

DESCRIPTION

TITLE OF THE INVENTION: HEAT SOURCE SYSTEM AND METHOD OF CONTROLLING HEAT SOURCE SYSTEM

TECHNICAL FIELD

[0001]

The present invention relates to a heat source system and a method of controlling a heat source system.

BACKGROUND ART

[0002]

A heat source system is a system including a plurality of heat source devices for supplying cold and heat energy to a heat load by a heat medium having a high temperature to a heat load or a system for (removing a heat from heat load by) supplying a heat medium having a low temperature to feed cold energy to a heat load.

In the heat source system, on operating, evaluation functions are set for a consumed energy of the whole of the heat source system, an operation cost of the whole of the heat source system, a quantity of carbon-dioxide emission from the heat source system, etc. and controlling is made to minimize the evaluation functions.

For example, if it is assumed that the evaluation function is an integrated value of all electric power energy and all gas energy consumed in the heat source system, it is allowed that the controlling is made such that consumed energy of the whole of the heat source system is minimized. In addition, for example, if it is assumed that the evaluation function is an integrated value of all electric power cost and all gas cost in the heat source system, it is allowed that the controlling is made such that an operation cost of the whole of the heat source system is minimized.

[0003]

Generally, a relation between a load factor and a coefficient of performance (COP) in the heat source device with which the heat source system is equipped is, for example, such that as shown in Fig 4 in the patent document 2, the COP increases with increase in the load factor.

Accordingly, the-number-of-operated-device control of the heat source devices in the heat source systems disclosed in the patent document 1 and the patent document 2 is done by operating a minimum number of heat source devices which can process a heat load quantity to be processed (demanded heat load quantity). The controlling made with the number of the heat source devices corresponds to the number of the heat source devices which can most reduce the consumed energy at the demanded heat load quantity.

Prior Art

Patent Document

[0004]

Patent document 1: JP 2008-292043

Patent document 2: JP 2005-114295

Summary of Invention

Problem to be solved by Invention

[0005]

As the heat source device, for example, there are heat source devices having different characteristics (for example, load factor-COP characteristic) such as a turbo refrigerator, an inverter turbo refrigerator, an absorbing type water chiller-warmer, an exhaust heat utilizing absorbing type water chiller-warmer, etc. Accordingly, in processing a demanded heat load quantity in the conventional heat source system (for example, see patent document 1, patent document 2), there may be a case where saving energy and decreasing a cost in the whole of the heat source system can be planned by appropriately distributing demanded heat load quantity to each heat source device not by changing the number of operated devices of the heat source devices.

[0006]

For example, if it is assumed that the heat source system includes, as a structure of the heat source devices, one inverter turbo refrigerator and a plurality of the exhaust heat utilizing absorbing type water chiller-

warmers having small processing powers, there may be a case where a consumed energy of the whole of the heat source system can be reduced by stopping operation of the inverter turbo refrigerator and starting operation of a plurality of the exhaust heat utilizing absorbing type water chiller-warmers when the demanded heat load quantity becomes small from a status in which only one inverter turbo refrigerator is operated, because there may be a case where the exhaust heat utilizing absorbing type water chiller-warmer shows a high COP at a low load (see (c) in Fig. 6).

[0007]

However, the-number-of-operated-device control for the heat source devices in the heat source system disclosed in Patent document 1 and Patent document 2 cannot cope with such a case. In addition, the problem in the-number-of-operated-device control for reducing the consumed energy becomes more complicated when the number or the kinds of the heat source devices included in the heat source system increases.

[0008]

Then, regarding the heat source system including a plurality of the heat source devices, embodiments of the present invention aim to provide a heat source system and a method of controlling the heat source system capable of reducing a consumed energy, an operation cost, or a quantity of carbon-dioxide emission.

Measure for solving problem

[0009]

According to a first aspect of the present invention, there is provided a heat source system comprising:

- at least two heat source devices;

- carrying means for carrying a heat carrying medium from the heat source devices to a heat load; and

- control means for controlling the heat source devices and the carrying means, wherein, the control means comprising:

- pattern generating means for generating a heat load distribution

pattern for the respective heat source devices;

simulating means for calculating an evaluation function of the heat source system regarding the generated heat load distribution pattern;

pattern extracting means for extracting one of the heat load distribution patterns from the heat load distribution patterns generated by the pattern generating means on the basis of the evaluation function; and

operation controlling means for controlling the heat source device and the carrying means on the basis of the extracted one of the heat load distribution patterns.

[0010]

According to a second aspect of the present invention, there is provided a method of controlling a heat source system, including at least two heat source devices; and carrying means for carrying a heat carrying medium from the heat source devices to a heat load, wherein the method comprises:

a generating step of generating a heat load distribution pattern to the respective heat source devices;

a calculating step of calculating an evaluation function of the heat source system in the heat load distribution pattern generated in the generating step;

an extracting step of extracting one of the heat load distribution patterns from the heat load distribution patterns generated in the generating step on the basis of the evaluation function calculated by the calculating step; and

a control step of controlling the heat source device and the carrying means on the basis of the heat load distribution pattern extracted by the extracting step.

Advantageous effect of the present invention

[0011]

According to the embodiments of the present invention, regarding the heat source

system including a plurality of the heat source devices, embodiments of the present invention can provide the heat source system and the method of controlling the heat source system, which can reduce the consumed energy, the operation cost, or the quantity of carbon-dioxide emission, etc. Particularly, even in a case where the heat source system includes heat source devices having different characteristics, the consumed energy, the operation cost, the quantity of carbon-dioxide emission, etc. of the whole of the heat source system can be reduced by controlling the number of the operated heat source devices and heat load quantities distributed to respective heat source devices.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 is a block diagram of a heat source system according to a first embodiment.

Fig. 2 is a flowchart showing operations of the control unit of the heat source system according to the first embodiment.

Fig. 3 is a schematic illustration showing division of a heat load to be processed by the heat source system.

Fig. 4 is a table of heat load distribution patterns generated by a heat load distribution pattern generating unit.

Fig. 5 is a table of the heat load distribution patterns extracted as an operational one.

Fig. 6 shows charts showing a load factor-COP characteristic of each heat source device, wherein (a) is that of the inverter turbo refrigerator, (b) is that of the turbo refrigerator, and (c) is that of exhaust heat utilizing absorbing type water chiller-warmers.

Fig. 7 is a table showing heat load distribution patterns generated by heat load distribution pattern generating unit according to a second embodiment.

Fig. 8 shows an example of the heat load distribution patterns.

Fig. 9 shows in (a) a table illustrating consumed powers of the heat

source devices consuming electric powers and in (b) a table illustrating a consumed gas of the heat source device.

MODE FOR CARRYING OUT THE INVENTION

[0013]

Hereinbelow will be described in detail embodiments of the present invention with reference to drawings (hereinafter referred to as embodiments for carrying out the present invention). In each of the drawings, the common parts are designated with the same reference and a duplicated description will be omitted.

[0014]

<<First embodiment>>

<Heat source system S>

Fig. 1 is a block diagram of a heat source system S according to a first embodiment.

As shown in Fig. 1, the heat source system S includes three systems of the heat source units (a first heat source unit 1, a second heat source unit 2, and a third heat source unit 3), and a heat load 4, cooling and heating pumps 5a, 5b, 5c, a cool/hot water supply header 6a, a cool/hot water returning header 6b and a controller 30 to circulates cool/hot water between the heat source units (a first heat source unit 1, a second heat source unit 2, and a third heat source unit 3) and the heat loads 4.

The description below will be made with assumption that the heat load 4 is a load source (for example, an air conditioner performing a cooling operation) as a cooling/heating demand, and that the heat source system S supplies a cold and heat energy to the heat load 4.

[0015]

The heat source unit (a first heat source unit 1, a second heat source unit 2, and a third heat source unit 3) have such a configuration that the heat source unit cools a cool/hot water flowing from a cool/hot water inlet port and the water flows out from a cool/hot water outlet port.

As shown in Fig. 1, the first heat source unit 1 (an inverter turbo

refrigerator 11 mentioned later) is connected, at the cool/hot water inlet port, to a discharge side of the cool/hot water pump 5a, and, at the cool/hot water outlet port, to the cool/hot water supply header 6a. The second heat source unit 2 (a turbo refrigerator 12 described later) is connected, at the cool/hot water inlet port, to a discharge side of a cool/hot water pump 5b, and, at the cool/hot water outlet port, to the cool/hot water supply header 6a. The third heat source unit 3 (an exhaust heat utilizing absorbing type water chiller-warmer 13 described later) is connected, at a cool/hot water inlet port, to a discharge side of the cool/hot water pump 5c, and, at a cool/hot water outlet port, to the cool/hot water supply header 6a.

In addition, details of the heat source unit (the first heat source unit 1, the second heat source unit 2, the third heat source unit 3) will be described later.

[0016]

The heat load 4 is a load source as a heat load demand and as shown in Fig. 1, an end of the heat load 4 (a side of cool/hot water inlet) is connected to the cool/hot water supply header 6a, and the other end (a side of cool/hot water outlet) is connected to the cool/hot water return header 6b.

[0017]

The cooling and heating pumps 5a, 5b, and 5c are pumps for circulating cool/hot water between the heat source units (the first heat source unit 1, the second heat source unit 2, the third heat source unit 3) and the heat load 4.

As shown in Fig. 1, the cooling and heating pump 5a is connected, at a suction side thereof, to a cool/hot water return header 6b, at a discharging side thereof, to a cool/hot water inlet port of the first heat source unit 1 (the inverter turbo refrigerator 11 described later). A cool/hot water pump 5b is connected, at a suction side thereof, to the cool/hot water return header 6b and at a discharging side thereof, to the second heat source unit 2 (the turbo refrigerator 12 described later). The

cool/hot water pump 5c is connected, at a suction side, to the cool/hot water return header 6b and at a discharge side thereof, to the third heat source unit 3 (the exhaust heat utilizing absorbing type water chiller-warmer 13 described later).

[0018]

The cooling and heating pumps 5a, 5b, 5c are respectively connected to inverters 21a, 21b, 21c. A control unit 30 can change flow rates of the cool/hot water in the cooling and heating pumps 5a, 5b, 5c in a predetermined range (for example, 40% of a rated flow rate to the rated flow rate) by controlling the inverters 21a, 21b, 21c.

[0019]

As described above, in the heat source system S, a cool/hot water flows from the cool/hot water return header 6b to the heat source units (the first heat source unit 1, the second heat source unit 2, the third heat source unit 3) by driving the cool/hot water pump 5a, 5b, 5c. The cool/hot water cooled at the heat source units (the first heat source unit 1, the second heat source unit 2, the third heat source unit 3) is supplied to the heat load 4 through the cool/hot water supply header 6a.

The cool/hot water supplied to the heat load 4 supplies cold and heat energy to the heat load 4 (because the cool/hot water is heated by a heat load 4), and the cool/hot water of which temperature is increased is returned to the cool/hot water return header 6b.

[0020]

<First heat source unit 1, second heat source unit 2, third heat source unit 3>

Next, the heat source units (the first heat source unit 1, the second heat source unit 2, the third heat source unit 3) will be described.

As shown in Fig. 1, a first heat source unit 1 includes an inverter turbo refrigerator (heat source device) 11, a cooling tower 7a having a blower fan 8a and a cooling water pump 9a to circulate the cooling water between the inverter turbo refrigerator 11, and the cooling power 7a.

In addition, the second heat source unit 2 includes a cooling tower

7b including the turbo refrigerator (heat source device) 12 and a blower fan 8b and a cool water pump 9b to circulate the cooling water between the turbo refrigerator 12 and the cooling tower 7b.

The third heat source unit 3 includes a cooling tower 7c including a exhaust heat utilizing absorbing type water chiller-warmer (heat source device) 13 and a blower fan 8c, and the cool water pump 9c, a hot water discharging pump 15, and a gas engine 14 in which a cooling water circulates between the exhaust heat utilizing absorbing type water chiller-warmer 13 and the cooling tower 7c and a discharged hot water circulates between the exhaust heat utilizing absorbing type water chiller-warmer 13 and the gas engine 14.

[0021]

The cooling towers 7a, 7b, 7c cool cooling water flowing from cooling water inlet ports by heat exchange with the air and/or by vaporization heat on vaporization of the cooling water, and the cooling water flows out from cooling water outlet ports.

As shown in Fig. 1, the cooling water inlet port of the cooling tower 7a is connected to a cooling water outlet port of the inverter turbo refrigerator 11. The cooling water outlet port of the cooling tower 7a is connected to a suction side of a cooling water pump 9a. A cooling water inlet port of the cooling tower 7b is connected to a cooling water outlet port of the turbo refrigerator 12, and a cooling water outlet port of the cooling tower 7b is connected to a suction side of the cool water pump 9b. A cooling water inlet port of the cooling tower 7c is connected to a cooling water outlet port of the exhaust heat utilizing absorbing type water chiller-warmer 13, and a cooling water outlet port of the cooling tower 7c is connected to a suction side of the cool water pump 9c.

[0022]

The cooling towers 7a, 7b, 7c include the blower fans 8a, 8b, 8c for taking the air in the cooling towers 7a, 7b, 7c to promote heat exchange between the cooling water and the air and/or vaporization of the cooling water, respectively.

[0023]

The blower fans 8a, 8b, 8c are respectively connected to inverters 22a, 22b, 22c. The control unit 30 is configured to change quantities of blower flow rates of the blower fans 8a, 8b, 8c by controlling the inverters 22a, 22b, 22c.

[0024]

The cooling water pumps 9a, 9b, 9c are pumps for circulating the cooling water between the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, the exhaust heat utilizing absorbing type water chiller-warmer 13) and the cooling towers 7a, 7b, 7c.

As shown in Fig. 1, the cooling water pump 9a is connected at a suction side thereof to the cooling water outlet port of the cooling tower 7a and at a discharging side thereof to the cooling water inlet port of the inverter turbo refrigerator 11. The cool water pump 9b is connected at a suction side thereof to a cooling water outlet port of the cooling tower 7b and at a discharging side thereof to a cooling water inlet port of the turbo refrigerator 12. The cool water pump 9c is connected, at suction side thereof, to cooling water outlet port of the cooling tower 7c and at discharging side thereof to a cooling water inlet port of the exhaust heat utilizing absorbing type water chiller-warmer 13.

[0025]

The cooling water pumps 9a, 9b, 9c are respectively connected to inverters 23a, 23b, 23c. The control unit 30 is configured to change flow rates of the cooling water pumps 9a, 9b, 9c by controlling the inverters 23a, 23b, 23c in predetermined ranges (from 40% of the rated flow rates to the rated flow rates).

[0026]

The inverter turbo refrigerator 11 has an not-shown refrigerating cycle (heat pump cycle) and is configured to draw cold and heat energy from the cooling water flowing from the cooling water inlet port to the cooling water outlet port by driving a compressor (not shown) for the refrigerating cycle (heat pump cycle) with consuming an electric power to

cool the cool/hot water flowing from a cool/hot water inlet port, and the cooled cool/hot water flows out from a cool/hot water outlet port.

[0027]

The turbo refrigerator 12 has an not-shown refrigerating cycle (heat pump cycle) and is configured to draw cool/heat energy from the cooling water flowing from the cooling water inlet port to the cooling water outlet port by driving a compressor (not shown) for the refrigerating cycle (heat pump cycle) with consuming an electric power to cool the cool/hot water flowing from the cool/hot water inlet port, and the cooled cool/hot water flows out from the cool/hot water outlet port.

[0028]

In addition, the inverter turbo refrigerator 11 can control a rotational speed of the compressor (not shown) in the refrigerating cycle (heat pump cycle) and the turbo refrigerator 12 has the compressor (not shown) in the refrigerating cycle (heat pump cycle), the compressor having a rotational speed which is constant. Therefore, as shown in (a) and (b) in Fig. 6, the characteristics (load factor-COP characteristic) are different from each other.

[0029]

The exhaust heat utilizing absorbing type water chiller-warmer 13 drives an absorbing refrigerating cycle by heating an absorbing liquid (not shown) by a high temperature discharge hot water flowing from a discharge hot water inlet port to a discharge hot water outlet port and burning a gas and cooling by a cooling water flowing from a cooling water inlet port thereto and the cool/hot water flows out from cool/hot water outlet port. In addition, as shown in (c) in Fig. 6 described later, a characteristic (load factor-COP characteristic) is different from those of the inverter turbo refrigerator 11 (see (a) in Fig. 6) and the turbo refrigerator 12 (see (b) in Fig. 6).

[0030]

Each of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type

water chiller-warmer 13) is operated to make a temperature of the cool/hot water flowing out from the cool/hot water outlet port (a cool/hot water outlet port temperature) equal to a control target temperature. The control unit 30 is configured to control the cool/hot water outlet port temperature by instructing each of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) about the control target temperature.

[0031]

The gas engine 14 is a device for generating a rotation force by burning a fuel (gas). The generated rotation force is transferred to an electric generator (not shown) to generate an electric power. In addition the gas engine 14 has a heat exchanger capable of heat exchange between a discharge gas after burning with a high temperature and a discharge water to heat the discharge water flowing into from a discharge hot water inlet port, and allow the discharge water flows out from the discharge water outlet port.

As shown in Fig. 1, a discharge water inlet port of the gas engine 14 is connected to a discharge hot water outlet port of the exhaust heat utilizing absorbing type water chiller-warmer 13, and a discharge hot water outlet port of the gas engine 14 is connected to a suction side of the hot water discharging pump 15.

[0032]

The hot water discharging pump 15 is a pump for circulating the discharge hot water between the exhaust heat utilizing absorbing type water chiller-warmer 13 and the gas engine 14.

As shown in Fig. 1, the suction side of the hot water discharging pump 15 is connected to the discharge hot water outlet port of the gas engine 14, and a discharging side thereof is connected to a discharge hot water inlet port of the exhaust heat utilizing absorbing type water chiller-warmer 13.

The hot water discharging pump 15 is connected to an inverter 24

and configured to change a flow rate of the discharge hot water of the hot water discharging pump 15 within a predetermined range by controlling the inverter 24.

[0033]

In addition, there is a configuration to supply an electric power generated by the gas engine 14 to an electric power demanding source (not shown), and the gas engine 14 and the hot water discharging pump 15 are operated in accordance with an electric power demand of the electric power demanding source (not shown).

[0034]

<Control unit 30>

Next, the control unit 30 included in the heat source system S will be described.

The control unit 30 includes, as shown in Fig. 1, a heat load distribution pattern generating means 31, a simulating means 32, a heat load distribution pattern extracting means 33, and an operation control instructing means 34.

[0035]

Here, the heat source system S includes various sensors (not shown) and detected values are inputted into the control unit 30.

More specifically, in the cooling water inlet port of each of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13), there are a temperature sensor (not shown) for detecting the temperature of the cooling water flowing into each of the heat source devices (cooling water inlet port temperature), a flow rate sensor (not shown) for detecting a flow rate of the cooling water flowing into each of the heat source devices (cooling water flow rate), and a temperature sensor (not shown) for detecting a temperature (cooling water outlet port temperature) of the cooling water flowing out from each of the heat source devices at the cooling water outlet port.

In addition, at the cool/hot water inlet port of each of the heat

source devices, there are a temperature sensor (not shown) for detecting the temperature of the cool/hot water flowing into the heat device (cool/hot water inlet port temperature), a flow rate sensor (not shown) for detecting a flow rate of the cool/hot water flowing into each of the heat source devices (cool/hot water flow rate), and a temperature sensor (not shown) for detecting a temperature (cool/hot water outlet port temperature) of the cool/hot water flowing out from each of the heat source devices at the cooling water outlet port.

[0036]

There are provided with at one end of the heat load 4 (on a side of the cool/hot water inlet port), a temperature sensor (not shown) for detecting a temperature of a cooling water flowing into the heat load 4 and a flow rate sensor (not shown) for detecting a flow rate of the cooling water flowing into the heat load 4, and at the other end of the heat load 4 (the cool/hot water outlet port side), a temperature sensor (not shown) for detecting a temperature of the cooling water flowing out from the heat load 4.

[0037]

The cooling towers 7a, 7b, 7c are provided with dry-bulb temperature sensors (not shown) and a relative temperature sensor (not shown) for detecting temperatures and humidities of the air taken into the cooling towers 7a, 7b, 7c, respectively, by the blower fans 8a, 8b, 8c.

[0038]

The heat load distribution pattern generating means 31 has a function for generating heat load distribution patterns for distributing a heat load quantity of the heat load 4 (demanded heat load quantity) to the respective heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, the exhaust heat utilizing absorbing type water chiller-warmer 13). In the heat load distribution patterns, when a heat load distributed into a heat source device is "0", this indicates the stopping of the heat source device. In other words, the heat load distribution patterns include the-number-of-heat source device information and heat load

distribution information to respective heat source devices.

[0039]

The simulating means 32 has functions for performing simulation on the heat load distribution patterns generated by the heat load distribution pattern generating means 31, obtaining an operation status (flow rates of the cooling and heating pumps 5a, 5b, 5c, flow rates of the blower fans 8a, 8b, 8c, and flow rates of the cooling water pumps 9a, 9b, 9c) for making an evaluation function (for example, consumed energy, an operation cost, or quantity of carbon-dioxide emission) minimum for each heat load distribution pattern, and obtaining a value of the evaluation function.

[0040]

The heat load distribution pattern extracting means 33 has a function for extracting heat load distribution patterns that minimizes a value of the evaluation function obtained by the simulating means 32 from a plurality of the heat load distribution patterns.

[0041]

The operation control instructing means 34 has a function for transmitting signals for controlling flow rates of the cooling and heating pumps 5a, 5b, 5c to the inverters 21a, 21b, 21c; transmitting signals for controlling blow flow rates of the blower fans 8a, 8b, 8c to the inverters 22a, 22b, 22c; transmitting signals for controlling flow rates of the cooling water pumps 9a, 9b, 9c to the inverters 23a, 23b, 23c to realize the heat load distribution pattern extracted by the heat load distribution pattern extracting means 33; and transmitting signals to respective heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, the exhaust heat utilizing absorbing type water chiller-warmer 13) for controlling cool/hot water outlet port temperatures.

[0042]

As described above, the control unit 30 in the heat source system S is configured to control the flow rates of the cooling and heating pumps 5a, 5b, 5c, the blowing flow rates of the blower fans 8a, 8b, 8c, the flow rates of the cooling water pumps 9a, 9b, 9c, and the cool/hot water outlet port

temperatures of respective heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, the exhaust heat utilizing absorbing type water chiller-warmer 13).

[0043]

The control unit 30 is configured to control the heat source system S so as to minimize the evaluation function. Here, if it is assumed that evaluation function is a consumed energy in the whole of the heat source system S, the control unit 30 controls the heat source system S so as to minimize the consumed energy of the heat source system S. In addition, the consumed energy of the heat source system S is a total of the consumption energies of the cooling and heating pumps 5a, 5b, 5c, the blower fans 8a, 8b, 8c, the cooling water pumps 9a, 9b, 9c, the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13.

[0044]

The heat source system S according to the embodiment is a concentrated heat source system in which the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) are connected to the heat load 4 through the cool/hot water supply header 6a and the cool/hot water return header 6b, wherein a cool/hot water inlet port temperature of the inverter turbo refrigerator 11 is equal to the cool/hot water inlet port temperature of the turbo refrigerator 12 and the cooling water inlet port temperature of the exhaust heat utilizing absorbing type water chiller-warmer 13.

In addition, the control target temperature is set and controlled to equalize the cool/hot water outlet port temperature of the inverter turbo refrigerator 11, the cool/hot water outlet port temperature of the turbo refrigerator 12, and the cool/hot water outlet port temperature of the exhaust heat utilizing absorbing type water chiller-warmer 13.

[0045]

Accordingly, a heat load distribution to each of the heat source

devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) is proportional to a flow rate of the cool/hot water flowing into the heat source device (cool/hot water flow rate), i.e., flow rates of the cooling and heating pumps 5a, 5b, 5c, respectively.

For example, when a temperature difference between the cooling water inlet port temperature and the cool/hot water outlet port temperature of the heat source device is 5 °C, if it is assumed that the flow rate of the cooling and heating pump 5a is 500m³/h, the flow rate of the cool/hot water pump 5b is 500m³/h, and the flow rate of the 5c is 200m³/h, heat load quantities of the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13 are 2907 kW, 2907 kW, and 1163 kW, respectively.

[0046]

Therefore, in the heat source system S of the embodiment, to realize the load distribution to the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) determined by the simulating means 32, ratios of the cool/hot water flow rates are controlled by performing the inverter controlling on the cooling and heating pumps 5a, 5b, 5c in response to instructions from the control unit 30.

[0047]

<Heat load distribution process to each heat source device>

A heat load distribution process to each heat source device in the heat source system S will be described with reference to Fig. 2. Fig. 2 is a flowchart illustrating operation of the control unit 30 of the heat source system S in the first embodiment.

[0048]

In step S101, the heat load distribution pattern generating means 31 of the control unit 30 calculates a demanded heat load quantity to be processed by the heat source system S (heat load demanded quantity Q₄). More specifically, the demanded heat load quantity is calculated on the

basis of a temperature T_{4in} of the cooling water flowing into the heat load 4, a temperature T_{4out} of the cooling water flowing out from the heat load 4, and a flow rate F_4 of the cooling water flowing into the heat load 4.

$$Q_4 = (T_{4out} - T_{4in}) \times F_4 \quad \text{--- (1)}$$

The below description will be made with assumption that $Q_4 = 1000\text{RT}$ (RT: refrigeration ton).

[0049]

In step S102, the heat load distribution pattern generating means 31 of the control unit 30 generates a heat load distribution pattern for distributing a heat load demanded quantities Q_4 to each of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13).

[0050]

The distribution of heat load quantities to respective heat source devices is performed by dividing the heat load demanded quantities Q_4 by an appropriate number n (for example, $n = 5$), and distributing the results to respective heat source devices. At first, the heat load distribution pattern generating means 31 divides the heat load quantity Q_4 into some blocks (dividing number : n) for distribution to respective heat source devices. In the example shown in Fig. 3, the heat load demanded quantity $Q_4 = (=1000\text{RT})$ is divided into five ($n = 5$) blocks. This division into blocks is made through equal dividing, so that the heat load demanded quantity Q_4 is divided into five blocks, each having 200RT .

[0051]

Fig. 4 is a table showing heat load distribution patterns generated by the heat load distribution pattern generating means 31. Here, a pattern number 401 is a serial number assigned to each heat load distribution pattern. A heat load distribution pattern 402 is a set of loads (distribution loads) distributed into respective heat source devices.

The heat load distribution pattern generating means 31 generates the heat load distribution pattern 402 for distributing the heat loads (200RT) in blocks to respective heat source devices.

[0052]

Next, the heat load distribution pattern generating means 31 obtains load factors 403 on the basis of the heat load distribution pattern 402. Here, the load factor of each heat source device is a factor obtained by dividing the distribution load into each heat source device by a maximum cooling capacity.

Here, it is assumed that a maximum cooling capacity of the inverter turbo refrigerator 11 is 1000RT, a maximum cooling capacity of the turbo refrigerator 12 is 500RT, and a maximum cooling capacity of the exhaust heat utilizing absorbing type water chiller-warmer 13 is 1000RT,

[0053]

Next, the heat load distribution pattern generating means 31 determines about operation possible/impossible 404.

The operation possible/impossible 404 indicates whether the heat load distribution pattern 402 can be operated in the heat source system S, in which the possibility of the operation is indicated with a circle of "○", the impossibility of the operation is indicated with a cross of "×".

As described earlier, the distribution of the heat load to respective heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) is proportional to a flow rate of the cool/hot water flowing into each heat source device (cool/hot water flow rate), i.e., a flow rate of each of the cooling and heating pumps 5a, 5b, 5c. Accordingly, the heat source devices have load factor ranges, providing possibility of operation for the heat devices (for example, 40% to 100%) in accordance with flow rate controllable ranges of the cooling and heating pumps 5a, 5b, 5c, respectively. In addition, a load factor of 0% (distribution load 0RT) indicates that the heat source device is stopped and is included in a load factor range, which is capable of operation.

[0054]

As described above, the heat load distribution pattern generating means 31 determines, when all of the heat source devices have operational

load factors in an operational range, that the heat load distribution pattern 402 is operational for the heat source system S (the operation possible/impossible 404 is determined to be "possible ○") and when at least one of the heat source devices has the load factor outside the operational load factor range, that the heat load distribution pattern 402 is operational for the heat source system S (the operation possible/impossible 404 is determined to be "impossible ×").

[0055]

Returning to Fig. 2, in step S103, the simulating means 32 of the control unit 30 obtains, as shown in Fig. 5, a value 504 of an evaluation function by extracting heat load distribution patterns which have been determined to be operational and perform simulation on the heat load distribution patterns.

[0056]

Here, to simplify the calculation in the simulating means 32, a description is made with assumption that the evaluation function corresponds to one of the heat source devices having a large ratio in the whole consumed energy of the heat source system S.

[0057]

First, the simulating means 32 obtains the COP of each heat source device regarding the heat load distribution patterns.

Fig. 6 shows charts showing a load factor-COP characteristic of each heat source device, wherein (a) is that of the inverter turbo refrigerator, (b) is that of the turbo refrigerator, and (c) is that of exhaust heat utilizing absorbing type water chiller-warmers. As shown in (a) to (c) in Fig. 6, the characteristics are different from each other in accordance with a type of the heat source device. The simulating means 32 converts the load factors 403 of the heat source devices (see Fig. 5) into the COPs of the heat source devices with the load factor-COP characteristics ((a) to (c) in Fig 6).

[0058]

Next, the simulating means 32 calculates consumed energy of each heat source device.

Here, the COP is a value obtained by dividing "heat load (distributed load of a heat source device)" by "a consumed energy of the heat source device". In other words, "consumed energy of the heat source device" is obtained by dividing "heat load (distributed load of a heat source device)" with the COP. The simulating means 32 can calculate a consumed energy of each heat source device in the heat load distribution patterns by dividing the distributed loads (see Fig. 5) of the heat load distribution pattern 402.

[0059]

Next, the simulating means 32 calculates the value 504 (see Fig. 5) of the evaluation function (consumed energy of the heat source system S).

Here, the inverter turbo refrigerator 11 and the turbo refrigerator 12 consume an electric energy (secondary energy) as an energy source. On the other hand, the exhaust heat utilizing absorbing type water chiller-warmer 13 consume the gas (secondary energy) as an energy source. Accordingly, an inverse of a conversion efficiency from the primary energy (for example, oil or natural gas) to the secondary energy (electric, gas) is obtained as a conversion coefficient, a consumption primary energy of each heat source device is obtained by multiplying the consumed energy of each heat source device by the conversion efficient, and the evaluation function (consumed energy in the heat source system S) is obtained by adding the consumed energies of respective load source devices.

As described above, the value 504 of the evaluation function is calculated for each heat load distribution pattern 402.

[0060]

Returning to Fig. 2, in step S104, the heat load distribution pattern extracting means 33 of the control unit 30 extracts one of the heat load distribution patterns 402 (see Fig. 5) providing a smallest of the value 504 of the evaluation function (see Fig. 5).

[0061]

In step S105, the operation control instructing means 34 controls the heat source system S to realize the heat load distribution pattern extracted

by the heat load distribution pattern extracting means 33.

[0062]

<Conclusion>

As described above, because the heat source system S according to the embodiment employs a concentrated heat source system, the distributing the heat load to respective heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) by controlling the flow rates of the cool/hot water to the cooling and heating pumps 5a, 5b, 5c. In addition, the heat load distribution pattern generating means 31, the simulating means 32, and the heat load distribution pattern extracting means 33 provides such a heat load distribution pattern that the evaluation function is minimized, the consumed energy can be reduced by operating the heat source system S to have the obtained heat load distribution pattern.

[0063]

In addition, there are numeral combinations of distribution of the heat load demanded quantities Q_4 (heat load distribution patterns) to three heat source devices in the heat load distribution pattern generating means 31. When the number of the heat load distribution patterns is large, this is unfavorable because a loss until the control is switched to an appropriate operation becomes large, the number of times of simulation increases with a result of long calculation time.

Accordingly, in step S102, simulation is made after the heat load demanded quantities Q_4 is divided by an appropriate number n (for example, $n = 5$ as shown in Fig. 3) and the divided quantities are distributed to respective heat source devices to reduce the number of times of simulation in the simulating means 32 at a rear stage to shorten the operation time to reduce the loss until the control is switched to an appropriate operation.

[0064]

In addition, if it is assumed that the number of the heat source

devices included in the heat source system S is r, and the number of dividing the heat load demanded quantity Q is n (in the embodiment, as shown in Fig. 1, r = 3 and n = 5 as shown in Fig. 3). A total of the heat load distribution patterns is given by:

$${}_{n+1}H_{r-1} = (n+r-1)! / (n! \cdot (r-1)!)$$

In other words, the maximum value of the number of times of simulation executed by step S103 described later is ${}_{n+1}H_{r-1}$. Accordingly, the number n of dividing is preferably determined as a total of the heat load distribution patterns that the control unit 30 can process.

[0065]

In addition, the description have been made with assumption that the evaluation function used in the simulation means 32 is of one of the heat source devices having a large ratio in the whole consumed energy of the heat source system S. However, the embodiment is not limited to this, but it may be allowed that the consumed energy of the whole of the heat source system S is used as the evaluation function, further considering consumed electric powers of the cooling and heating pumps 5a, 5b, 5c, the blower fans 8a, 8b, 8c, and the cool water pumps 9a, 9b, 9c.

[0066]

In addition, the description has been made with assumption that, when the simulating means 32 obtains the COP of each of the heat source devices, as shown in (a) to (c) in Fig. 6, the COP of each of the heat source devices is uniquely determined from the load factor. However, more specifically, the COP also depends on the cooling water inlet port temperature of the heat source device and a wet bulb temperature of the ambient air. Accordingly, in consideration of this circumstance, the simulating means 32 may be configured to obtain the COPs of the heat source devices.

[0067]

When a start-stop status of each of the heat source devices in the heat load distribution pattern simulated by the simulating means 32 is different from a current start-stop status, the start-stop will occur in each

heat source device in transition from the current heat load distribution pattern to the heat load distribution patterns being currently simulated. For example, there is a case where the inverter turbo refrigerator 11 and the turbo refrigerator 12 are in an operation status in the current heat load distribution pattern, the heat load distribution pattern is being simulated, and the inverter turbo refrigerator 11 and the exhaust heat utilizing absorbing type water chiller-warmer 13 are in operation statuses. In this status, when the heat load distribution pattern being simulated is applied to a control, stop of the turbo refrigerator 12 and start of the exhaust heat utilizing absorbing type water chiller-warmer 13 will occur.

[0068]

In the heat source system S, when the heat source device starts and stops, in a transient period to when a temperature status of the heat source system S and the status of the heat source device becomes constant statuses, there may occur a case where a large energy consumption is necessary for the heat load to be processed, which may result in a loss of the consumed energy.

Accordingly, when the start-stop status of each heat source device in the heat load distribution pattern being simulated is different from a current start-stop status of each heat source device, there may be a configuration providing an estimation in which a loss in a consumed energy caused by the stop-start of the heat source device is taken in an evaluation function by adding a correction value including a loss in the transition period to the evaluation function or the estimation function is multiplied by a correction coefficient including the loss in the transition period.

[0069]

<<Second embodiment>>

Next, the heat source system S according to a second embodiment will be described. The heat source system S according to the second embodiment is similar in configuration to the heat source system S according to the first embodiment (see Fig. 1) and a description will be

omitted. On the other hand, the heat source system S according to the second embodiment has a difference from the heat source system S according to the first embodiment in a process (process in step S102 in Fig. 2) of the heat load distribution pattern generating means 31 for generating the heat load distribution patterns and a process of the simulating means 32 for calculating the evaluation function (process of the step S103 in Fig. 2).

[0070]

<Distributing process of heat load to each heat source device>

The distribution process of the load to each heat source device in the heat source system S according to the second embodiment will be described with reference to Fig. 2. Here, the processes in steps S101, S104, S105 are the same as those of the heat source system S according to the first embodiment, and thus a duplicated description will be omitted.

[0071]

In step S102, the heat load distribution pattern generating means 31 generates the heat load distribution patterns for distributing the heat load demanded quantities Q_4 to the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13).

[0072]

Here the heat load distribution pattern generating means 31 generates the heat load distribution patterns by changing a load factor (%) of each of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) by, for example, 10%.

[0073]

Fig. 7 is a table showing the heat load distribution patterns generated by heat load distribution pattern generating unit 31 according to the second embodiment. Here, a pattern number 701 is a serial number assigned to each heat load distribution pattern (load factor pattern 702). A load factor pattern 702 is a set of the load factors of the heat source

devices. An operation possible/impossible 703 indicates whether the load factor pattern 702 is able to be operated in the heat source system S, wherein the "operation possible" is indicated with a circle (○) and "operation impossible" is indicated with a cross (×). In addition, when load factors of all the heat source devices are in a load factor range (for example, 0%, 40% to 100%), the operation possible/impossible 703 indicates "operation possible".

[0074]

A method of obtaining the heat load distribution patterns from the load factor pattern 702 will be described with reference to Fig. 8.

For example, when the load factor of the heat source device (inverter turbo refrigerator) 11 is 50%, the load factor of the heat source device (the turbo refrigerator) 12 is 60%, and the load factor of the heat source device (the exhaust heat utilizing absorbing type water chiller-warmer) 13 is 60%, as shown in Fig. 8, the heat load processed by each heat source device can be obtained from the maximum cooling capacity and the load factor of each heat source device. The obtained set of the heat loads processed by respective heat source devices corresponds to the heat load distribution patterns.

[0075]

The heat load distribution pattern generating means 31 extracts one from the load factor patterns 702 which are operational, one having a total of the heat load to be processed by each heat source device equivalent to the heat load demanded quantities Q_4 calculated in a step S101 and sends the one to the simulating means 32.

[0076]

In step S103, the simulating means 32 performs simulation about the load factor patterns 702 (heat load distribution patterns) to obtain a value of the evaluation function.

[0077]

Here, description will be made with assumption that the evaluation function of the simulating means 32 according to the second embodiment

corresponds to a running cost per hour (yen/h). The evaluation function is set as described above, so that the heat source system S can be operated with a minimized running cost.

[0078]

At first, the simulating means 32 obtains a consumed energy of the devices forming the heat source system S. In the embodiment, there are as devices consuming energy, the cooling and heating pumps 5a, 5b, 5c, the cooling water pump 9a, 9b, 9c, the blower fans 8a, 8b, 8c, the inverter turbo refrigerator 11, the turbo refrigerator 12 as devices consuming energy, and the exhaust heat utilizing absorbing type water chiller-warmer 13 consuming the gas.

[0079]

Here, the gas engine 14 also consumes the gas. The gas engine 14 is operated in accordance with an electric power demand of the electric power demanding source (not shown) which is different from the heat load demand of the heat load 4. The operating status of the gas engine 14 is inputted into the control unit 30.

[0080]

Consumed powers P [kW] of the cooling and heating pumps 5a, 5b, 5c, the cooling water pumps 9a, 9b, 9c, the blower fans 8a, 8b, 8c are calculated by:

$$P = PR \times (FR/100)^3 = PR \times (F/RF)^3 \quad \text{--- (2)}$$

Here, PR is a power consumption [kW] at the rated operation, FR is a flow rate ratio [%], F is a flow rate of a pump or a blow flow rate of a blower fun [m³/h], and RF is a flow rate of a pump or a blow flow rate of a blower fun [m³/h].

[0081]

Fig. 9 shows in (a) a table illustrating consumed powers of the heat source devices (the inverter turbo refrigerator 11 and the turbo refrigerator 12) consuming electric powers and in (b) a table illustrating a consumed gas of the heat source device (the exhaust heat utilizing absorbing type water chiller-warmer 13) consuming the gas.

The consumption energies (consumed electric power, consumed gas) of the heat source devices (the inverter turbo refrigerator 11, the turbo refrigerator 12, and the exhaust heat utilizing absorbing type water chiller-warmer 13) are calculated based on the table in which the load factor [%] and cooling water outlet port temperatures are parameters. In addition for interpolation of the data, a linear interpolation is used.

[0082]

As described above, the evaluation function (the running cost of the heat source system S) AF [yen/h] is given by Eq. (3).

$$AF = PSUM \times PC + GSUM \times GC \quad \text{--- (3)}$$

Here, PSUM is a total consumed power [kW], PC is an electric power cost [yen/kWh], GSUM is a total consumed gas [m³/h], GC is a gas cost [yen/(m³)]

[0083]

As described above, in the heat source system S according to the second embodiment, the heat load distribution pattern extracting means 33 extracts one of the heat load distribution patterns, providing a minimum evaluation function (the running cost of the heat source system S) and operates the heat source system S to have the extracted heat load distribution pattern so that the running cost of the heat source system S can be reduced.

[0084]

<<Modification>>

In addition, the heat source system S according to the embodiment is not limited to the configuration of the above-describe configuration, but may be modified without departure of the subject matter of the present invention.

[0085]

In the heat source system S according to the embodiment, the description has been made regarding a configuration in which the heat load 4 is a load source for supplying cool/ heat energy as a heat demand (for example, air conditioner performing a cooling operation) and the heat

source device functions as the refrigerator. However, the present invention is not limited to this. The configuration may be such that the heat load 4 is a load source (for example, an air conditioner performing a warming operation) as a heat demand and the heat source device functions as a heating device.

[0086]

The heat source system S has been described regarding a configuration that the heat source devices (refrigerators) having different characteristics are used in combination. However, the present invention is not limited to this. For example, a configuration may be such that the heat source devices (refrigerators) having the same characteristic are used in combination.

In addition, the number of the heat source devices (refrigerators) included in the heat source system S is not limited to three, but may be two or more than three.

[0087]

In addition, the heat source system S according to the embodiment has been described such that in the first embodiment as the evaluation function, the consumed energy (consumed energy of the whole of the heat source system S) is estimated and in the second embodiment, the running cost per hour (yen/h) is estimated. However, the present invention is not limited to this. The evaluation function may be, for example, the consumed energy of the whole of the heat source system S, the operation cost of the whole of the heat source system S, a quantity of carbon-dioxide emission from the heat source system S, etc.

[0088]

The heat source system S according to the embodiment has been described such that the simulating means 32 performs simulation about the heat load distribution patterns, which can be operated and a value of the evaluation function is obtained for all the operational heat load distribution pattern, values of evaluation function about all the operational heat load distribution patterns, and then, the heat load distribution pattern

extracting means 33 extracts one of the heat load distribution patterns minimizing the value of the evaluation function. However, the present invention is not limited to this. At first, the simulating means 32 performs simulation about an operational one of the heat load distribution patterns and when a value of the evaluation function obtained by the heat load distribution pattern extracting means 33 is equal to or lower than a predetermined value, the heat load distribution pattern is extracted. When the value is greater than the predetermined value, the simulating means 32 performs simulation on the heat load distribution patterns.

According to such a configuration, the number of times of simulation to obtain a favorable heat load distribution patterns can be more reduced than a case where the simulation is performed for all the heat load distribution patterns to shorten the operation time, so that the loss can be reduced until the control has been switched.

Description of reference code

[0089]

- S heat source system
- 1 first heat source unit
- 2 second heat source unit
- 3 third heat source unit
- 4 heat load
- 5a, 5b, 5c cooling and heating pump (carrying means)
- 6a cool/hot water supply header
- 6b cool/hot water return header
- 7a, 7b, 7c cooling tower
- 8a, 8b, 8c blower fan
- 9a, 9b, 9c cooling water pump
- 11 inverter turbo refrigerator (heat source device)
- 12 turbo refrigerator (heat source device)
- 13 exhaust heat utilizing absorbing type water chiller-warmer (heat source device)
- 14 gas engine

- 15 hot water discharging pump
- 30 control unit (control means)
- 31 heat load distribution pattern generating means (pattern generating means)
- 32 simulating means
- 33 heat load distribution pattern extracting means (pattern extracting means)
- 34 control instructing means (operation controlling means)
- 21a, 21b, 21c, 22a, 22b, 22c, 23a, 23b, 23c, 24 inverter
- 402 heat load distribution pattern
- 504 evaluation function

CLAIMS:

1. A heat source system comprising
 - at least two heat source devices;
 - carrying means for carrying a heat carrying medium from the heat source devices to a heat load; and
 - control means for controlling the heat source devices and the carrying means,wherein the control means comprises:
 - pattern generating means for generating a heat load distribution pattern for the respective heat source devices;
 - simulating means for calculating an evaluation function of the heat source system regarding the generated heat load distribution pattern;
 - pattern extracting means for extracting one of the heat load distribution patterns from the heat load distribution patterns generated by the pattern generating means on the basis of the evaluation function; and
 - operation controlling means for controlling the heat source device and the carrying means on the basis of the extracted one of the heat load distribution patterns.
2. The heat source system as claimed in claim 1, wherein the pattern extracting means extracts the one of the heat load distribution patterns providing a minimum of the evaluation function calculated by the simulating means.
3. The heat source system as claimed in any one of claims 1 and 2, wherein the operation controlling means controls the heat source devices and the carrying means to provide the extracted one of the heat load distribution patterns by control including an inverter control or a temperature control.
4. The heat source system as claimed in any one of claims 1 to 3, wherein

a consumed electric power of the heat source system is used as the evaluation function.

5. The heat source system as claimed in any one of claims 1 to 3, wherein a running cost of the heat source system is used as the evaluation function.

6. The heat source system as claimed in any one of claims 1 to 3, wherein the simulating means uses a quantity of carbon-dioxide emission of the heat source system as the evaluation function.

7. The heat source system as claimed in any one of claims 1 to 6, wherein the pattern generating means generates the heat load distribution pattern by dividing a total of load quantity of the heat load by the predetermined number of the heat source devices and distributing the total load quantity to the respective heat source devices at a unit of the divided load quantity.

8. The heat source system as claimed in any one of claims 1 to 6, wherein the pattern generating means generates the heat load distribution patterns by changing a load factor of each of the heat source devices at a predetermined interval.

9. A method of controlling a heat source system, including at least two heat source devices; and carrying means for carrying a heat carrying medium from the heat source devices to a heat load, wherein the method comprises:

 a generating step of generating a heat load distribution pattern to the respective heat source devices;

 a calculating step of calculating an evaluation function of the heat source system in the heat load distribution pattern generated in the generating step;

 an extracting step of extracting one of the heat load distribution

patterns from the heat load distribution patterns generated in the generating step on the basis of the evaluation function calculated by the calculating step; and

a control step of controlling the heat source device and the carrying means on the basis of the heat load distribution pattern extracted by the extracting step.

ABSTRACT

[Abstract]

In a heat source system including a plurality of heat source devices, a consumed energy, an operation cost, a quantity of carbon-dioxide emission, or the like is reduced.

A control unit (30) of a heat source system (S) includes heat load distribution pattern generating means (31) for generating a heat load distribution pattern for the heat source devices (11, 12, 13) simulating means (32) for calculating an evaluation function of the heat source system (S) in the generated heat load distribution pattern; heat load distribution pattern extracting means (33) for extracting one of the heat load distribution patterns from the heat load distribution patterns generated by the heat load distribution pattern generating means (31) on the basis of the evaluation function, and operation control instructing means (34) for controlling the heat source devices (11, 12, and 13), and the cooling and heating pumps (5a, 5b, 5c).