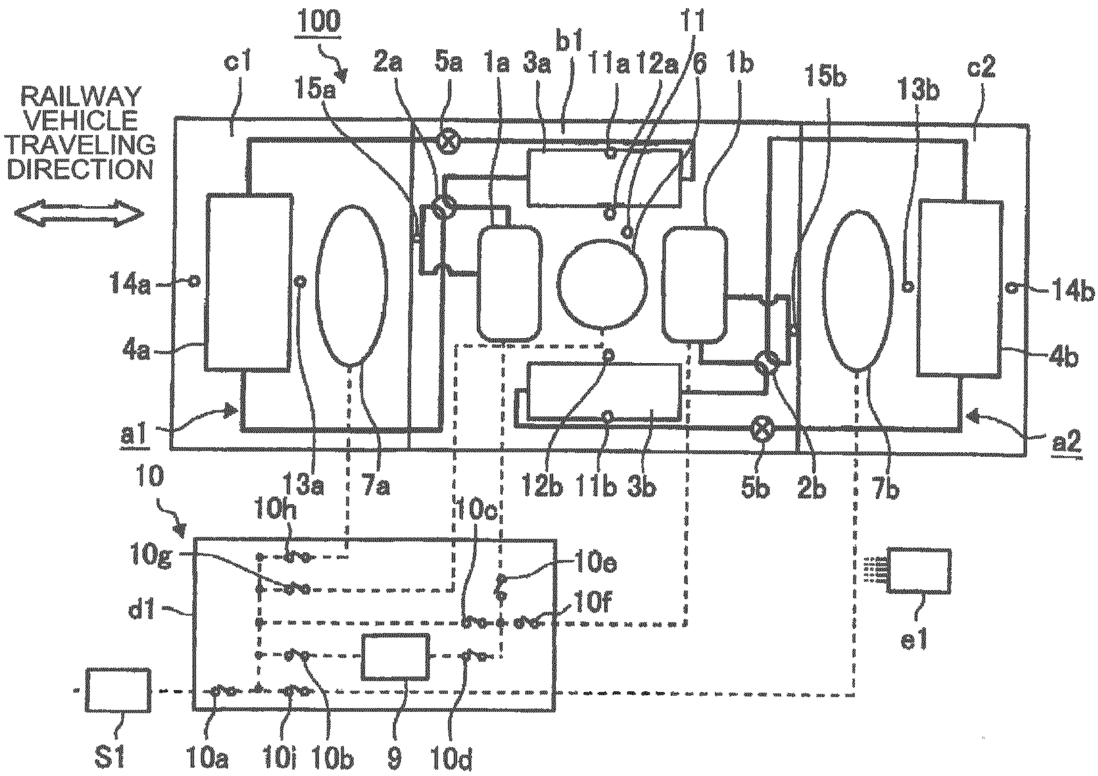
6. The air-conditioning apparatus for a railway vehicle of any one of claims 1 to 5, further comprising a motor configured to drive the compressor, the motor including a three-phase AC induction motor.

7. The air-conditioning apparatus for a railway vehicle of claim 6, wherein the motor has a voltage-frequency characteristic in which the compressor is driven at a voltage that is equal to or lower than a voltage of power to be output from the auxiliary power supply device at a frequency of the power to be output from the auxiliary power supply device.

8. The air-conditioning apparatus for a railway vehicle of any one of claims 1 to 7, further comprising a capacity control mechanism configured to control a capacity of the compressor,
wherein the controller is configured to control a switching operation of the capacity control mechanism on a basis of the air conditioning load.

9. The air-conditioning apparatus for a railway vehicle of any one of claims 1 to 8,
wherein the controller is configured to control the switching operation of the switching unit in such a manner that, when the air conditioning load is higher than a maximum load threshold value, wiring for directly supplying power from the auxiliary power supply device to all of the compressors is established.

FIG. 1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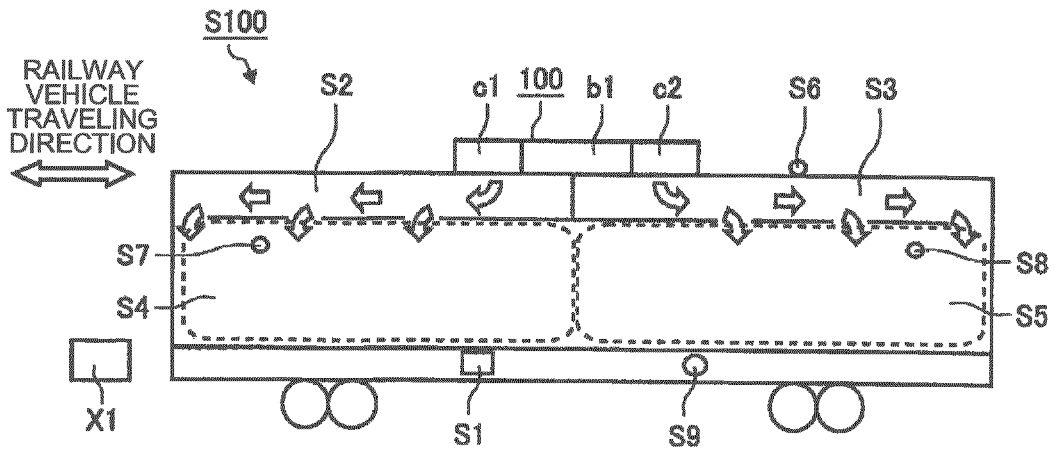
2a
5a
1a
3a
b1
11a
12a
11
6
1b
15b
13b
c2
14a
4a
a1
14b
4b
a2
10
13a
7a
12b
11b
3b
5b
2b
7b
10h
10c
10g
10e
d1
10f
e1
S1
10a
10i
10b
9
10d

FIG. 2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RAILWAY VEHICLE TRAVELING DIRECTION
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100
b1
c2
S6
S3
S7
S8
S4
S5
X1
S1
S9

FIG. 3

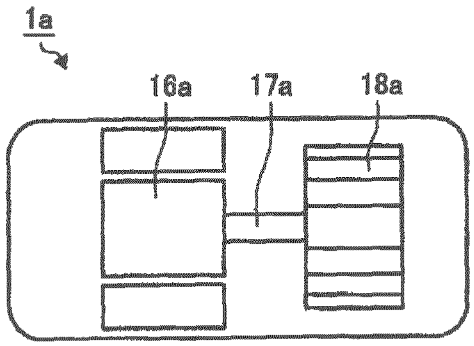


FIG. 4

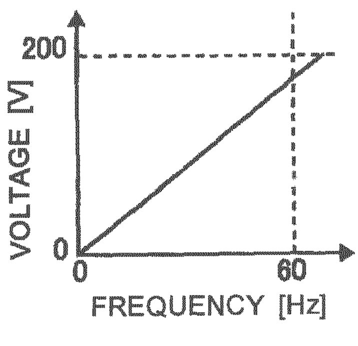


FIG. 5

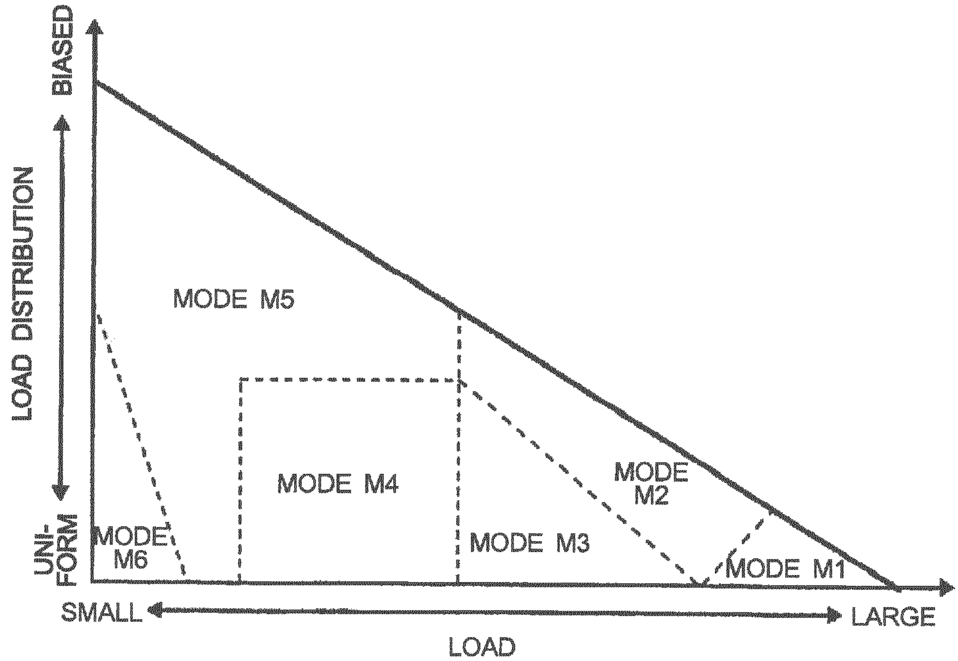

BIASED
LOAD DISTRIBUTION
UNI-FORM
MODE M5
MODE M4
MODE M3
MODE M2
MODE M1
MODE M6
SMALL
LARGE
LOAD

FIG. 6

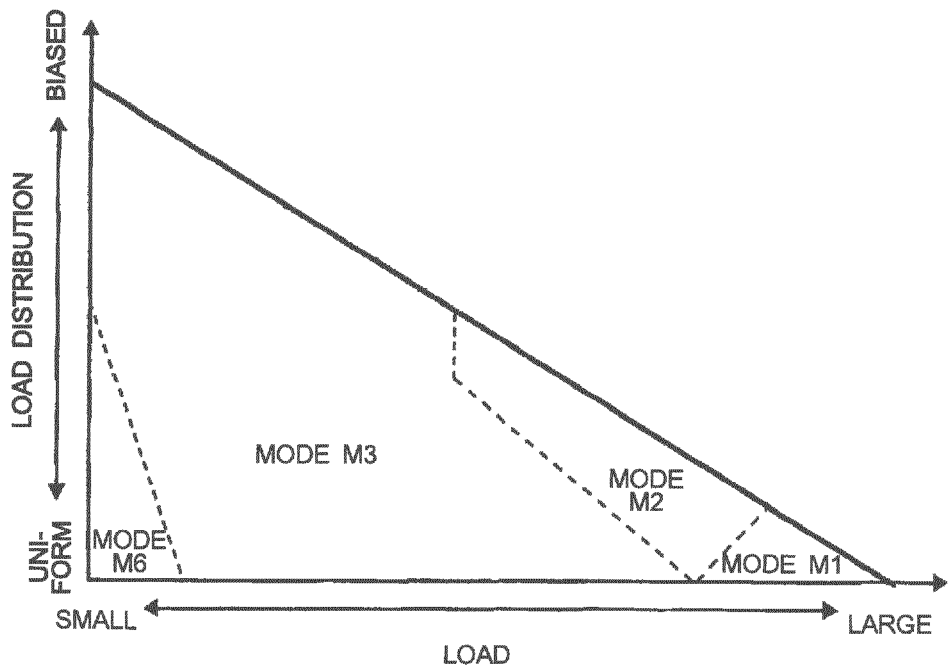

BIASED
LOAD DISTRIBUTION
UNI-FORM
MODE M3
MODE M2
MODE M1
MODE M6
SMALL
LARGE
LOAD

FIG. 7

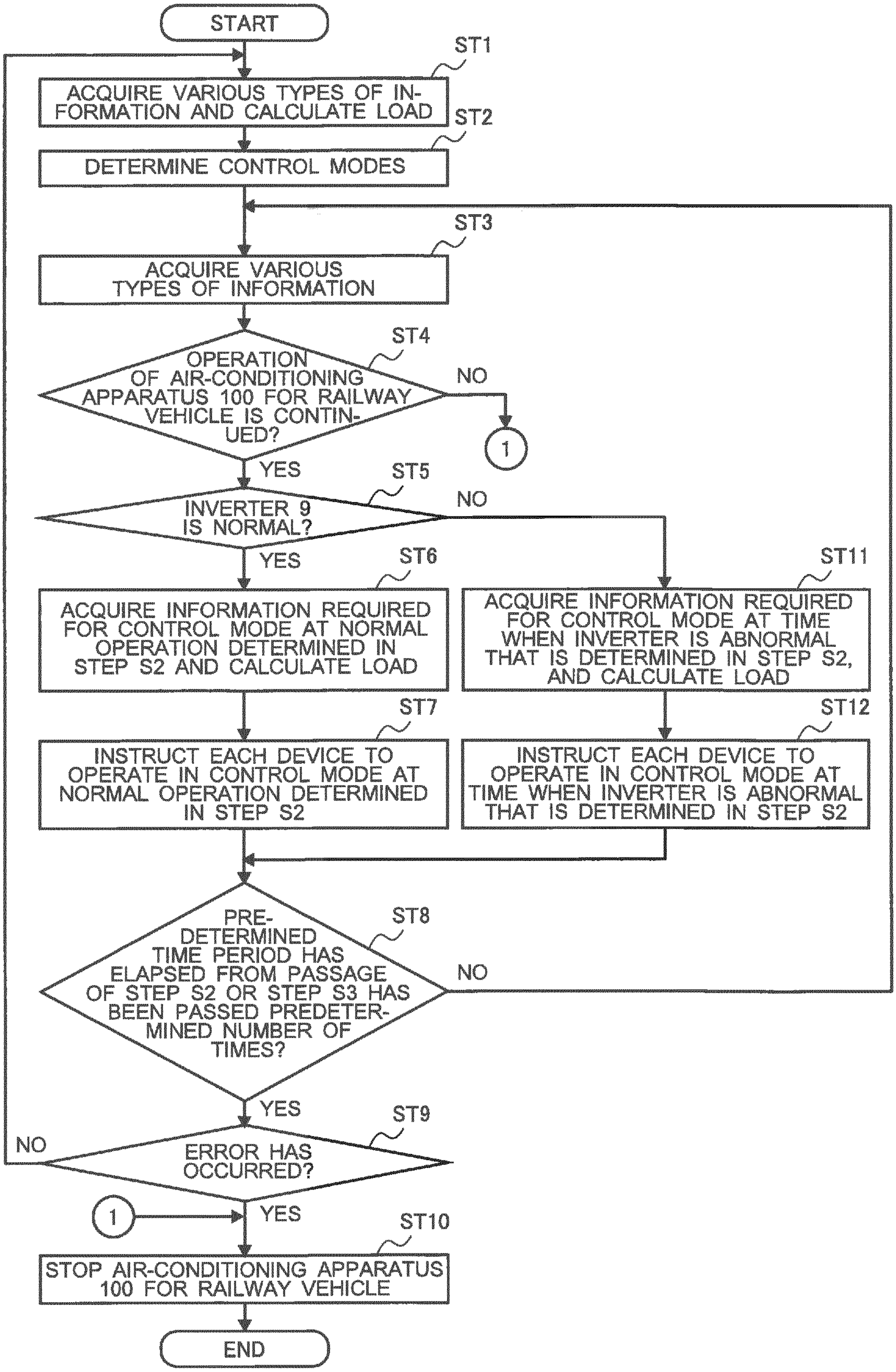

START
ST1
ACQUIRE VARIOUS TYPES OF INFORMATION AND CALCULATE LOAD
ST2
DETERMINE CONTROL MODES
ST3
ACQUIRE VARIOUS TYPES OF INFORMATION
ST4
OPERATION OF AIR-CONDITIONING APPARATUS 100 FOR RAILWAY VEHICLE IS CONTINUED?
NO
1
YES
ST5
INVERTER 9 IS NORMAL?
NO
YES
ST6
ACQUIRE INFORMATION REQUIRED FOR CONTROL MODE AT NORMAL OPERATION DETERMINED IN STEP S2 AND CALCULATE LOAD
ST11
ACQUIRE INFORMATION REQUIRED FOR CONTROL MODE AT TIME WHEN INVERTER IS ABNORMAL THAT IS DETERMINED IN STEP S2, AND CALCULATE LOAD
ST7
INSTRUCT EACH DEVICE TO OPERATE IN CONTROL MODE AT NORMAL OPERATION DETERMINED IN STEP S2
ST12
INSTRUCT EACH DEVICE TO OPERATE IN CONTROL MODE AT TIME WHEN INVERTER IS ABNORMAL THAT IS DETERMINED IN STEP S2
ST8
PREDETERMINED TIME PERIOD HAS ELAPSED FROM PASSAGE OF STEP S2 OR STEP S3 HAS BEEN PASSED PREDETERMINED NUMBER OF TIMES?
NO
YES
ST9
NO
ERROR HAS OCCURRED?
1
YES
ST10
STOP AIR-CONDITIONING APPARATUS 100 FOR RAILWAY VEHICLE
END

FIG. 8

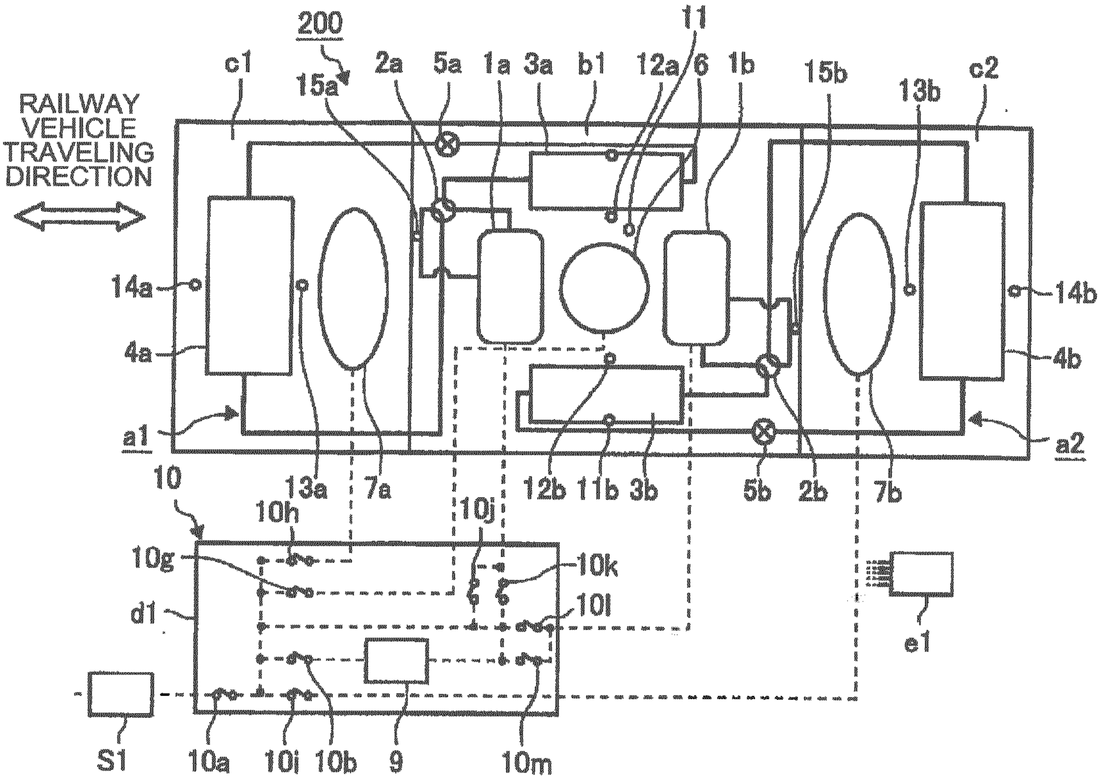
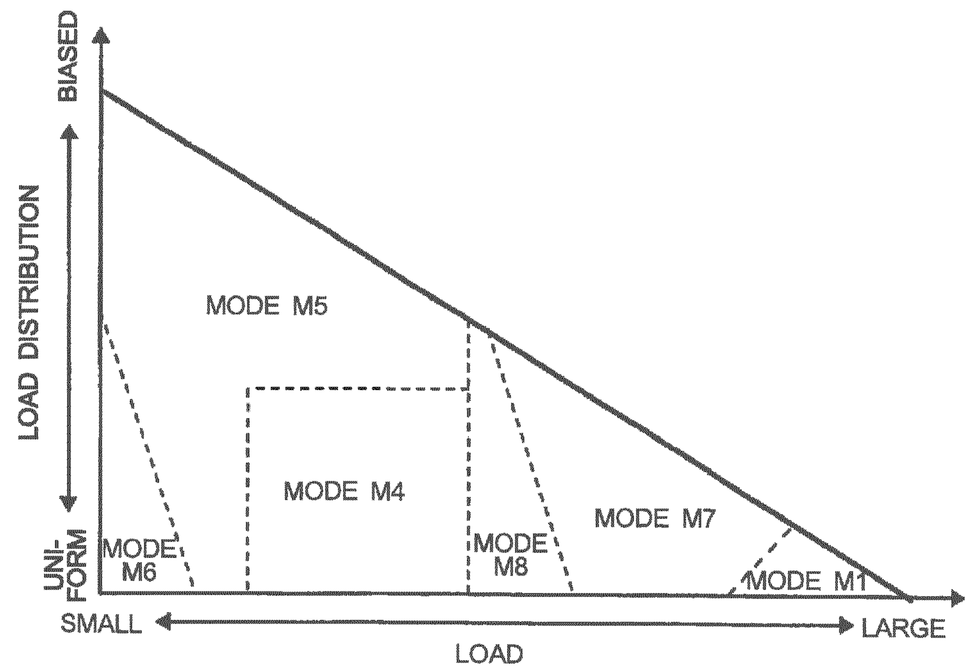

200
c1
15a
2a
5a
1a
3a
b1
11
12a
6
1b
15b
13b
c2
RAILWAY VEHICLE TRAVELING DIRECTION
14a
4a
a1
14b
4b
a2
10
13a
7a
10j
12b
11b
3b
5b
2b
7b
10h
10g
10k
d1
10l
e1
S1
10a
10i
10b
9
10m

FIG. 9


BIASED
LOAD DISTRIBUTION
UNI-FORM
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MODE M4
MODE M6
MODE M8
MODE M7
MODE M1
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LARGE
LOAD

FIG. 10

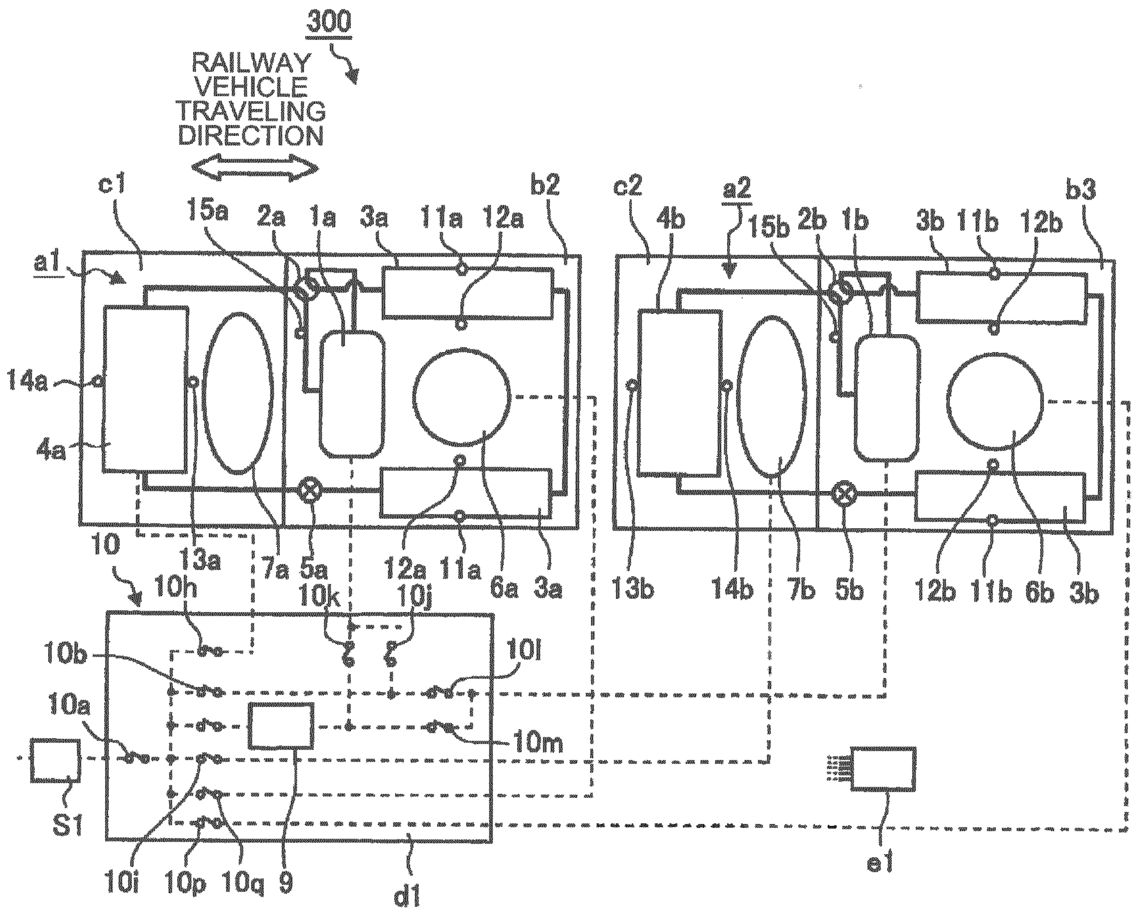

300
RAILWAY VEHICLE TRAVELING DIRECTION
c1
b2
c2
a2
b3
15a
2a
1a
3a
11a
12a
4b
15b
2b
1b
3b
11b
12b
a1
14a
4a
10
13a
7a
5a
12a
11a
6a
3a
13b
14b
7b
5b
12b
11b
6b
3b
10h
10k
10j
10b
10l
10a
10m
S1
10i
10p
10q
9
d1
e1

FIG. 11

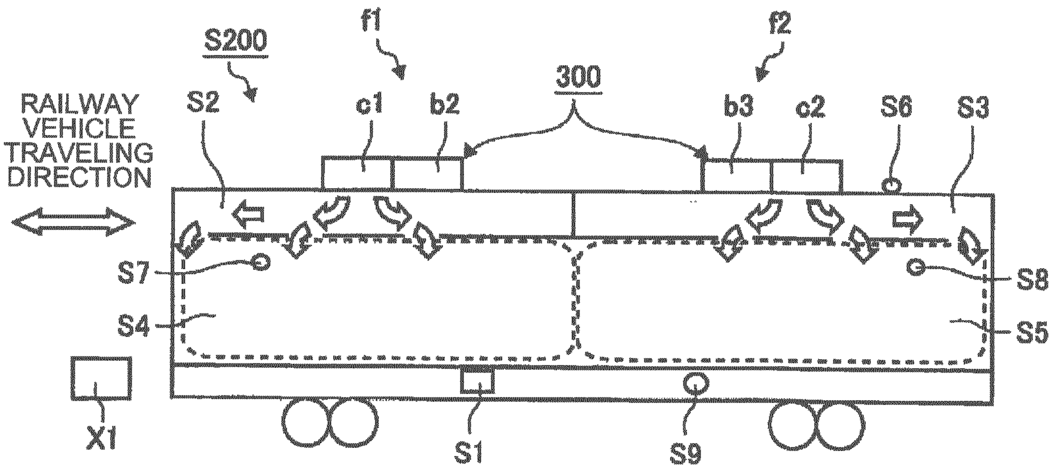

f1
f2
S200
300
RAILWAY VEHICLE TRAVELING DIRECTION
S2
c1
b2
b3
c2
S6
S3
S7
S8
S4
S5
X1
S1
S9

FIG. 12

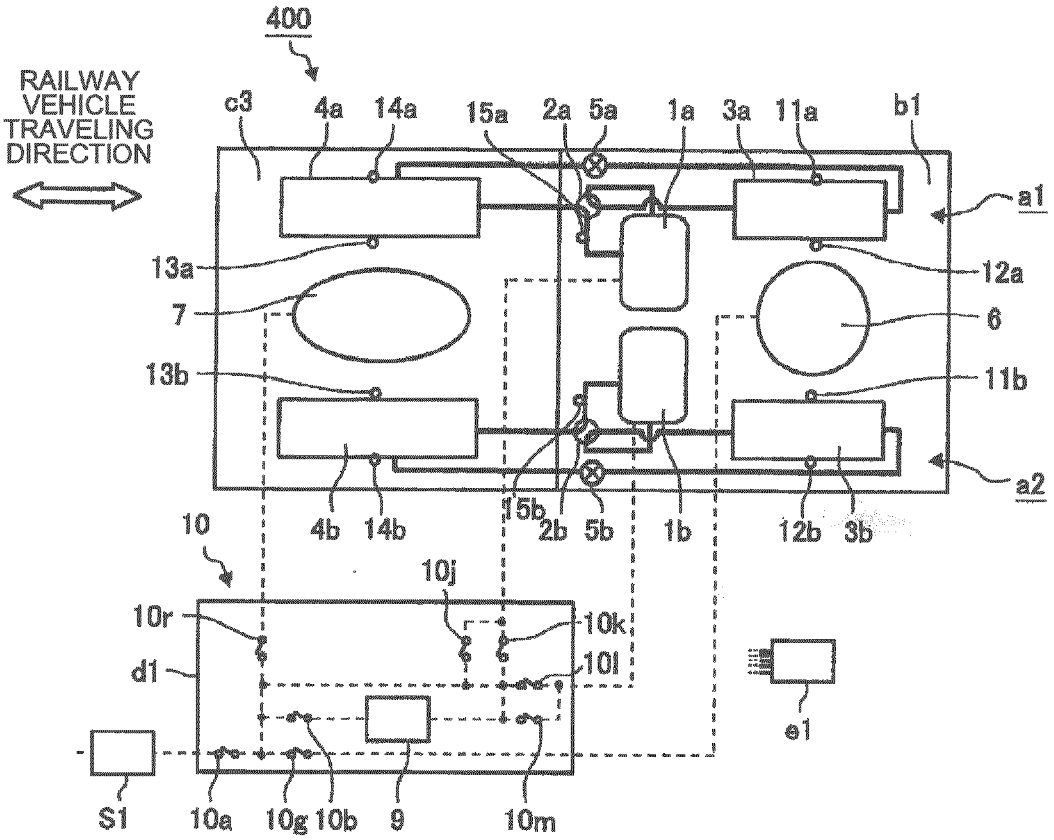

400
RAILWAY VEHICLE TRAVELING DIRECTION
c3
4a
14a
15a
2a
5a
1a
3a
11a
b1
a1
13a
12a
7
6
13b
11b
a2
15b
4b
14b
2b
5b
1b
12b
3b
10
10j
10r
10k
d1
10l
e1
S1
10a
10g
10b
9
10m

FIG. 13

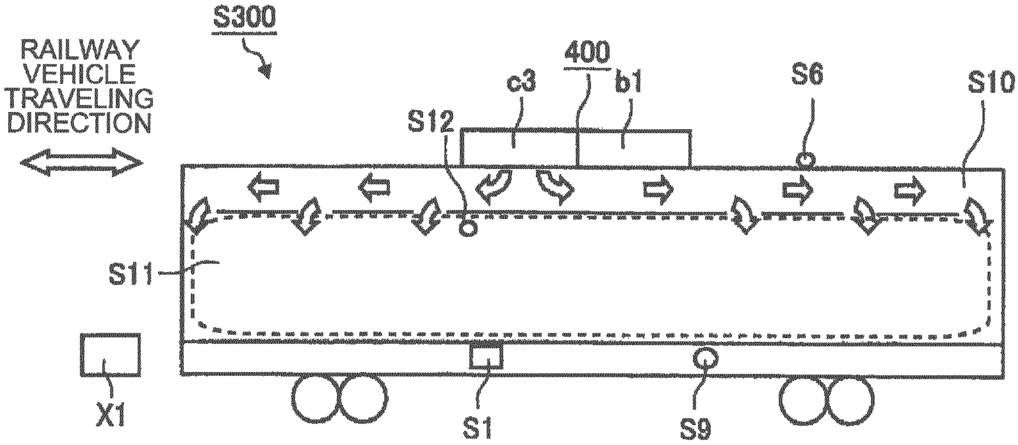

S300
RAILWAY VEHICLE TRAVELING DIRECTION
400
c3
b1
S6
S10
S12
S11
X1
S1
S9

FIG. 14

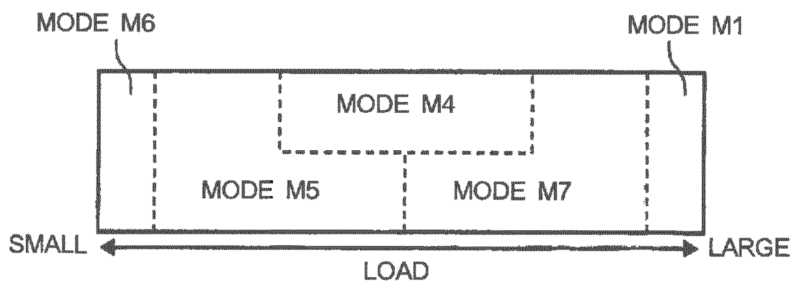


FIG. 15

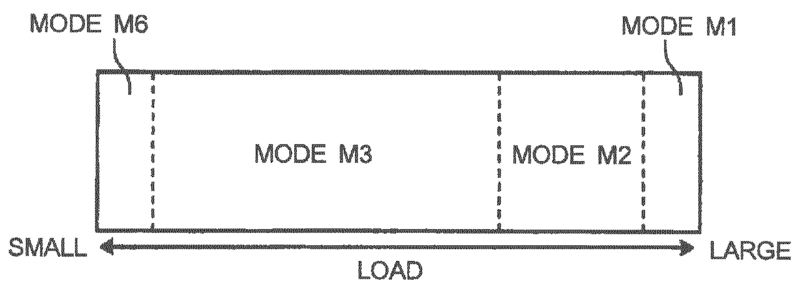


FIG. 16

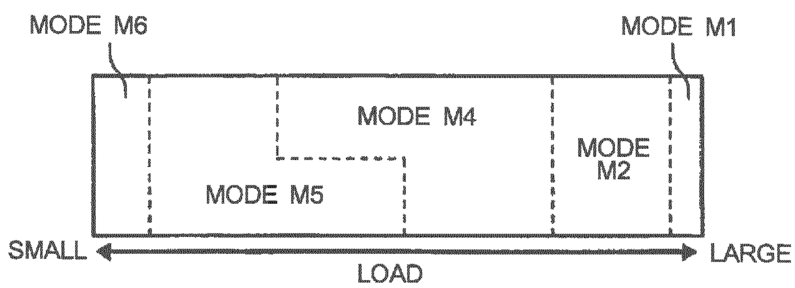


FIG. 17

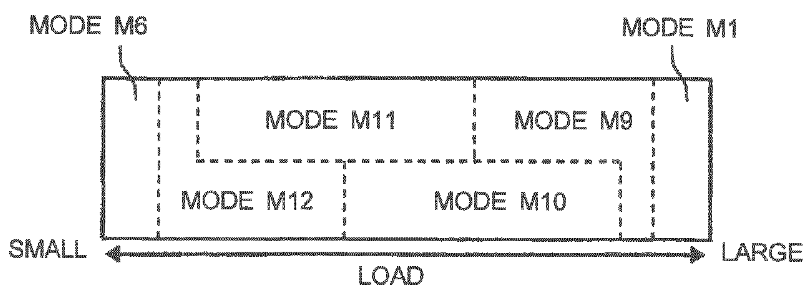


FIG. 18

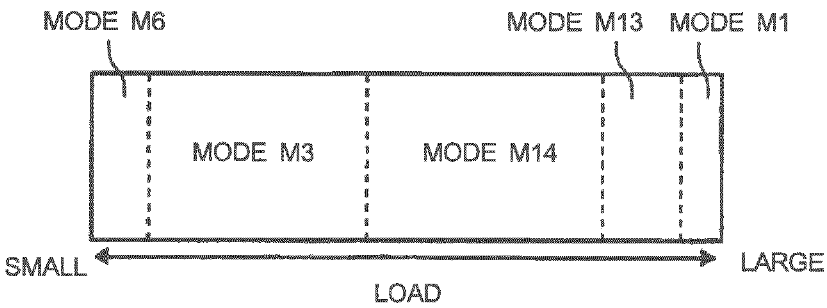


FIG. 19

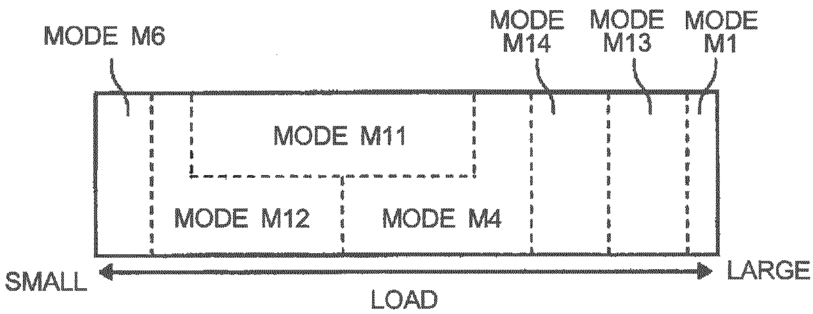


FIG. 20

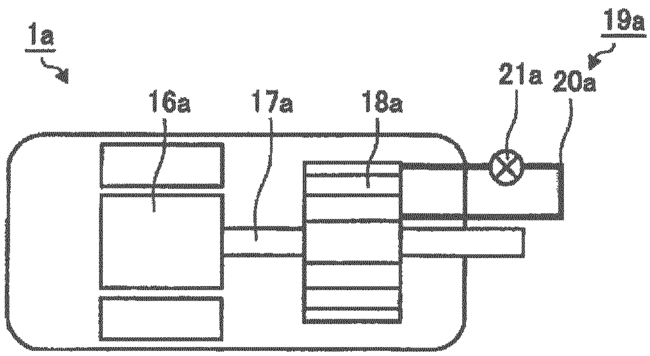
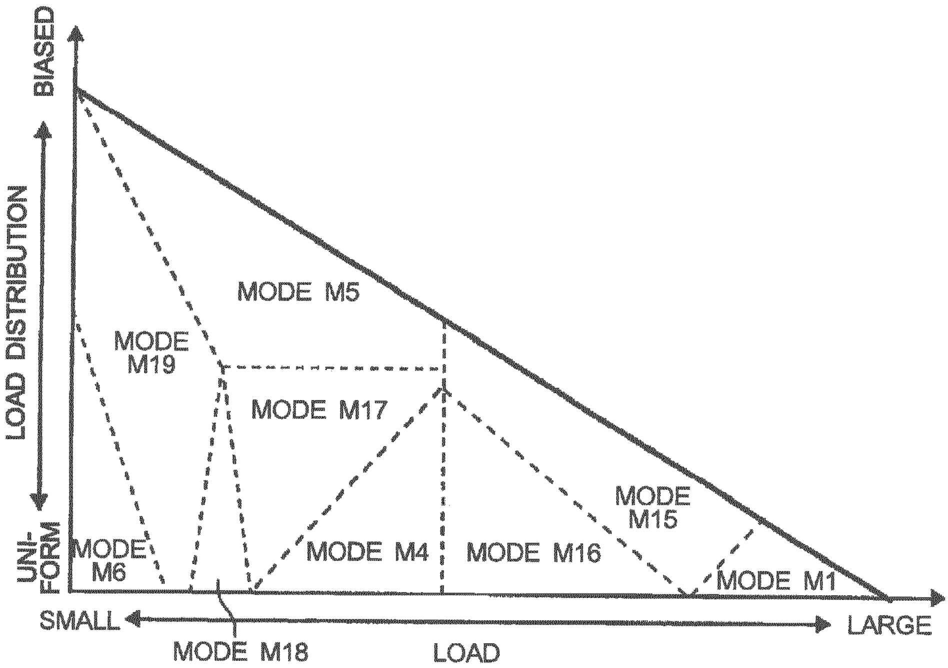


FIG. 21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M15
MODE
M6
MODE M4
MODE M16
MODE M1
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LARGE
MODE M18
LOAD

FIG. 22

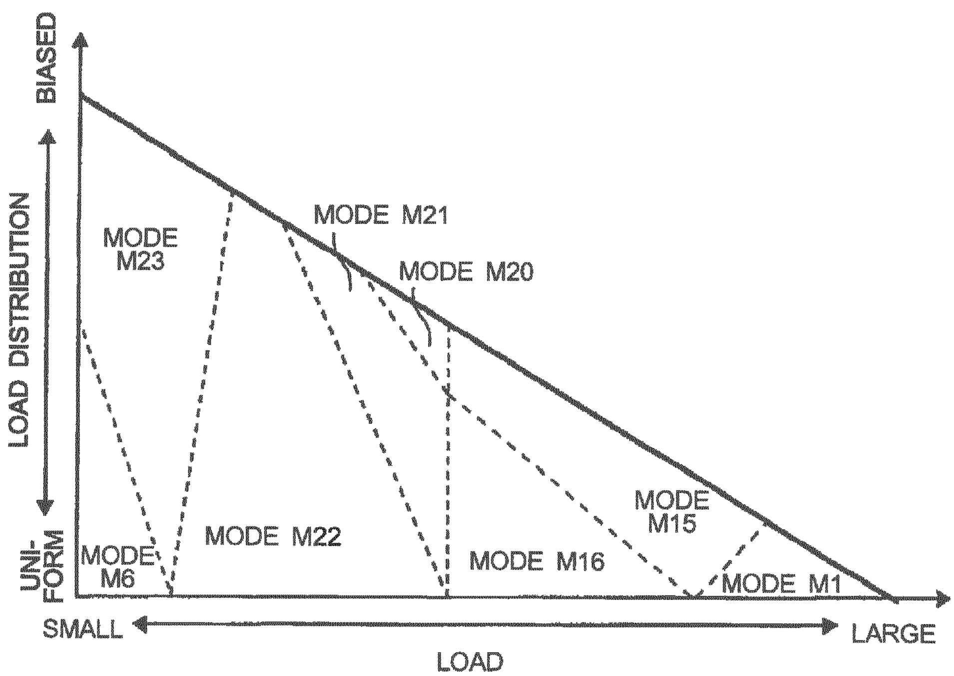

BIASED
LOAD DISTRIBUTION
UNI-
FORM
MODE M21
MODE
M23
MODE M20
MODE
M15
MODE
M6
MODE M22
MODE M16
MODE M1
SMALL
LARGE
LOAD

FIG. 23

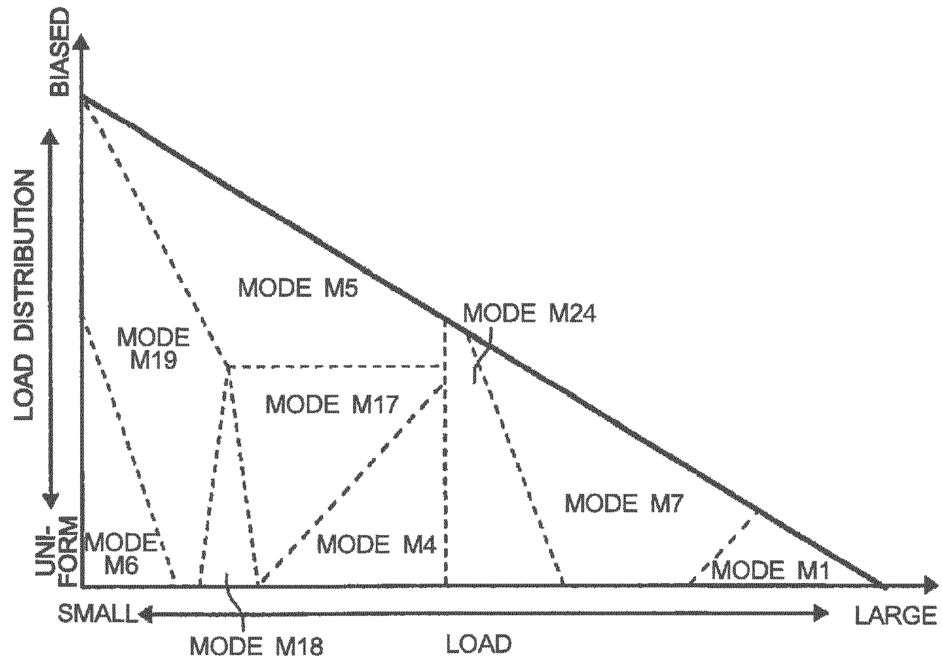


FIG. 24

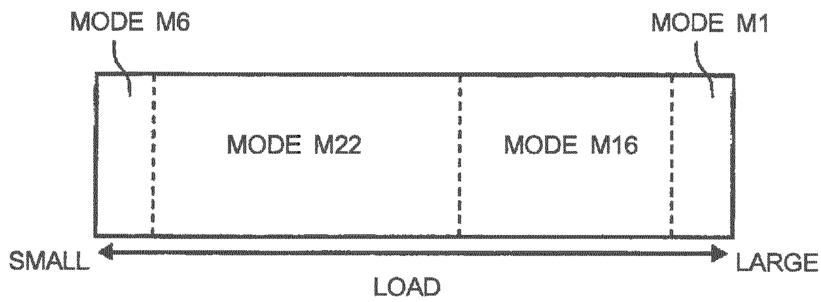


FIG. 25

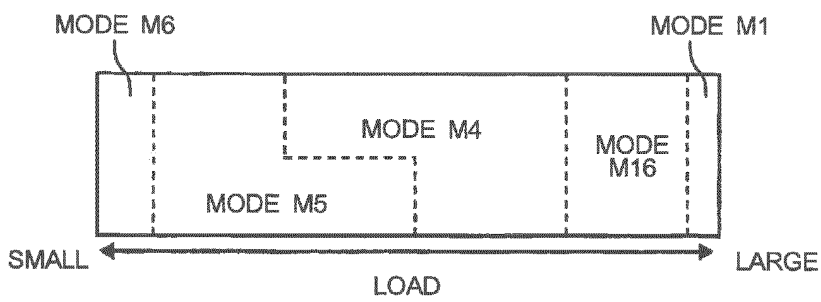
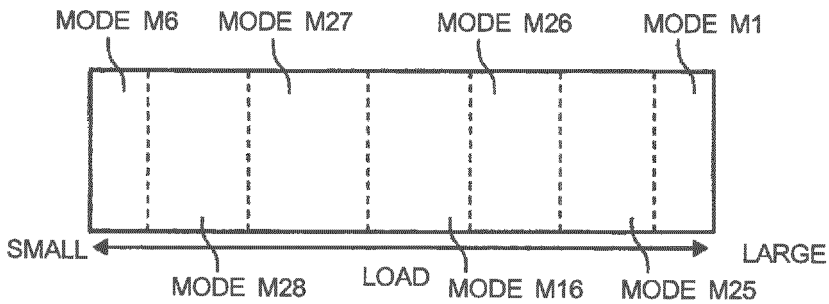


FIG. 26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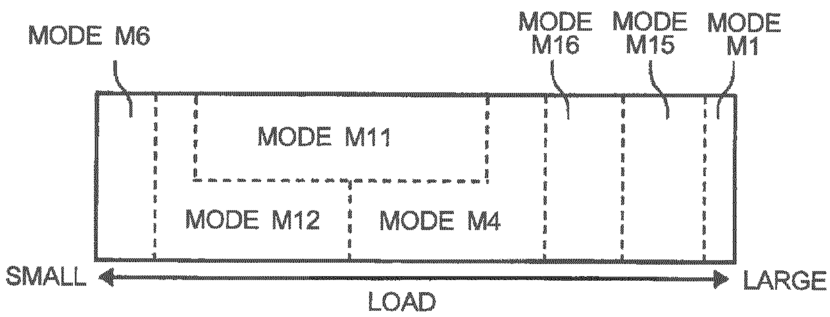
MODE M16
MODE M25

FIG. 27


MODE M6
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MODE M11
MODE M12
MODE M4
SMALL
LARGE
LOAD

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2017/004989

A. CLASSIFICATION OF SUBJECT MATTER
B61D27/00(2006.01)i, *F24F11/02*(2006.01)i, *F25B1/00*(2006.01)i

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)
B61D27/00, F24F11/02, F25B1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2017
Kokai Jitsuyo Shinan Koho	1971-2017	Toroku Jitsuyo Shinan Koho	1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2014-218210 A (Mitsubishi Electric Corp.), 20 November 2014 (20.11.2014), paragraphs [0031] to [0042]; fig. 1 to 3 (Family: none)	1-3,5-9 4
Y A	JP 64-57055 A (Toshiba Corp.), 03 March 1989 (03.03.1989), pages 2 to 3; fig. 1 to 5 (Family: none)	1-3,5-9 4
Y A	JP 2014-172596 A (Mitsubishi Electric Corp.), 22 September 2014 (22.09.2014), paragraphs [0016] to [0061], [0120] to [0125]; fig. 1 to 4, 12 (Family: none)	2-3,5-9 4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 March 2017 (02.03.17)	14 March 2017 (14.03.17)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/004989

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2005-226980 A (Ebara Refrigeration Equipment & Systems Co., Ltd.), 25 August 2005 (25.08.2005), paragraph [0021]; fig. 3 (Family: none)	9 1-8
A	JP 2009-210213 A (Hitachi, Ltd.), 17 September 2009 (17.09.2009), (Family: none)	1-9

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 7017397 A **[0003]**