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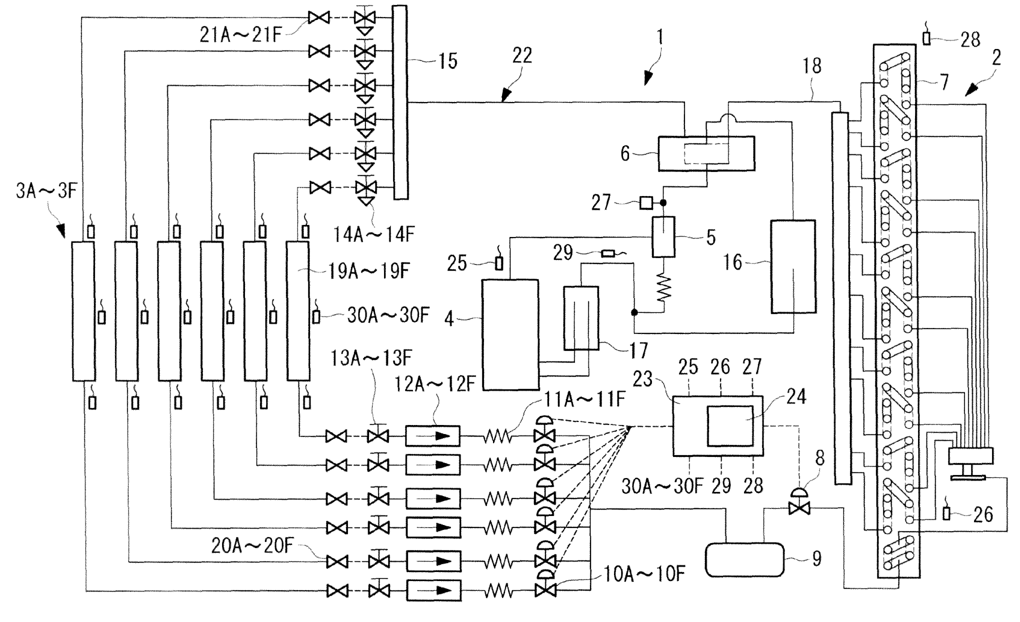
(54) **Multi-type air conditioner and control method therefor**

(57) Provided are a multi-type air conditioner and a control method therefor, in which it is possible to swiftly reach an ideal zone-control region at a switchover from open-loop control to zone control and to the multi-type air conditioner with high COP while ensuring stable operation of a compressor. In a multi-type air conditioner (1) that includes a first electronic expansion valve (8) and a plurality of second electronic expansion valves (10A to 10F) corresponding to respective rooms, the first electronic expansion valve (8) is open-loop controlled for a predetermined period of time at a degree of opening calculated based on particular parameters, at a starting time of a heating operation and at a time of a change in the number of operated indoor units; is switched to zone control in which a discharge degree of superheat is controlled so as to fall within a target zone; and is provided with an expansion-valve control section (24) that corrects, when a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, a degree of opening of the first electronic expansion valve for the next open-loop control in response thereto.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a multi-type air conditioner in which a plurality of indoor units are connected in parallel to an outdoor unit and to a control method for the multi-type air conditioner.

Background Art

[0002] In a conventional multi-type air conditioner, an expansion valve is controlled so as to be open-loop controlled for a predetermined period of time at a starting time and so as to be zone controlled thereafter. Specifically, at the starting time, for a predetermined period of time during which the state of the refrigerant becomes stable, the air conditioner is operated with the degree of opening of the electronic expansion valve being set in proportion to the rotational speed of the compressor by using the outside air temperature, the discharge degree of superheat, and the suction degree of superheat as parameters. After that, the degree of opening of the electronic expansion valve is zone controlled to perform feedback control such that the degree of superheat falls in a target zone. Thus, an appropriate operating point is maintained, and the air conditioner is operated with high COP (coefficient of performance) (for example, see PTL 1).

[0003] PTL 2 proposes a technique in which, at the starting time of a heating operation, an initial degree of opening of an electronic expansion valve, which is uniformly set based on the indoor temperature and the outdoor temperature, is corrected based on the starting state of the air conditioner at the starting time to reduce the rising time for the next starting time, thereby improving quick heating. Furthermore, PTL 3 proposes that, in an air conditioner in which the degree of opening of an electronic expansion valve is zone controlled such that the discharge degree of superheat of the refrigerant becomes a target degree of superheat, the target degree of superheat be corrected so as to be reduced in a stepwise fashion as the discharge refrigerant temperature is increased, thereby preventing the compressor from being superheated and allowing the life of the compressor to be extended.

Citation List

Patent Literature

[0004]

{PTL 1} Japanese Unexamined Patent Application, Publication No. 2005-291553
{PTL 2} Publication of Japanese Patent No. 3546544
{PTL 3} Publication of Japanese Patent No. 3495486

Summary of Invention

Technical Problem

[0005] However, in the above-described conventional techniques, depending on the number of indoor units connected to the outdoor unit or the capacity of heat exchangers thereof, the difference in the required refrigerant amount between cooling and heating operations is increased. Therefore, only by throttling the expansion valve corresponding to each room, it is difficult to perform appropriate distribution of the refrigerant and to control the operation of the entire system at an appropriate operating point. During the heating operation, surplus refrigerant is accumulated in the indoor heat exchangers to increase the degree of supercooling. As a result, to satisfy the required performance, it is necessary to increase the rotational frequency of the compressor, thus causing an inefficient operation.

[0006] Furthermore, in open-loop control during the heating operation, the air conditioner is operated with the degree of opening of the electronic expansion valve being set at a certain degree of opening calculated based on particular parameters. Therefore, operations in which the degree of opening is over-throttled and over-relaxed may be repeated depending on the operating conditions, thus causing a delay in switching over to an optimum operating point and making the operation of the compressor less stable, in some cases, and undermining high-COP operation.

[0007] The present invention has been made in view of such circumstances, and an object thereof is to provide a multi-type air conditioner and a control method therefor, in which it is possible to swiftly reach an ideal zone-control region at the switchover from open-loop control to zone and to the air conditioner with high COP while ensuring the stable operation of the compressor.

{Sotution to Problem}

[0008] In order to solve the above-described problems, the multi-type air conditioner and the control method therefor of the present invention employ the following solutions.
Specifically, a first aspect of the present invention provides a multi-type air conditioner in which a plurality of indoor units are connected in parallel to a single outdoor unit, and a closed-cycle refrigerant circuit is formed of a compressor, a four-way switching valve, an outdoor heat exchanger, a first electronic expansion valve, a receiver, a plurality of second electronic expansion valves connected in parallel to a plurality of indoor heat exchangers, and the plurality of the indoor heat exchangers connected in parallel to each other, in which the first electronic expansion valve is open-loop controlled for a predetermined period of time at a degree of opening calculated based on particular parameters at a starting time of a heating operation and at a time of a change in the number of operated indoor units ; in which the first electronic expansion valve is then switched over to zone control in which a discharge degree of superheat is controlled so as to fall within a target zone; and in which the first electronic expansion valve is provided with an expansion-valve control section that corrects, when a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, a degree of opening of the first electronic expansion valve for the next open-loop control in response thereto.

[0009] In the multi-type air conditioner according to the first aspect of the present invention, which includes the first electronic expansion valve that is zone controlled such that the discharge degree of superheat of the refrigerant falls within a target zone, in addition to the plurality of second electronic expansion valves that individually control the volumes of the refrigerant for the plurality of the indoor heat exchangers, the first electronic expansion valve is open-loop controlled for the predetermined period of time at the degree of opening calculated based on particular parameters at the starting time of a heating operation and at the time of a change in the number of operated indoor units; the first electronic expansion valve is then switched over to zone control in which the discharge degree of superheat is controlled so as to fall within the target zone; and the first electronic expansion valve is provided with the expansion-valve control section, which, then a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, corrects the degree of opening of the heating electronic expansion valve for the next open-loop control in response thereto. In open-loop control during the heating operation, the air conditioner is operated with the degree of opening of the first electronic expansion valve being set at a certain degree of opening calculated based on particular parameters; therefore, operations in which the degree of opening is over-throttled and over-relaxed may be repeated depending on the operating conditions, thus causing a delay in switching over to an optimum operating point, in some cases, However, when the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat are large at the switchover to zone control after a predetermined period of time has elapsed, the degree of opening for the next open-foop control is corrected in response thereto. Thus, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve in open-loop control to an appropriate degree of opening. Therefore, it is possible to swiftly reach the optimum operating point, that is, the ideal zone-control region, at the switchover from open-loop control to zone control and to operate the air conditioner with high COP while ensuring the stable operation of the compressor.

[0010] Furthermore, in the multi-type air conditioner according to the first aspect of the present invention, in the expansion-valve control section, the degree of opening of the first electronic expansion valve in the open-loop control is calculated by using at least an outside air temperature and a capacity of the plurality of the indoor heat exchangers, as the parameters.

[0011] In the multi-type air conditioner, the difference in the required refrigerant amount between cooling and heating operations is increased. However, according to the first aspect of the present invention, in the expansion-valve control section, the degree of opening of the first electronic expansion valve in open-loop control is calculated by using at least the outside air temperature and the capacity of the plurality of the indoor heat exchangers as the parameters. Therefore, during the heating operation, the operating point of the entire system is adjusted by the first electronic expansion valve, and the surplus refrigerant produced during the heating operation is held in the receiver, thereby making it possible to ensure appropriate degrees of supercooling at the respective indoor heat exchangers, and the degree of opening of the first electronic expansion valve is controlled by using at least the outside air temperature and the capacity of the plurality of the indoor heat exchangers as the parameters, thereby making it possible to set the degree of opening of the first electronic expansion valve in open-toop control to a more appropriate degree of opening. Therefore, even when the capacity of the indoor heat exchangers is changed depending on the connected indoor units, it is possible to swiftly attain the optimum operating point at the switchover to zone control to reduce the time to reach the ideal zone-control region, and it is possible to operate the air conditioner with high COP while ensuring the stable operation of the compressor.

[0012] Furthermore, in the multi-type air conditioner according to the first aspect of the present invention, in the expansion-valve control section, a correction coefficient for the degree of opening of the first electronic expansion valve is determined according to an outside air temperature and a capacity of the plurality of the indoor heat exchangers of the indoor units connected to the outdoor unit.

[0013] According to the first aspect of the present invention, in the expansion-vatve control section, the correction coefficient for the degree of opening of the first electronic expansion valve is determined based on the outside air temperature and the capacity of the plurality of the indoor heat exchangers of the indoor units connected to the outdoor unit. Therefore, when the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat are large at the switchover to zone control, the correction coefficient that is changed based on the outside air temperature and the capacity of the plurality of the indoor heat exchangers is accordingly updated, thereby making it possible to reflect the updated correction coefficient in calculating the degree of opening of the first electronic expansion valve for the next open-loop control. Therefore, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve to an appropriate operating point with this correction coefficient to swiftly reach the ideal zone-control region at the switchover to zone control, and to operate the air conditioner with high COP while ensuring the stable operation of the compressor.

[0014] Furthermore, in the multi-type air conditioner according to the first aspect of the present invention, in the expansion-valve control section, a correction coefficient for the degree of opening of the first electronic expansion valve is increased or decreased when a percentage at which the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat, calculated at sampling intervals, are equal to or higher than a predetermined value or are equal to or lower than a predetermined value that exceeds a predetermined percentage, at the switchover to zone control.

[0015] According to the first aspect of the present invention, in the expansion-valve control section, the correction coefficient for the degree of opening of the first electronic expansion valve is increased or decreased when the percentage at which the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat, calculated at sampling intervals, are equal to or higher than a predetermined value or are equal to or lower than a predetermined value that exceeds a predetermined percentage, at the switchover to zone control. Thus, by increasing or decreasing this correction coefficient, it is possible to prevent a situation in which, at the switchover to zone control, the degree of opening of the first electronic expansion valve is over-throttled, thus making the discharge degree of superheat overshoot the target zone and causing hunting, or is over-relaxed, thus causing a delay in reaching the target zone. Therefore, it is possible to set the degree of opening of the first electronic expansion valve in open-loop control to an appropriate degree of opening to swiftly reach the ideal zone-control region at the switchover to zone control, and to ensure the stable operation of the compressor.

[0016] Furthermore, a second aspect of the present invention provides a control method for a multi-type air conditioner in which a plurality of indoor units are connected in parallel to a single outdoor unit, and a closed-cycle refrigerant circuit is formed of a compressor, a four-way switching valve, an outdoor heat exchanger, a first electronic expansion valve, a receiver, a plurality of second electronic expansion valves connected in parallel to a plurality of indoor heat exchangers, and the plurality of the indoor heat exchangers connected in parallel to each other, the control method including: performing open-loop control for the first electronic expansion valve for a predetermined period of time at a degree of opening calculated based on particular parameters, at a starting time of a heating operation and at a time of a change in the number of operated indoor units; switching over to zone control in which a discharge degree of superheat is controlled so as to fall within a target zone; and correcting, when a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, the degree of opening of the first electronic expansion valve for the next open-loop control in response thereto.

[0017] In the multi-type air conditioner according to the second aspect of the present invention, which includes the first electronic expansion valve that is zone controlled such that the discharge degree of superheat of the refrigerant falls within a target zone, in addition to the plurality of second electronic expansion valves individual control the volumes of the refrigerant for the plurality of the indoor heat exchangers, the first electronic expansion valve is open-loop controlled for the predetermined period of time at the degree of opening calculated based on particular parameters at the starting time of a heating operation and at the time of a change in the number of operated indoor units; and the first electronic expansion valve is then switched over to zone control in which the discharge degree of superheat is controlled so as to fall within the target zone; and, when the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat are large at the switchover to zone control, the degree of opening of the first electronic expansion valve for the next open-loop control is corrected in response thereto. In open-loop control during the heating operation, the air conditioner is operated with the degree of opening of the first electronic expansion valve being set at a certain degree of opening calculated based on particular parameters; therefore, operations in which the degree of opening is over-throttled and over-relaxed may be repeated depending on the operating conditions, thus causing a delay in switching over to an optimum operating point, in some cases. However, when the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat are large at the switchover to zone control after a predetermined period of time has elapsed, the degree of opening for the next open-loop control is corrected in response thereto. Thus, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve in open-loop control to an appropriate degree of opening. Therefore, it is possible to swiftly reach the optimum operating point, that is, the ideal zone-control region, at the switchover from open-loop control to zone control and to operate the air conditioner with high COP while ensuring the stable operation of the compressor.

Advantageous Effects of Invention

[0018] According to the multi-type air conditioner and the control method therefor of the present invention, in open-loop control during the heating operation, the air conditioner is operated with the degree of opening of the first electronic expansion valve being set at a certain degree of opening calculated based on particular parameters; therefore, operations in which the degree of opening is over-throttled and over-relaxed may be repeater depending on the operating conditions, thus causing a delay in switching over to an optimum point, in some cases. However, when the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat are large at the switchover to zone control after a predetermined period of time has elapsed, the degree of opening for the next open-loop control is corrected in response thereto. Thus, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve in open-loop control to an appropriate degree of opening. Therefore, it is possible to swiftly reach the optimum operating point, that is, the ideal zone-control region, at the switchover from open-loop control to zone control and to operate the air conditioner with high COP while ensuring the stable operation of the compressor.

Brief Description of Drawings

[0019]

Fig. 1 is a configuration diagram (refrigerant circuit diagram) of a multi-type air conditioner according to one embodiment of the present invention.
Fig. 2 is a diagram for explaining the operation of a heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Fig. 3 is a diagram for explaining the operation of the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1, at a switchover from open-loop control to zone control.
Fig. 4 is a table showing an example correction coefficient a used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Fig. 5 is a table showing an example correction coefficient b used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fug. 1.
Fig. 6 is a table showing an example correction coefficient c used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Fig. 7 is a table showing an example correction coefficient d used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Fig. 8 is a table showing an example correction coefficient Z_4 used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fug. 1.
Fig. 9 is a table showing a calculation example of condenser performance (heat exchanger capacity) of a plurality of indoor heat exchangers connected to the multi-type air conditioner shown in Fig. 1.
Fig. 10 is an outside-air-temperature setting diagram used to obtain a correction coefficient used in open-loop control for the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Fig. 11 is a showing an example case where a control pulse is given in zone control to the heating electronic expansion valve of the multi-type air conditioner shown in Fig. 1.
Description of Embodiments

[0020] One embodiment of the present invention will be described below with reference to Fig. 1 to Fig. 11. Fig. 1 is a configuration diagram (refrigerant circuit diagram) of a multi-type air conditioner according to the embodiment of the present invention. Fig. 2 is a diagram for explaining the operation of a heating electronic expansion valve of the multi-type air conditioner. Fig. 3 is a diagram for explaining the operation of the heating electronic expansion valve at a switchover from open-loop control to zone control.
A multi-type air conditioner 1 has a configuration in which a plurality of (six in this example, but the number of indoor units is not limited thereto) indoor units 3A to 3F are connected in parallel to a single outdoor unit 2.
[0021] In the outdoor unit 2, a compressor 4; an oil separator 5; a four-way switching valve 6; an outdoor heat exchanger 7; a first electronic expansion valve (EEVH) 8; a receiver 9; individual-room second electronic expansion valves (EEVs)

10A to 10F connected in parallel to each other, corresponding to the indoor units 3A to 3F; sound-damping capillary tubes 11A to 11F; strainers 12A to 12F; liquid-side actuating valves 13A to 13F; gas-side actuating valves 14A to 14F; a header 15; a first accumulator 16; and a second accumulator 17 are provided and are sequentially connected with refrigerant pipes, thus forming an outdoor-side refrigerant circuit 18, as is well known.

[0022] With respect to the above-described outdoor unit 2, indoor heat exchangers 19A to 19F of the plurality of the indoor units 3A to 3F are connected to the liquid-side actuating valves 13A to 13F and the gas-side actuating valves 14A to 14F via piping joints 20A to 20F and piping joints 21A to 21F, respectively, thereby forming a single-system closed-cycle refrigerant circuit 22 serving as the mufti-type air conditioner 1. Blower fans (not shown) are provided for the outdoor heat exchanger 7 and the indoor heat exchangers 19A to 19F to make outside air and air in the rooms circulate to the respective heat exchangers.

[0023] In the multi-type air conditioner 1, during a cooling operation, a refrigerant compressed in the compressor 4 is circulated via the oil separator 5, the four-way switching valve 6, the outdoor heat exchanger 7, the first electronic expansion valve 8, the receiver 9, the second electronic expansion valves 10A to 10F, the sound-damping capillary tubes 11A to 11F, the strainers 12A to 12F, the liquid-side actuating valves 13A to 13F, the indoor heat exchangers 19A to 19F, the gas-side actuating valves 14A to 14F, the header 15, the four-way switching valve 6, the first accumulator 16, and the second accumulator 17. While circulating, the refrigerant is condensed in the outdoor heat exchanger 7, is reduced in pressure in the first electronic expansion valve 8 and the second electronic expansion valves 10A to 10F, and is then evaporated by absorbing heat in the indoor heat exchangers 19A to 19F, thereby cooling indoor air at the indoor heat exchangers 19A to 19F and using the cooled air for indoor cooling.

[0024] On the other hand, during a heating operation, the circulation direction of the refrigerant is switched by the four-way switching valve 6. The refrigerant compressed in the compressor 4 is circulated via the oil separator 5, the four-way switching valve 6, the header 15, the gas-side actuating valves 14A to 14F, the indoor heat exchangers 19A to 19F, the liquid-side actuating valves 13A to 13F, the strainers 12A to 12F, the sound-damping capillary tubes 11A to 11F, the second electronic expansion valves 10A to 10F, the receiver 9, the first electronic expansion valve 8, the outdoor heat exchanger 7, the four-way switching valve 6, the first accumulator 16, and the second accumulator 17. While circulating, the refrigerant is condensed by releasing heat in the outdoor heat exchanger 7, is reduced in pressure in the second electronic expansion valves 10A to 10F and the first electronic expansion valve 8, and is then evaporated in the outdoor heat exchanger 7, thereby heating indoor air at the indoor heat exchangers 19A to 19F and using the heated air for indoor heating.

[0025] In the above-described multi-type air conditioner 1, the first electronic expansion valves 8 and the second electronic expansion valves 10A to 10F are controlled by an expansion-valve control section 24 of an outdoor controller 23, as described below.

The first electronic expansion valve 8 and the second electronic expansion valves 10A to 10F are put under normal control or transient control. The transient control is control performed within a predetermined period of time (for example, three minutes) after the compressor 4 is turned on from the OFF state or within a predetermined period of time (for example, three minutes) after the number of operated units among the plurality of the indoor units 3A to 3F is changed. The normal control is control performed when the transient control is not performed.

[0026] During the cooling operation, in the transient control, the second electronic expansion valves 10A to 10F are set at degrees of opening corresponding to the indoor target rotational speeds for the respective rooms, to control the volumes of circulating refrigerant for the respective indoor heat exchangers 19A to 19F. The first electronic expansion valve 8 is open-loop controlled at the degree of opening calculated by Formula (1), in which the actual rotational speed of the compressor 4 is corrected based on the outside air temperature, the suction degree of superheat, and the discharge degree of superheat. Furthermore, in the normal control, the first electronic expansion valve 8 is zone controlled such that a discharge degree of superheat TDSH obtained from the difference between the detected value from a discharge temperature sensor 25 and the detected value from an outdoor heat-exchanger sensor 26 falls within a target zone.

[0027]

$$\text{The degree of opening OP of the first electronic expansion valve 8} = (a \times N + b) \times Z_2 \times Z_3 \cdots (1)$$

wherein

a, b: correction coefficients determined based on the outside air temperature;

Z_2: a correction coefficient used to maintain an appropriate value of the suction degree of superheat of the entire system and aimed at stabilizing the open-loop control during the transient time;

Z_3: a correction coefficient to maintain an appropriate value of the discharge degree of superheat of the entire system; and

N: the actual rotational speed of the compressor 4.

[0028] Similarly, during the heating operation, in the transient control, the second electronic expansion valves 10A to 10F are set at degrees of opening corresponding to the indoor target rotational speeds for the respective rooms, to control the volumes of circulating refrigerant for the respective indoor heat exchangers 19A to 19F. The first electronic expansion valve 8 is open-loop controlled at the degree of opening calculated by Formula (2), in which the actual rotational speed of the compressor 4 is corrected based on the outside air temperature, the capacity of the plurality of the indoor heat exchangers, the number of stopped units, the presence or absence of a large wall-type unit that includes a high-capacity indoor heat exchanger, the suction degree of superheat, and the discharge degree of superheat. Furthermore, during the heating operation, in the normal control, the first electronic expansion valve 8 is zone controlled such that the discharge degree of superheat TDSH of the refrigerant obtained from the detected value from the discharge temperature sensor 25 and the detected value from a high-pressure pressure sensor 27 falls within a target zone.

[0029]

$$\text{The degree of opening OP of the first electronic expansion valve 8} = (a \times N + b + c + d) \times Z_2 \times Z_3 \times Z_4 \cdots (2)$$

wherein

a, b: correction coefficients determined based on the outside air temperature and the capacity of the indoor heat exchangers;

c: the sum of a pulses corresponding to the number of stopped units;

d: a correction coefficient determined based on the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat at the switchover from open-loop control to zone control;

Z_2: a correction coefficient used to maintain an appropriate value of the suction degree of superheat of the entire system and aimed at stabilizing the open-loop control during the transient time;

Z_3: a correction coefficient used to maintain an appropriate value of the discharge degree of superheat of the entire system;

Z_4: a correction coefficient determined based on the presence or absence of a large wall-type unit that includes a high-capacity indoor heat exchanger; and

N: the actual rotational speed of the compressor 4.

[0030] Fig. 2 is the diagram for explaining the operation, in which the first electronic expansion valve (EEVH) 8 is open-loop controlled in transient control, which is performed when the compressor, 4 is turned on from the OFF state or when the number of operated units among the indoor units 3A to 3F is changed, and is zone in the normal control, which is performed when the transient control is not performed. The degree of opening of the first electronic expansion valve 8 in zone control is obtained by the degree of opening set in the zone control to the degree of opening set in the open-loop control.

[0031] Here, during the heating operation, in the open-loop control, the degree of opening of the first electronic expansion valve (EEVH) 8 is controlled by using the capacity of the plurality of the indoor heat exchangers as a parameter. In conventional multi-type air conditioners, control for reaching an appropriate operating point and control for distributing the refrigerant to the rooms have been carried out by throttling the second electronic expansion valves 10A to 10F corresponding to the rooms. However, when the number of indoor units 3A to 3F is increased, since the difference in the required refrigerant amount between cooling and heating operations is increased, surplus refrigerant produced during the heating operation cannot be handled, and the refrigerant is accumulated in the condensers (indoor heat exchangers), thus increasing the degree of supercooling. As a result, to satisfy the required performance, it is necessary to increase the rotational frequency of the compressor 4, thus causing an inefficient operation.

[0032] Therefore, the first electronic expansion valve (EEVH) 8, which is used to adjust the operating point of the entire system, is provided, and the receiver 9 is disposed immediately before the first electronic expansion valve 8, thereby making it possible to hold the surplus refrigerant and ensure an appropriate degree of supercooling, Furthermore, in order to reach the appropriate operating point as soon as possible, the throttle level of the first electronic expansion valve (EEVH) 8 is controlled by using, as parameters, not only the outside air temperature, the suction degree of superheat, and the discharge degree of superheat but also the capacity of the plurality of the indoor heat exchangers, the number of stopped units, and the presence or absence of a large wall-type unit that includes a high-capacity indoor heat exchanger, and the distribution of the refrigerant to the indoor units 3A to 3F is controlled according to the demand rotational speeds for the rooms via the second electronic expansion valves (EEVS) 10A to 10F corresponding to the rooms, thereby making it possible to swiftly attain the optimum operating point.

[0033] Specifically, during the heating operation, in the transient control, the degree of opening OP of the first electronic expansion valve 8 is calculated by Formula (2). Parameters used in the calculation include not only the outside air temperature, the suction degree of superheat, and the discharge degree of superheat but also the correction coefficients a and b, determined based on the outside air temperature and the capacity of the indoor heat exchangers, the correction coefficient c, determined based on the number of stopped units, the correction coefficient d, determined based on the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat at the switchover from open-loop control to zone control, and the correction coefficient Z_4, determined based on the presence or absence of a large wall-type unit that includes a high-capacity indoor heat exchanger.

[0034] In the table shown in Fig. 4, the correction coefficient a is determined based on the total capacity of the plurality of the indoor heat exchangers 19A to 19F connected to the multi-type air conditioner 1 and the values A to D of the outside air temperature detected by an outside air temperature sensor 28. In the table shown in Fig. 5, the correction coefficient b is determined based on the total capacity of the plurality of the indoor heat exchangers 19A to 19F connected to the multi-type air conditioner 1 and the values A to D of the outside air temperature detected by the outside air temperature sensor 28. For example, in the multi-type air conditioner 1, if the total capacity of the plurality of the indoor heat exchangers falls within a range from 301 to 400, when the outside air temperature is set to the value C, the correction coefficient a is set to 0.6, and the correction coefficient b is set to 55.

[0035] The total capacity of the plurality of the indoor heat exchangers in the tables shown in Figs. 4 and 5 is obtained by summing the capacities of the heat exchangers of the plurality of the indoor units connected to the multi-type air conditioner 1, from the table shown in Fig. 9 indicating, for the of the capacities of the heat exchangers of the other indoor units, where the capacity of the heat exchanger of a medium wall-type indoor unit is set to 100.
Furthermore, as shown in Fig. 10, the outside air temperature is set to the value A when the outside air temperature detected by the outside air temperature sensor 28 has a difference of +12 °C or greater from the reference value; the outside air temperature is set to the value B when it has a difference that falls in a range from -1 °C to +11 °C from the reference value; the outside air temperature is set to the value C when it has a difference that falls in a range from -1 °C to -9 °C from the reference value; and the outside air temperature is set to the value D when it has a difference smaller than -9 °C from the reference value.

[0036] Furthermore, in the table shown in Fig. 6, the correction coefficient c is the sum of a pulses determined according to the value of the total capacity of the indoor heat exchangers of stopped units among the indoor units 3A to 3F. For example, if the total capacity of the indoor heat exchangers of stopped units is smaller than 90, the correction coefficient c is set to 3. If the total capacity thereof is 111 or greater, the correction coefficient c is set to 10. Furthermore, in particular, if a large wall-type unit that includes a high-capacity indoor heat exchanger (large wall type shown in Fig. 9) is included in the plurality of the indoor units 3A to 3F, the correction coefficient Z_4 is used as a multiplicative factor. As shown in Fig. 8, the correction coefficient Z_4 is set to 1.1 when the total capacity of the indoor heat exchangers is 399 or smaller and is set to 1.5 when the total capacity of the indoor heat exchangers is 400 or greater.

[0037] Furthermore, in the open-loop control, the correction coefficients Z_2 and Z_3, which are used to maintain appropriate values of the suction degree of superheat and the discharge degree of superheat, respectively, are selected as follows. A preset coefficient Z_2 is selected based on the suction degree of superheat calculated from the difference between the detected value from a suction temperature sensor 29 and the average value of the detected values from the indoor heat-exchanger sensors 30A to 30F, during the cooling operation, or the difference between the detected value from the suction temperature sensor 29 and the detected value from the outdoor heat-exchanger sensor 26, during the heating operation. Furthermore, a preset coefficient Z_3 is selected based on the discharge degree of superheat calculated from the difference between the detected value from the discharge temperature sensor 25 and the detected value from the outdoor heat-exchanger sensor 26, during the cooling operation, or the difference between the detected value from the discharge temperature sensor 25 and the maximum value among the detected values from the indoor heat-exchanger sensors 30A to 30F, during the heating operation.

[0038] As described above, the actual rotational speed of the compressor 4 is corrected by using the correction coefficients a, b, c, Z_2, Z_3, Z_4, as parameters, to calculate the degree of opening OP of the first electronic expansion valve 8, thereby making it possible to swiftly attain the optimum operating point. However, at the switchover from open-loop control to zone control after a predetermined period of time (for example, three minutes) has elapsed, if a deviation from the appropriate degree of opening in open-loop control is large, as shown in Fig. 3, when the discharge degree of superheat TDSH of the refrigerant calculated from the detected value from the discharge temperature sensor 25 and the detected value from the high-pressure pressure sensor 27 is controlled so as to fall within the target zone, operations in which the degree of opening of the first electronic expansion valve 8 is over-throttled and over-relaxed may be repeated depending on the operating conditions, thus causing a delay in switching over to the target zone (optimum operating point), in some cases.

[0039] In order to solve this problem, in this embodiment, the correction coefficient d, which is determined in consideration of a temperature deviation E(n) of the discharge degree of superheat TDSH with respect to the target zone and a time variation DE of the discharge degree of superheat TDSH at the switchover from open-loop control to zone control, is added to the above-described parameters. In the table shown in Fig. 7, the correction coefficient d is determined from the total capacity of the plurality of the indoor heat exchangers 19A to 19F connected to the multi-type air conditioner 1 and the values A to D of the outside air temperature detected by the outside air temperature sensor 28, and is set to a value that is sequentially updated according to the past operating conditions. Specifically, if the total capacity of the plurality of the indoor heat exchangers 19A to 19F connected to the multi-type air conditioner 1 falls within a range from 301 to 400, the correction coefficient d is increased or decreased according to the past operating conditions and is sequentially updated.

[0040] The correction coefficient d is used to prevent a situation in which, during the operation, at the switchover from open-loop control to zone control, a deviation from the appropriate operating point in the open-loop control becomes large, and the degree of opening of the first electronic expansion valve 8 is over-throttled, thus overshooting the target zone and causing hunting, as indicated by curve X in Fig. 3, or the degree of opening is over-relaxed, thus casing a delay in reaching the target zone, as indicated by curve Y. In the case of the curve X, the high pressure is increased, and the oil level of the compressor 4 is reduced. In the case of the curve Y, the oil temperature cannot be ensured. Therefore, it is difficult to stably operate the compressor, 4.

[0041] Furthermore, the correction coefficient d is sequentially rewritten in the table shown in Fig. 7, as follows. When the above-described situations occur in certain operating conditions, the temperature deviation E(n) of the discharge degree of superheat TDSH with respect to the target zone and the time variation DE of the discharge degree of superheat TDSH are calculated at sampling intervals (for example, every 40 seconds). In the table in Fig. 11 showing the relationship between the temperature deviation E(n) and the time variation DE, for example, when the percentage of the calculated values of the time variation DE and the temperature deviation E(n) satisfying $1 < DE$ and $2 < E(n)$, respectively, exceeds a predetermined percentage, it is judged that the degree of opening of the first electronic expansion valve 8 is over-throttled, and the correction coefficient d is increased by +1. When the percentage of the calculated values of the time variation DE and the temperature deviation E(n) satisfying $Dye < -1$ and $E(n) < -2$, respectively, exceeds a predetermined percentage, it is judged that the degree of opening of the first electronic expansion valve 8 is over-relaxed, and the correction coefficient d is decreased by -1.

[0042] Therefore, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve 8 in open-loop control to an appropriate degree of opening, to resolve a delay in reaching the target zone, which is caused when the degree of opening of the first electronic expansion valve 8 is over-throttled or over-relaxed, and to swiftly reach the optimum operating point, that is, the ideal zone-control region, as indicated by curve Z shown in Fig. 3.

[0043] Therefore, according to this embodiment, the following advantageous effects are afforded.

In the multi-type air conditioner 1, the first electronic expansion valve (EEVH) 8, which is used to adjust the operating point of the entire system, is provided separately from the individual-room second electronic expansion valves (EEVS) 10A to 10F, which are used to adjust the volumes of refrigerant to be supplied to the indoor heat exchangers 19A to 19F of the indoor units 3A to 3F, and the receiver 9 is disposed between the first electronic expansion valve (EETH) 8 and the second electronic expansion valves (EEVs) 10A to 10F. Therefore, during the heating operation, the surplus refrigerant can be held in the receiver 9. As a result, accumulation of the refrigerant in the indoor heat exchangers 19A to 19F can be eliminated to ensure an appropriate degree of supercooling.

[0044] Therefore, while suppressing the rotational speed of the compressor 4, efficient operation satisfying the required performance can be realized. Furthermore, during this operation, the degree of opening of the first electronic expansion valve (EEVH) 8 is corrected by using, as parameters, the outside air temperature, the indoor-heat-exchanger capacity, the number of stopped units (indoor units), the suction degree of superheat, and the discharge degree of superheat, so as to swiftly reach the optimum operating point, that is, the ideal zone-control region. Therefore, it is possible to operate the multi-type air conditioner 1 with high COP while ensuring the stable operation of the compressor 4.

[0045] Specifically, during the heating operation, in open-loop control the degree of opening of the first electronic expansion valve (EEVH) 8 is controlled by using, as parameters, at least the outside air temperature and the capacity of the plurality of the indoor heat exchangers, thereby making it possible to set the degree of opening of the first electronic expansion valve 8 in open-loop control to a more appropriate degree of opening. Thus, even when the total capacity of the indoor heat exchangers 19A to 19F is changed depending on the plurality of connected indoor units 3A to 3F, at the switchover to zone control, it is possible to swiftly attain the optimum operating point to reduce the time to reach the ideal zone-control region, and it is possible to operate the multi-type air conditioner 1 with high COP while ensuring the stable operation of the compressor 4.

[0046] Furthermore, since the air conditioner 1 is operated with the degree of opening of the first electronic expansion valve (EEVH) 8 in the open-loop control during the heating operation being set at a certain degree of opening calculated based on the above-described various parameters, operations in which the degree of opening is over-throttled and over-relaxed may be repeated depending on the operating conditions, thus causing a delay in switching over to the optimum operating point, in some cases. However, according to this embodiment, at the switchover to zone control, the temperature deviation E(n) of the discharge degree of superheat TDSH with respect to the target zone and the time variation DE of the discharge degree of superheat TDSH are calculated, and, when the temperature deviation E(n) with respect to the target zone and the time variation DE of the discharge degree of superheat TDSH are large, the of opening of the first electronic expansion valve 8 for the next open-loop control is corrected in response thereto.

[0047] Thus, if a similar operating point appears in the operation thereafter, it is to correct the degree of opening of the first electronic expansion valve (EEVH) 8 in the open-loop control to an appropriate degree of opening. Therefore, at the switchover from open-loop control to zone control, it is possible to make the degree of opening of the first electronic expansion valve (EEVH) 8 swiftly reach the optimum operating point, that is, the ideal zone-control region, and to realize high-COP operation of the multi-type air conditioner 1 while ensuring the stable operation of the compressor 4.

[0048] Furthermore, in this embodiment, the correction coefficient d, which is used to correct the degree of opening of the first electronic expansion valve (EEVH) 8, is determined based on the outside air temperature and the total capacity of the plurality of the indoor heat exchangers 19A to 19F. Thus, when the temperature deviation E(n) of the discharge degree of superheat TDSH with respect to the target zone and the time variation DE of the discharge degree of superheat TDSH are large at the switchover to zone control, the correction coefficient d, which is changed according to the outside air temperature and the capacity of the plurality of connected indoor heat exchangers 19A to 19F, can be accordingly updated sequentially in the table and reflected in calculating the degree of opening of the first electronic expansion valve 8 for the next open-loop control. Therefore, if a similar operating point appears in the operation thereafter, it is possible to correct the degree of opening of the first electronic expansion valve 8 to an appropriate operating point by using the correction coefficient d and to swiftly reach the ideal zone-control region at the switchover to zone control.

[0049] Furthermore, the correction coefficient d is increased or decreased when the percentage at which the temperature deviation E(n) of the discharge degree of superheat TDSH with respect to the target zone and the time variation DE of the discharge degree of superheat TDSH, calculated at sampling intervals, are equal to or higher than a predetermined value or are equal to or lower than a predetermined value exceeds a predetermined percentage, at the switchover to zone control. Thus, by increasing or decreasing the correction coefficient d, it is possible to prevent a situation in which, at the switchover to zone control, the degree of opening of the first electronic expansion valve 8 is over-throttled, thus making the discharge degree of superheat TDSH overshoot the target zone and causing hunting, or is over-relaxed, thus causing a delay in reaching the target zone. Therefore, it is possible to set the degree of opening of the first electroni c expansion valve 8 in open-loop control to an appropriate degree of opening to swiftly reach the ideal zone-control region at the switchover to zone control, and to ensure the stable operation of the compressor 4.

[0050] The present invention is not limited to the invention according to the above-described embodiment, and appropriate modifications can be made without departing from the scope thereof. For example, although a description has been given of an example in which six indoor units 3A to 3F are connected in the above-described embodiment, the number of the indoor units 3A to 3F may be higher than or lower than six. Furthermore, the refrigerant circuit 22 can be modified to various types of circuits as long as it has the first electronic expansion valve (EEVH) 8, the second electronic expansion valves (EEVs) 10A to 10F corresponding to the indoor units 3A to 3F, and the receiver 9 disposed between the first electronic expansion valve (EEVH) 8 and the second electronic expansion valves (EEVs) 10A to 10F.

[0051] Furthermore, in the above-described embodiment, a description has been given of an example in which the second electronic expansion valves (EEVs) 10A to 10F are disposed closer to the outdoor unit 2; however, as a matter of course, the second electronic expansion valves (EEVs) 10A to 10F corresponding to the indoor units 3A to 3F can be disposed closer to the indoor units 3A to 3F.

{Reference Signs List}

[0052]

1	multi-type air conditioner
2	outdoor unit
3A to 3F	indoor units
4	compressor
6	four-way switching valve
7	outdoor heat exchanger
8	first electronic expansion (EEVH)
9	receiver
10A to 10F	second electronic expansion valves (EEVs)
19A to 19F	indoor heat exchangers
23	outdoor controller
24	expansion-valve control section
25	discharge temperature sensor
27	high-pressure pressure sensor
28	outside air temperature sensor

Claims

1. A multi-type air conditioner (1) in which a plurality of indoor units (3A-3F) are connected in parallel to a single outdoor unit (2), and a closed-cycle refrigerant circuit is formed of a compressor (4), a four-way switching valve (6), an outdoor heat exchanger (7), a first electronic expansion valve (8), a receiver (9), a plurality of second electronic expansion valves (10A-10F) connected in parallel to a plurality of indoor exchangers (19A-19F), and the plurality of the indoor heat exchangers (19A-19F) connected in parallel to each other,
wherein the first electronic expansion valve (8) is open-loop controlled for a predetermined period of time at a degree of opening calculated based on particular parameters at a starting time of a heating operation and at the time of a change in the number of operated indoor units; is then switched over to zone control in which a discharge degree of superheat is controlled so as to fall within a target zone; and is provided with an expansion-valve control section (24) that corrects, when a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, a degree of opening of the first electronic expansion valve (8) for the next open-loop control in response thereto.

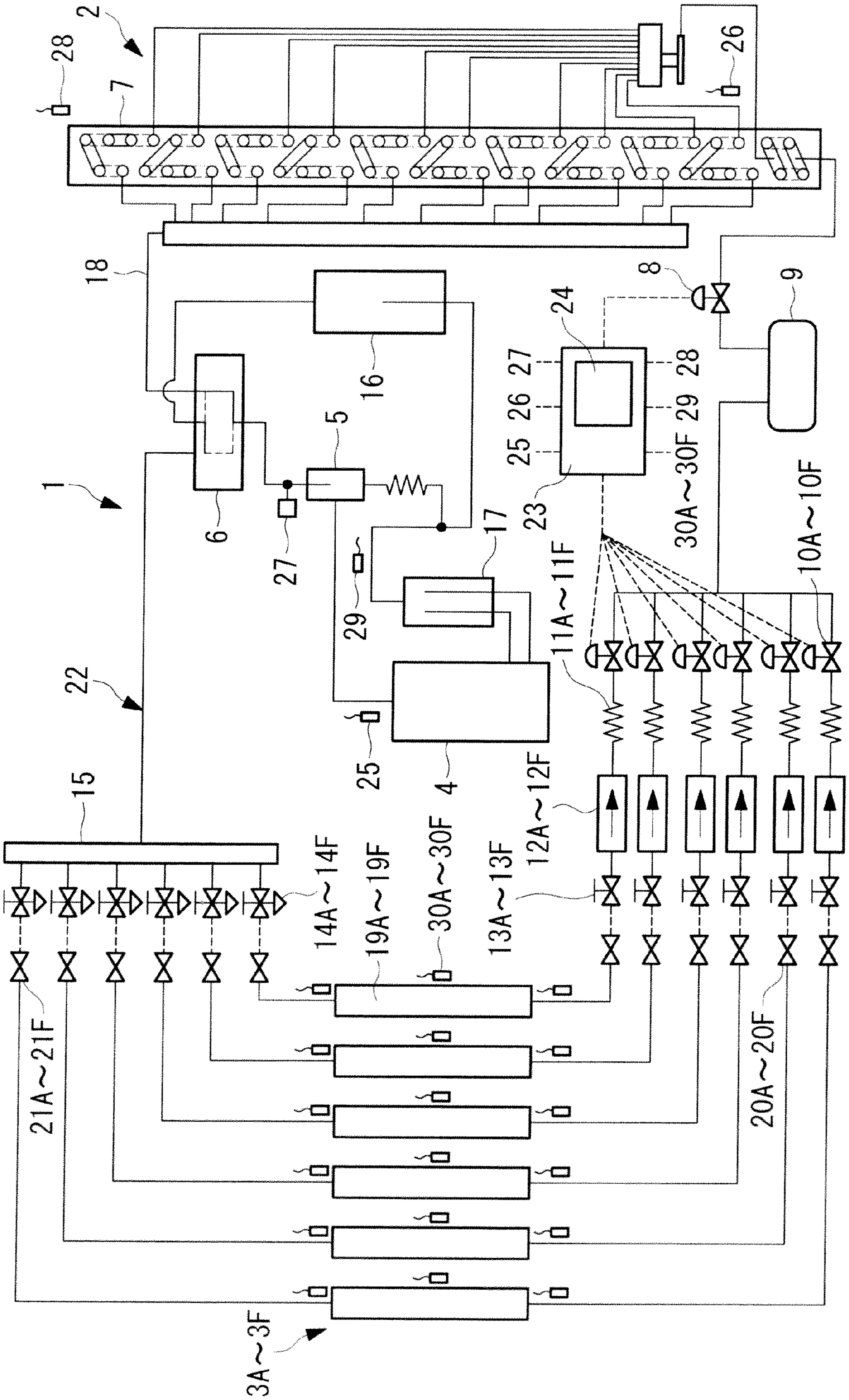
2. A multi-type air conditioner (1) according to claim 1, wherein, in the expansion- valve control section (24), the degree of opening of the first electronic expansion valve (8) in the open-loop control is calculated by using at least an outside air temperature and a capacity of the plurality of the indoor heat exchangers (19A-19F), as the parameters.

3. A multi-type air conditioner (1) according to claim 1 or 2, wherein, in the expansion-valve control section (24), a correction coefficient for the degree of opening of the first electronic expansion valve (8) is determined according to an outside air temperature and a capacity of the plurality of the indoor heat exchangers (19A-19F) of the indoor units (3A-3F) connected to the outdoor unit (2).

4. A multi-type air conditioner (1) according to any one of claims 1 to 3, wherein, in the expansion-valve control section (24), a correction coefficient for the degree of opening of the first electronic expansion valve (8) is increased or decreased when a percentage at which the temperature deviation of the discharge degree of superheat with respect to the target zone and the time variation of the discharge degree of superheat, calculated at sampling intervals, are equal to or higher than a predetermined value or are equal to or lower than a predetermined value that exceeds a predetermined percentage, at the switchover to zone control.

5. A control method for a multi-type air conditioner (1) in which a plurality of indoor units (3A-3F) are connected in parallel to a single outdoor unit (2), and a closed-cycle refrigerant circuit is formed of a compressor (4), a four-way switching valve (6), an outdoor heat exchanger (7), a first electronic expansion valve (8), a receiver (9), a plurality of second electronic expansion valves (10A-10F) connected in parallel to a plurality of indoor heat exchangers, and the plurality of the indoor heat exchangers (19A-19F) connected in parallel to each other, the control method comprising:

   - performing open-loop control for the first electronic expansion valve (8) for a predetermined period of time at a degree of opening calculated based on particular parameters, at a starting time of a heating operation and at a time of a change in the number of operated indoor units;
   - switching over to zone control in which a discharge degree of superheat is controlled so as to fall within a target zone; and
   - correcting, when a temperature deviation of the discharge degree of superheat with respect to the target zone and a time variation of the discharge degree of superheat are large at the switchover to zone control, the degree of opening of the first electronic expansion valve (8) for the next open-loop control in response thereto.


1
2
3A～3F
4
5
6
7
8
9
10A～10F
11A～11F
12A～12F
13A～13F
14A～14F
15
16
17
18
19A～19F
20A～20F
21A～21F
22
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26
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28
29
30A～30F

FIG. 1

FIG. 2

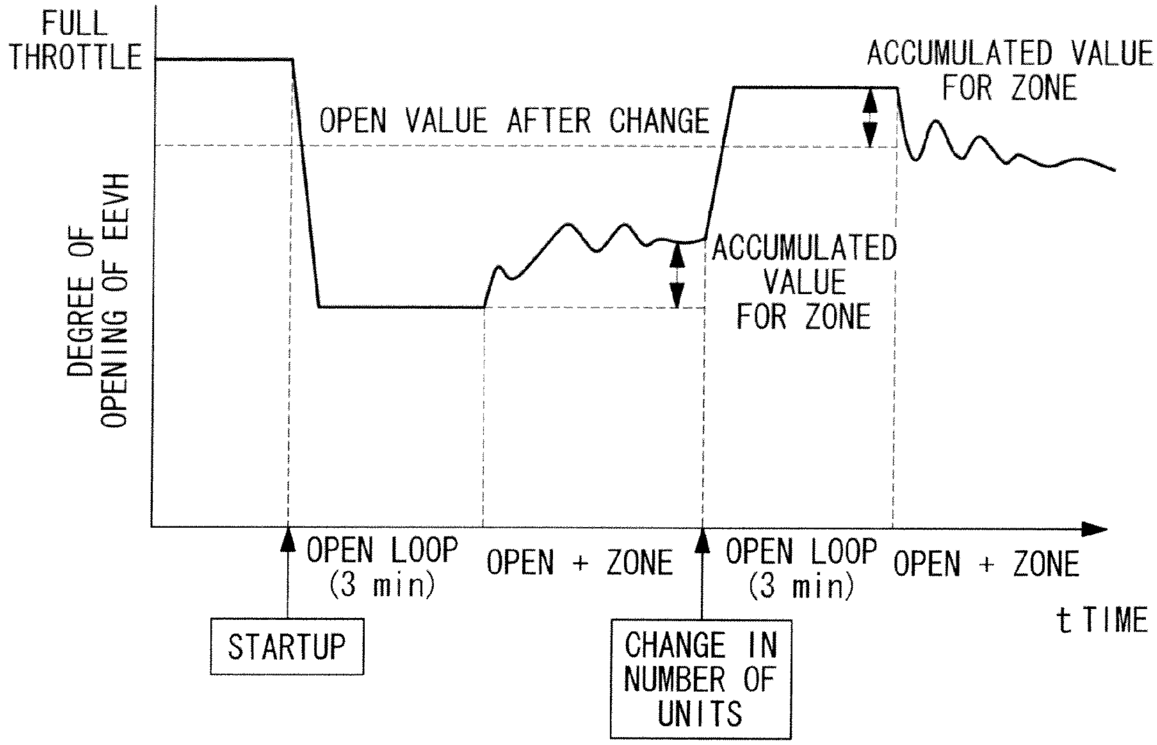
FULL
THROTTLE
OPEN VALUE AFTER CHANGE
ACCUMULATED VALUE
FOR ZONE
DEGREE OF
OPENING OF EEVH
ACCUMULATED
VALUE
FOR ZONE
OPEN LOOP
(3 min)
OPEN + ZONE
OPEN LOOP
(3 min)
OPEN + ZONE
t TIME
STARTUP
CHANGE IN
NUMBER OF
UNITS

FIG. 3

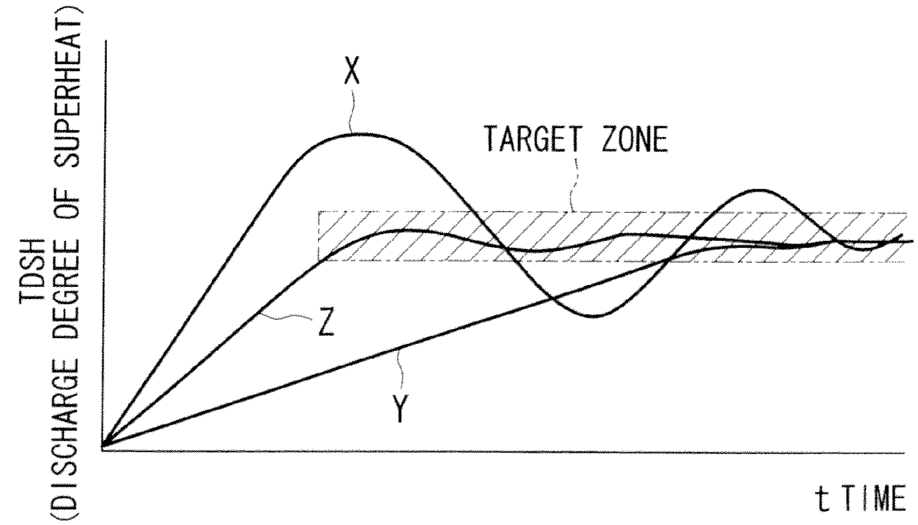
X
TARGET ZONE
TDSH
(DISCHARGE DEGREE OF SUPERHEAT)
Z
Y
t TIME

FIG. 4

COEFFICIENT a

		CONDENSER PERFORMANCE (TOTAL CAPACITY OF HEAT EXCHANGERS OF CONNECTED UNITS)			
		~300	301~400	401~500	501~
OUTSIDE TEMPERATURE	A	0.9	1.1	1.4	1.5
	B	0.7	0.8	1.0	1.2
	C	0.5	0.6	0.8	1.0
	D	0.3	0.4	0.6	0.8

FIG. 5

COEFFICIENT b

		CONDENSER PERFORMANCE (TOTAL CAPACITY OF HEAT EXCHANGERS OF CONNECTED UNITS)			
		~300	301~400	401~500	501~
OUTSIDE TEMPERATURE	A	60	70	80	90
	B	55	60	65	70
	C	50	55	55	60
	D	45	45	50	50

FIG. 6

COEFFICIENT c

CAPACITY OF HEAT EXCHANGERS OF STOPPED UNITS	~90	91~110	111~
α	3	5	10

FIG. 7

COEFFICIENT d

		CONDENSER PERFORMANCE (TOTAL CAPACITY OF HEAT EXCHANGERS OF CONNECTED UNITS)			
		~300	301~400	401~500	501~
OUTSIDE TEMPERATURE	A	0	+2	0	0
	B	0	+3	0	0
	C	0	0	0	0
	D	0	−4	0	0

FIG. 8

COEFFICIENT Z_4

	CAPACITY OF CONNECTED INDOOR HEAT EXCHANGERS	Z_4
WHEN LARGE WALL TYPE IS NOT INCLUDED IN CONNECTED UNITS		1.0
WHEN LARGE WALL TYPE IS INCLUDED IN CONNECTED UNITS	~399	1.1
	400~	1.5

FIG. 9

	CAPACITY OF UNIT TYPE	20	25	35	50	60	71
INDOOR UNIT TYPE SIGNAL	MEDIUM WALL TYPE	100	100	100	100	100	—
	SMALL WALL TYPE	63	63	63	63	(63)	—
	LARGE WALL TYPE	—	—	—	—	—	125
	FLOOR TYPE	(77)	77	97	97	(97)	—
	DUCT TYPE	(67)	67	67	78	78	—
	CEILING CASSETTE TYPE	(64)	64	64	64	64	—
	DUCT TYPE II	(65)	(65)	(65)	65	(65)	—
	CEILING HANGING TYPE	(92)	(92)	(92)	92	(92)	—
	DUCT TYPE III	(67)	(67)	(67)	(78)	(78)	—

FIG. 10

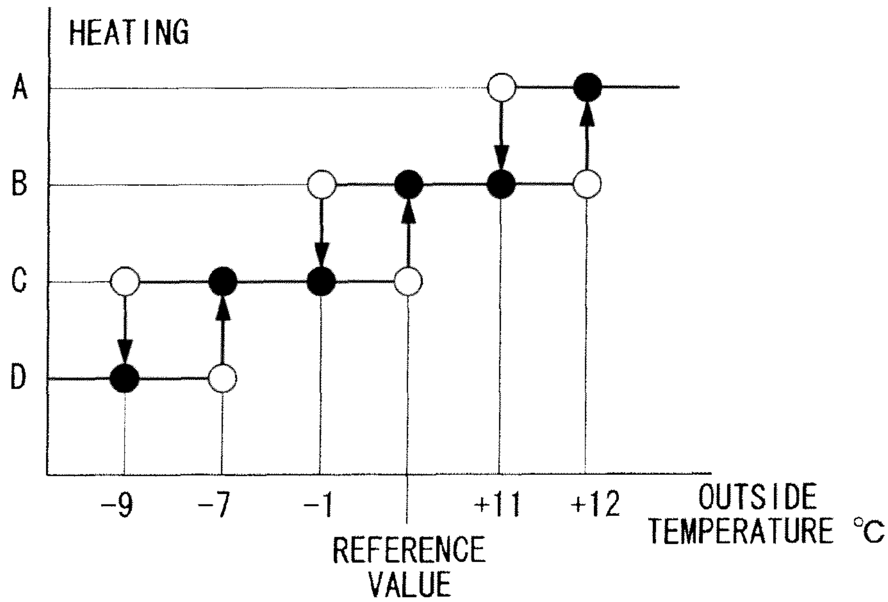

FIG. 11

E(n) \ DE	DE＜－1	－1≦DE≦1	1＜DE
2＜E(n)	0	＋1	＋1
0＜E(n)≦2	0	0	＋1
E(n)＝0	－1	0	＋1
－2≦E(n)＜0	－1	0	0
E(n)＜－2	－1	TDSH＜0. 5：－2 TDSH≧0. 5：－1	0

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 0925

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 2 261 580 A1 (DAIKIN IND LTD [JP]) 15 December 2010 (2010-12-15) * paragraphs [0046] - [0049], [0063] - [0071]; figure 1 * -----	1-4 5	INV. F25B13/00 F25B49/02
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F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 September 2012	Ritter, Christoph

2

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