

DESCRIPTION

COLD SOURCE SYSTEM

5 Field of the invention

【0001】

The present invention relates to cold source systems.

Background Art

10 【0002】

Cold source systems have been widely known that have a plurality of cold source machines and supply cold energy to a heat load by providing the heat load with a heat transfer medium at a low temperature. As a background art of this technical field, Patent Literature 1, for example,
15 recites "When the number of inverter-driven turbo freezers 1c-1e is controlled by the controller 9 according to a requested heating value to be born by a plurality of inverter-driven turbo freezers 1c-1e, the controller 9 determines a load ratio range where a result factor becomes a predetermined value or more in the relation between the result factor of the
20 freezers 1c-1e determined depending on the temperature of cooling water detected by a thermometer t and a load ratio, and controls the inverters of the freezers 1c-1e so that the load ratios of the individual freezers 1c, 1d and 1e are within the determined load ratio range" (see Abstract).

25 Prior Art Document

Patent Document

【0003】

【Patent Literature 1】JP2005-114295A

30 Summary of the Invention

Problems to be Solved by the Invention

【0004】

A refrigerator included in a cold source system has such a relationship between a load ratio and a coefficient of performance (COP) that as the load ratio increases, the COP increases. Accordingly, when there is such a cold demand that the load ratio of the refrigerator decreases, cold energy stored beforehand in a cold storage tank is supplied to the load. This avoids operating the refrigerator at a low load ratio (i.e., a low COP operation), so that this configuration may save energy.

In addition, energy consumption characteristics of equipment (i.e., utility equipment such as a pump and a cooling tower) other than the refrigerator included in the cold source system change depending on operating conditions. Thus, the COP of the whole cold source system changes depending on an atmospheric wet-bulb temperature and an amount of heat load to be processed (i.e., a cold demand met by the heat load). When the cold demand varies and the atmospheric wet-bulb temperature fluctuates depending on a season and a time zone, the order of operation of the refrigerator may be changed in the cold source system including a plurality of refrigerators. At that time, the number of operated refrigerators and utility equipment is changed, so that the COP of the whole cold source system markedly shifts.

【0005】

In order to run such a cold source system at energy-saving mode, it is preferable to operate under operation conditions with a high COP.

However, an amount and rate of change in the wet-bulb temperature and the cold demand of the heat load vary depending on a season and a time zone. Consequently, the operation conditions with a high COP also vary. The cold source system including a plurality of refrigerators has a different operation priority for the refrigerators. Hence, it is difficult to keep a consistently high COP of the cold source system including a plurality of refrigerators.

For example, even the cold source system disclosed in Patent Literature 1 has difficulty controlling a plurality of freezers while keeping a high COP when a heat load is changed.

【0006】

5 It is an object of the present invention to provide a cold source system capable of controlling a plurality of refrigerators while keeping a high coefficient of performance.

Means to Solve the Problems

10 【0007】

 In order to solve the above problem, the present invention provides a cold source system including at least two sets of cold source machines with refrigerators. An aspect of the present invention provides a cold source system including: a simulation unit which calculates a coefficient of
15 performance of each of cold source machines; a priority-determining unit which determines an order of operation in such a manner that the higher maximum coefficient of performance the cold source machines have, the higher the priority of the operation is set to be; a schedule-determining unit which determines an operation schedule in such a manner that the cold
20 source machines with the higher priority are preferentially operated based on a prediction of a change in cold demand of a heat load; and an operation-controlling unit which operates the cold source machines based on the operation schedule.

25 Effect of the Invention

【0008】

 The present invention can provide a cold source system capable of controlling a plurality of refrigerators while keeping a high coefficient of performance.

30

Brief Description of the Drawings

【0009】

FIG. 1 illustrates how to configure a cold source system according to an embodiment of the present invention.

FIG. 2 illustrates functional blocks of a controller.

5 FIG. 3A is a graph showing varied evaluation functions of refrigerators with different modules. FIG. 3B is a chart showing refrigerator evaluation functions varied depending on a season.

10 FIG. 4 is a graph showing a change in cold demand and a graph showing a coefficient of refrigerator performance varied depending on the change.

FIG. 5 is a flow chart illustrating how to determine an operation schedule for a cold source system operated by an energy-saving cold-storage-and-release-schedule-determining unit.

15 FIG. 6 is a graph showing a time course of cold demand and an example of a cold-storage-operation target level STL and a cold-release-operation target level RTL which have been determined in accordance with the time course.

Mode(s) for Carrying out the Invention

20 【0010】

With reference to the appropriate drawings, the following details embodiments of the present invention.

Embodiments

25 【0011】

FIG. 1 illustrates how to configure a cold source system according to an embodiment of the present invention.

Hereinafter, a cold source machine refers to a refrigerator and utility equipment operated together with the refrigerator as a whole.

30 Note that FIG. 1 illustrates a cold source system including 3 sets of cold source machines. The number of cold source machines, however, is not

limited to 3. The cold source system may include 2 sets of cold source machines or may include 4 sets or more of cold source machines.

【0012】

As illustrated in FIG. 1, a cold source system 1 includes 3 sets (i.e., the first set 1a, the second set 1b, and the third set 1c) of cold source machines. A controller 13 controls each cold source machine.

In this embodiment, the first set 1a includes an inverter-driven turbo refrigerator 4a as a refrigerator; the second set 1b includes a turbo refrigerator 4b as a refrigerator; and the third set 1c includes a waste-heat-utilizing absorption water heater-chiller 4c as a refrigerator.

Note that a combination of the refrigerators included in the respective cold source machines is not limited to this combination.

【0013】

The first set 1a is a system in which the first cooling water W1a circulates by means of a cooling water pump 2a. The first set 1a includes utility equipment such as a cooling tower 5a (COOL) which cools the first cooling water W1a; a cooling fan 17a which sends air to the cooling tower 5a; an inverter 9a (INV) which drives the cooling fan 17a; and an inverter 10a (INV) which drives the cooling water pump 2a.

The rotation speed of the cooling fan 17a is changeable by inverter control. Preferably, an amount of cooling of the first cooling water W1a can be adjusted in the cooling tower 5a. In addition, a flow rate of the first cooling water W1a can be preferably adjusted by inverter control in the cooling water pump 2a.

【0014】

The second set 1b is a system in which the first cooling water W1b circulates by means of a cooling water pump 2b. The second set 1b includes utility equipment such as a cooling tower 5b (COOL) which cools the second cooling water W1b; a cooling fan 17b which sends air to the cooling tower 5b; an inverter 9b (INV) which drives the cooling fan 17b; and an inverter 10b (INV) which drives the cooling water pump 2b.

The rotation speed of the cooling fan 17b is changeable by inverter control. Preferably, an amount of cooling of the second cooling water W1b can be adjusted in the cooling tower 5b. In addition, a flow rate of the second cooling water W1b can be preferably adjusted by inverter control in the cooling water pump 2b.

5 【0015】

The third set 1c is a system in which the third cooling water W1c circulates by means of a cooling water pump 2c. The third set 1c includes utility equipment such as a cooling tower 5c (COOL) which cools the third cooling water W1c; a cooling fan 17c which sends air to the cooling tower 5c; an inverter 9c (INV) which drives the cooling fan 17c; and an inverter 10c (INV) which drives the cooling water pump 2c.

10 The rotation speed of the cooling fan 17c is changeable by inverter control. Preferably, an amount of cooling of the second cooling water W1c can be adjusted in the cooling tower 5c. In addition, a flow rate of the third cooling water W1c can be preferably adjusted by inverter control in the cooling water pump 2c.

15 Also, a gas engine 12 (ENG) is connected to the waste-heat-utilizing absorption water heater-chiller 4c. The gas engine 12 and a waste-water pump 16 connected to the gas engine 12 operate according to a power demand of a power demand source (not shown).

20 【0016】

In addition, the cold source system 1 includes a header 7a (Ha) for sending hot and cold water and a header 7b (Hb) for receiving hot and cold water. The header 7a for sending hot and cold water and the header 7b for receiving hot and cold water are each connected to a heat load 8 (L). The heat load 8 is a load source that generates a cold demand, and imparts heat to cold water W3 that is supplied via the header 7a from each cold source machine. Also, the heat load 8 returns the cold water W3 at a high temperature to each cold source machine by way of the header 7b.

30 【0017】

The header 7a is connected to the inverter-driven turbo refrigerator 4a of the first set 1a, the turbo refrigerator 4b of the second set 1b, and the waste-heat-utilizing absorption water heater-chiller 4c of the third set 1c. Meanwhile, the first hot and cold water W2a that has been cooled with the first cooling water W1a in the inverter-driven turbo refrigerator 4a, the second hot and cold water W2b that has been cooled with the second cooling water W1b in the turbo refrigerator 4b, and the third hot and cold water W2c that has been cooled with the third cooling water W1c in the waste-heat-utilizing absorption water heater-chiller 4c pass through the header 7a and merge into the cold water W3. Then, the cold water W3 is supplied to the heat load 8.

【0018】

In addition, the header 7b is connected to the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b and the waste-heat-utilizing absorption water heater-chiller 4c. Then, the cold water W3 that has become hot at the heat load 8 is sent as the first hot and cold water W2a from the header 7b to the inverter-driven turbo refrigerator 4a by using the hot and cold water pump 3a. An inverter 11a (INV) drives the hot and cold water pump 3a.

Also, the cold water W3 that has become hot at the heat load 8 is sent as the second hot and cold water W2b from the header 7b to the turbo-refrigerator 4b by using the hot and cold water pump 3b. An inverter 11b (INV) drives the hot and cold water pump 3b. Further, the cold water W3 that has become hot at the heat load 8 is sent as the third hot and cold water W2c from the header 7b to the waste-heat-utilizing absorption water heater-chiller 4c by using the hot and cold water pump 3c. An inverter 11c (INV) drives the hot and cold water pump 3c.

【0019】

In addition, the cold source system 1 of this embodiment includes, as a cold storage tank, a water storage tank 20 (TANK) that stores cold water W3.

The water storage tank 20 is a storage member that retains cold water W3 cooled in the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b, and the waste-heat-utilizing absorption water heater-chiller 4c and fed into the header 7a for sending hot and cold water. The water storage tank 20 is a device that stores cold energy by retaining the cold water W3.

The water storage tank 20 further includes a pump (i.e., a cold supply pump 21). Then, the cold energy (cold water W3) stored in the water storage tank 20 is supplied to the heat load 8 by means of the cold supply pump 21.

Note that the rotation speed of the cold supply pump 21 is preferably adjusted by, for example, inverter control. This configuration, for example, makes it possible for the controller 13 to adjust the rotation speed of the cold supply pump 21. Accordingly, the controller 13 can adjust a supply of the cold water W3 from the water storage tank 20 to the heat load 8.

【0020】

An inlet A1i and an outlet A1o for the first cooling water W1a of the inverter-driven turbo refrigerator 4a have thermometers 41a and 41b that measure temperatures of the first cooling water W1a. An inlet A2i and an outlet A2o for the first hot and cold water W2a of the inverter-driven turbo refrigerator 4a have thermometers 42a and 42b that measure temperatures of the first hot and cold water W2a.

An inlet B1i and an outlet B1o for the second cooling water W1b of the turbo refrigerator 4b have thermometers 51a and 51b that measure temperatures of the second cooling water W1b. An inlet B2i and an outlet B2o for the second hot and cold water W2b of the turbo refrigerator 4b have thermometers 52a and 52b that measure temperatures of the second hot and cold water W2b.

An inlet C1i and an outlet C1o for the third cooling water W1c of the waste-heat-utilizing absorption water heater-chiller 4c have thermometers 61a and 61b that measure temperatures of the third cooling water W1c. An inlet C2i and an outlet C2o for the third hot and cold water W2c of the

waste-heat-utilizing absorption water heater-chiller 4c have thermometers 62a and 62b that measure temperatures of the third hot and cold water W2c.

【0021】

5 In addition, the first set 1a includes flow meters 43 and 44 that measure flow rates of the first hot and cold water W2a and the first cooling water W1a flowing into the inverter-driven turbo refrigerator 4a. Also, the second set 1b includes flow meters 53 and 54 that measure flow rates of the second hot and cold water W2b and the second cooling water W1b flowing
10 into the turbo refrigerator 4b.

 Further, the third set 1c includes flow meters 63 and 64 that measure flow rates of the third hot and cold water W2c and the third cooling water W1c flowing into the waste-heat-utilizing absorption water heater-chiller 4c.

15 Furthermore, there are wet-bulb thermometers 45, 55, and 65 which measure atmospheric wet-bulb temperatures and relative humidity meters 46, 56, and 66 which measure atmospheric humidity (relative humidity) at or near the cooling towers 5a, 5b, and 5c, respectively.

【0022】

20 The controller 13 receives the respective measured values from the thermometers 41a, 41b, 42a, 42b, 51a, 51b, 52a, 52b, 61a, 61b, 62a, and 62b, the flow meters 43, 44, 53, 54, 63, and 64, the wet-bulb thermometers 45, 55, and 65, and the relative humidity meters 46, 56, and 66.

【0023】

25 FIG. 2 illustrates functional blocks of the controller 13.

 The controller 13 is a common controller including a CPU (Central Processing Unit), a ROM (Read Only Memory), a RAM (Random Access Memory), and a storage device (e.g., HDD: Hard Disk Drive) (not shown). For example, the CPU runs a program written in the ROM to fulfill
30 functions of each functional block.

【0024】

As illustrated in FIG. 2, the controller 13 of this embodiment includes, as functional blocks, a cold-source-system-controlling unit 31, a simulation unit 32, an energy-saving-operation-ranking unit 33, and an energy-saving cold-storage-and-release-schedule-determining unit 34.

5 A program run by the controller 13 incorporates functions of these functional blocks. Accordingly, the controller 13 runs the program to implement each functional block.

【0025】

10 The simulation unit 32 calculates an individual evaluation function of each cold source machine (i.e., the first set 1a, the second set 1b, or the third set 1c) based on input data. Further, in order to minimize the calculated evaluation function, the simulation unit 32 calculates a load ratio when each cold source machine operates alone.

15 In this embodiment, the evaluation function means "CO₂ emission per cold production (kg-CO₂/GJ). The evaluation coefficient of this evaluation function is a coefficient of CO₂ emission with regard to consumed energy (e.g., electric power, gas).

20 In this case, the evaluation function of each cold source machine (i.e., CO₂ emission per cold production) is represented by "CO₂ Emission / Cold Production". In addition, the coefficient of performance (COP) of each cold source machine is expressed as "Cold Production / Heat Consumption". Accordingly, the evaluation function is "CO₂ Emission / (COP x Heat Consumption)". This holds a correlation that the smaller the evaluation function, the higher the coefficient of performance (COP).

25 Hence, when the cold source machines operate to minimize the evaluation function, the coefficient of performance (COP) becomes higher in this embodiment.

【0026】

30 Note that data input into the simulation unit 32 are data indicating equipment information on the cold source system 1, including: a coefficient of CO₂ emission; data on cold demand prediction; an energy fee structure; equipment data on each cold source machine (i.e., the first set 1a, the second

set 1b, and the third set 1c) and utility equipment; and system data. The system data refers to data specifying a connection relationship between a refrigerator of each cold source machine (i.e., the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b, and the waste-heat-utilizing absorption water heater-chiller 4c) and utility equipment.

【0027】

FIG. 3A is a graph showing varied evaluation functions of refrigerators with different modules. FIG. 3B is a chart showing refrigerator evaluation functions varied depending on a season.

For example, the inverter-driven turbo refrigerator 4a (see FIG. 1) of the first set, the turbo refrigerator 4b (see FIG. 1) of the second set, and the waste-heat-utilizing absorption water heater-chiller 4c (see FIG. 1) of the third set have different characteristics. As illustrated in FIG. 3A, when each refrigerator has the same atmospheric wet-bulb temperature, each refrigerator has a different load ratio at which its evaluation function is minimum.

Further, as illustrated in FIG. 3B, the evaluation functions of the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b, and the waste-heat-utilizing absorption water heater-chiller 4c vary depending on a season (in particular, an atmospheric wet-bulb temperature of each cold source machine).

【0028】

Then, the simulation unit 32 outputs an evaluation function which represents energy consumption characteristics in each cold source machine and includes energy consumption in utility equipment. Thus, the simulation unit 32 evaluates the energy consumption characteristics of each cold source machine (i.e., each of the first set 1a, the second set 1b, and the third set 1c as shown in FIG. 1). Accordingly, the simulation unit 32 defines, as one set, each set having each cold source machine including each refrigerator (i.e., the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b, or the waste-heat-utilizing absorption water heater-chiller 4c) and utility equipment. Then, the simulation unit 32 determines the

evaluation function of each set (cold source machine). In this embodiment, the simulation unit 32 calculates the evaluation function of each cold source machine by using the following equation (1):

$$EF = (EP + EPUMP + EFAN) \times CEP + EG \times CEG \cdots (1),$$

EF: Evaluation Function (kg-CO₂/GJ);

EP: Power Consumption of Cold Source Machine (kWh);

EG: Gas Consumption of Cold Source Machine (m³N);

10 EPUMP: Power Consumption of Pump (kWh);

EFAN: Power Consumption of Cooling Tower Fan (kWh);

CEP: Coefficient of CO₂ Emission per Power (kg-CO₂/kWJ); and

CEG: Coefficient of CO₂ Emission per Gas (kg-CO₂/m³N).

15 【0029】

In addition, as illustrated in FIG. 3B, the evaluation function of each cold source machine varies depending on a season (i.e., a wet-bulb temperature). For example, each cold source machine has a coefficient corresponding to the wet-bulb temperature. Then, the evaluation function of each cold source machine is multiplied by the coefficient corresponding to the wet-bulb temperature.

It is preferable to preset such a coefficient as, for example, a designed value and/or a characteristic value of each cold source machine.

In view of the above, the evaluation function EF as so calculated using the equation (1) has parameters of a load ratio (LR) of each cold source machine and an atmospheric wet-bulb temperature (TWB), and can be expressed as the following equation (2):

$$EF = f(LR, TWB) \cdots (2),$$

30

LR: Load Ratio of Cold Source Machine (%); and

TWB: Atmospheric Wet-bulb Temperature (Degree).

The above equation (2) indicates that the evaluation function EF of each cold source machine changes depending on changes in the load ratio (LR) and the atmospheric wet-bulb temperature (TWB).

5 【0030】

In such a manner, the simulation unit 32 according to this embodiment optionally defines the wet-bulb temperature. In addition, while changing the load ratio of each cold source machine under the preset wet-bulb temperature, the simulation unit 32 calculates the evaluation function
10 of each cold source machine (i.e. the first set 1a, the second set 1b, and the third set 1c) based on the equation (1) and a coefficient corresponding to the wet-bulb temperature. Further, the simulation unit 32 calculates a controlling amount of each cold source machine so as to minimize the evaluation function.

15 Specifically, the simulation unit 32 simulates and changes the wet-bulb temperature and the load ratio, and calculates a load ratio of each cold source machine to minimize the evaluation function. Furthermore, the simulation unit 32 has a function to calculate a controlling amount when each cold source machine operates with the load ratio.

20 【0031】

An energy-saving-operation-ranking unit 33 determines a priority of operation of each cold source machine (i.e., the first set 1a, the second set 1b, and the third set 1c), and functions as a priority-determining unit.

That is, when each cold source machine operates with a controlling
25 amount to minimize the evaluation function calculated by the simulation unit 32, the energy-saving-operation-ranking unit 33 determines a priority of operation of each cold source machine in order to generate cold production in need and to minimize the evaluation functions of the cold source system
1.

30 【0032】

The atmospheric wet-bulb temperature and the load ratio of each cold source machine change depending on environment and operation

conditions of the cold source system 1 as illustrated in FIG. 1. For example, provided that the wet-bulb temperature is 17°C (during a midseason in Tokyo), the cold source system 1 having a plurality of cold source machines operated fails to have a markedly low load.

As an example, the inverter-driven turbo refrigerator 4a of the first set 1a, the turbo refrigerator 4b of the second set 1b, and the waste-heat-utilizing absorption water heater-chiller 4c of the third set 1c all have a capacity of 100 kW. In addition, the priority of operation is ranked in the order of the inverter-driven turbo refrigerator 4a, the turbo refrigerator 4b, and the waste-heat-utilizing absorption water heater-chiller 4c.

In this case, if only the inverter-driven turbo refrigerator 4a operates when the cold demand of the heat load 8 is 90 kW, the load ratio is 90%. If the inverter-driven turbo refrigerator 4a and the turbo refrigerator 4b operate when the cold demand of the heat load 8 is 100kW, the load ratio is 50%.

Accordingly, when the cold demand (load) of the heat load 8 fluctuates during operation of the cold source system 1, the load ratio can be changed in the range from 50 to 100%.

【0033】

In addition, the energy-saving-operation-ranking unit 33 of this embodiment compensates the cold source machine evaluation function $EF(f(LR, TWB))$ expressed as the equation (1) by using the atmospheric wet-bulb temperature (TWB) and the probability P of the load ratio as the following equation (3):

$$EF' = \Sigma(f(LR, TWB) \times LR \times P(LR, TWB)) / \Sigma LR \cdots (3),$$

EF': Evaluation Function of Cold Source Machine (kg-CO₂/GJ); and

P: Probability of Combination between Atmospheric Wet-bulb

Temperature TWB and Load Ratio LR.

The energy-saving-operation-ranking unit 33 compares how small the cold source machine evaluation function EF' expressed as the equation

(3) is. Then, the energy-saving-operation-ranking unit 33 determined the priority of each cold source machine in such a manner that the smaller the evaluation function EF', the higher the priority of operation of the cold source machine.

5 Note that the symbol " Σ " in the equation (3) denotes that all the combinations between the atmospheric wet-bulb temperature TWB and the load ratio LR of the cold source machine are integrated.

【0034】

10 In such a manner, the evaluation function EF of the cold source machine is compensated by the probability P of the combination between the atmospheric wet-bulb temperature (TWB) and the load ratio (LR).

Accordingly, the evaluation function EF' can be considered as an evaluation function in which the effects of changes in the evaluation function EF are taken into consideration in accordance with a season corresponding to a
15 specific day.

For example, if the season corresponding to the specific day is "summer", the wet-bulb temperature (TWB) is high. In addition, the probability P of the combination with a high load ratio (LR) is high.

Such a probability P is preferably predetermined based on, for
20 example, statistical data indicating a correlation between past weather data (wet-bulb temperatures) and a load ratio of the cold source machine.

【0035】

The energy-saving-operation-ranking unit 33 determines a priority of operation of each cold source machine and this priority is input to the
25 energy-saving cold-storage-and-release-schedule-determining unit 34. The energy-saving-operation-ranking unit determines the priority and the cold source system 1 (see FIG. 1) operates in accordance with a cold demand to be processed in the cold source machines. At that time, the energy-saving cold-storage-and-release-schedule-determining unit 34 determines an
30 operation schedule (i.e., a cold-storage-and-release schedule) for operating each cold source machine so as to minimize the evaluation function of the entire cold source system 1 (i.e., to maximize the coefficient of performance).

Thus, the energy-saving cold-storage-and-release-schedule-determining unit 34 of this embodiment functions as a schedule-determining unit.

Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 determines the evaluation function on energy consumption of the entire cold source system 1 when each cold source machine operates with an controlling amount to minimize the evaluation function of each cold source machine, which evaluation function has been calculated by the simulation unit 32, and operates with the priority ranked by the energy-saving-operation-ranking unit 33.

【0036】

FIG. 4 is a graph showing a change in cold demand and a graph showing a coefficient of refrigerator performance shifted depending on the change.

For example, as illustrated in FIG. 4, the cold demand of the heat load 8 (see FIG. 1) may change. At that time, the coefficient of performance (evaluation function) changes depending on how many cold source machines operate when the number of cold source machines operated is changed depending on changes in the cold demand.

【0037】

Note that, as illustrated in FIG. 4, the coefficient of performance (evaluation function) changes as the cold demand changes while keeping the same number of cold source machines operated. This is because the cold source system 1 (see FIG. 1) generally controls: influences on properties of each cold source machine (i.e., the first set 1a, the second set 1b, and the third set 1c) as shown in FIG. 1; a flow rate of cold water W3; flow rates of cooling water (i.e., the first cooling water W1a, the second cooling water W1b, and the third cooling water W1c); and temperatures of the cooling water at the outlets of the cooling towers 5a, 5b, and 5c. In addition, as the number of cold source machines operated increases, the coefficient of performance tends to be decreased (the evaluation function is increased). This is because the energy-saving-operation-ranking unit 33 determines the priority of operation of each cold source machine in such a manner that as

the evaluation function decreases (i.e., the coefficient of performance increases), the priority of the cold source machine becomes higher.

【0038】

In order to increase the coefficient of performance (COP) when the cold source system 1 shown in FIG. 1 operates, it is preferable to reduce CO₂ emission. That is, the cold source system 1 preferably operates so as to decrease the evaluation function of the entire cold source system 1 according to this embodiment. Here, as illustrated in FIG. 4, the energy-saving cold-storage-and-release-schedule-determining unit 34 according to this embodiment determines a load ratio (i.e., an optimal point) of cold source machines during operation in such a manner that their evaluation function becomes minimum when each different number of cold source machines (i.e., the first set 1a, the second set 1b, and the third set 1c) is used for operation. For example, when one set of cold source machine operates, the optimal point (i.e., the load ratio) is defined as PA1. When two sets of cold source machine operate, the optimal point (i.e., the load ratio) is defined as PA2. When three sets of cold source machine operate, the optimal point (i.e., the load ratio) is defined as PA3.

【0039】

The optimal point PA1 is when a single set of cold source machine operates, and gives a load ratio at which the cold source machine, whose evaluation function EF' on a particular day (in a particular season) is minimum, operates to achieve that evaluation function EF' (CO₂ emission). The optimal point PA2 is when two sets of cold source machines operate, and gives a total load ratio at which the two sets of cold source machines, whose minimum evaluation function EF' on a particular day (in a particular season) is smaller, operate to achieve a minimum evaluation function EF' for each cold source machine.

In addition, the optimal point PA3 is when three sets of cold source machines operate, and gives a total load ratio at which each cold source machine operates to achieve its minimum evaluation function EF' on a particular day (in a particular season).

【0040】

Note that the "PL1", "PL2", and "PL3" shown in FIG. 4 each denote a point different from the optimal point, indicating a load ratio at which each cold source machine operates. Their details are described below.

5 【0041】

Meanwhile, as for each different number of cold source machines operated, the energy-saving cold-storage-and-release-schedule-determining unit 34 as illustrated in FIG. 2 calculates a controlling amount of each cold source machine (i.e., a controlling amount of each refrigerator and utility equipment) operated with a load ratio at this optimal point (PA1, PA2, or PA3). Further, when cold production of each cold source machine as so operated is insufficient for a cold demand of the heat load 8 (see FIG. 1), cold energy stored in the water storage tank 20 (see FIG. 1) is used. Specifically, when the cold production of the cold source machines is insufficient for the cold demand of the heat load 8, the energy-saving cold-storage-and-release-schedule-determining unit 34 supplies the heat load 8 with the cold water W3, which has been stored in the water storage tank 20, by driving the cold supply pump 21 (see FIG. 1).

【0042】

20 For example, a map may be predetermined which indicates a relationship among: how much cold production of the cold source machines is insufficient for a cold demand of the heat load 8; how much cold water W3 is supplied to the heat load 8 from the water storage tank 20 by means of the cold supply pump 21; and what is a temperature of the cold water W3 stored in the water storage tank 20. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 can use the map and determine how much cold water W3 is supplied to the heat load 8 from the water storage tank 20, based on how much cold production of the cold source machines is insufficient for a cold demand of the heat load 8 and what is a temperature of the cold water W3 stored in the water storage tank 20.

30 In addition, for example, a map may be predetermined which indicates a relationship between how much cold water W3 is supplied to the

heat load 8 from the water storage tank 20 and how fast the cold supply pump 21 rotates. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 can use the map and determine how fast the cold supply pump 21 rotates in accordance with how much cold water W3 is supplied to the heat load 8 from the water storage tank 20. Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 is set to drive the cold supply pump 21 at the rotation speed as so determined.

【0043】

Note that the temperature of the cold water W3 stored in the water storage tank 20 may be set to a temperature of cooling water at the outlet of the cold source machine operated.

As an example, when one cold source machine of the first set 1a operates, the temperature of the cold water W3 stored in the water storage tank 20 is, for example, a temperature of the first hot and cold water W2a, which temperature is measured with the thermometer 42b at the outlet A2o of the inverter-driven turbo refrigerator 4a.

As another example, when two cold source machines of the first set 1a and the second set 1b operate, the temperature of the cold water W3 stored in the water storage tank 20 is, for example, an average of a temperature of the first hot and cold water W2a, which temperature is measured with the thermometer 42b at the outlet A2o of the inverter-driven turbo refrigerator 4a, and a temperature of the second hot and cold water W2b, which temperature is measured with the thermometer 52b at the outlet B2o of the turbo refrigerator 4b.

In addition, when three cold source machines of the first set 1a, the second set 1b, and the third set 1c operate, the temperature of the cold water W3 stored in the water storage tank 20 is, for example, an average of a temperature of the first hot and cold water W2a, which temperature is measured with the thermometer 42b at the outlet A2o of the inverter-driven turbo refrigerator 4a, a temperature of the second hot and cold water W2b, which temperature is measured with the thermometer 52b at the outlet B2o of the turbo refrigerator 4b, and a temperature of the third hot and cold

water W2c, which temperature is measured with the thermometer 62b at the outlet C2o of the waste-heat-utilizing absorption water heater-chiller 4c.

Alternatively, the water storage tank 20 may include a thermometer (not shown) which measures a temperature of the cold water W3.

5 **【0044】**

For example, as illustrated in FIG. 4, the energy-saving cold-storage-and-release-schedule-determining unit 34 operates one cold source machine when the cold demand is "H1". When the cold demand is less than "H1", the energy-saving cold-storage-and-release-schedule-determining unit 34 does
10 not operate the cold source machine and supplies the cold energy (cold water W3) stored in the water storage tank 20 to the heat load 8. In addition, the energy-saving cold-storage-and-release-schedule-determining unit 34 operates two cold source machines when the cold demand is "H2". Then, when the cold demand is less than "H2", the energy-saving cold-storage-and-
15 release-schedule-determining unit 34 operates one cold source machine, compensating an amount of cold energy that runs short in the cold energy supplied from the cold source machine by supplying the cold energy (cold water W3) stored in the water storage tank 20 to the heat load 8. Further, the energy-saving cold-storage-and-release-schedule-determining unit 34
20 operates three cold source machines when the cold demand is "H3". Then, when the cold demand is less than "H3", the energy-saving cold-storage-and-release-schedule-determining unit 34 operates two cold source machines, compensating an amount of cold energy that runs short in the cold energy supplied from the cold source machines by supplying the cold energy (cold
25 water W3) stored in the water storage tank 20 to the heat load 8.

That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 offsets the difference between the cold production of the cold source machines and the cold demand of the heat load 8 by using the cold energy stored in the water storage tank 20.

30 **【0045】**

However, when each cold source machine operates at the optimal point (i.e., PA1, PA2, or PA3) that minimizes its evaluation function, each

cold source machine has a narrow operable range. Consequently, the cold energy stored in the water storage tank 20 may not be used to compensate the shortage resulting from the cold demand of the heat load 8.

【0046】

5 In view of the above, the energy-saving cold-storage-and-release-schedule-determining unit 34 may have a configuration in which in addition to the optimal points (i.e., PA1, PA2, and PA3) with the minimum evaluation function and the highest coefficient of performance (COP), points (low load points) smaller than the load ratio with the highest coefficient of
10 performance are selected.

For example, the energy-saving cold-storage-and-release-schedule-determining unit 34 defines an additional low load point with a smaller load ratio than the optimal point with the smallest evaluation function of each cold source machine by a predetermined proportion (e.g., 10%).

15 Note that the value "10%" as described so as to define the low load point is an example, so that the low load point is not limited to this value. This value, for example, may be a designed value that is defined based on the configuration and required performance of the cold source system 1.

【0047】

20 Then, in the energy-saving cold-storage-and-release-schedule-determining unit 34, the load ratio when one cold source machine operates with the additional load ratio is set to a low load point PL1 as illustrated in FIG. 4. In addition, in the energy-saving cold-storage-and-release-schedule-determining unit 34, the total load ratio when two cold source machines
25 operate with the additional load ratio is set to a low load point PL2 as illustrated in FIG. 4. Further, in the energy-saving cold-storage-and-release-schedule-determining unit 34, the total load ratio when three cold source machines operate with the additional load ratio is set to a low load point PL3 as illustrated in FIG. 4.

30 In such a manner, the energy-saving cold-storage-and-release-schedule-determining unit 34 selects a load ratio to operate the cold source machines from the six load ratios including the load ratios at the optimal

points (PA1, PA2, and PA3) and the load ratios at the low load points (PL1, PL2, and PL3).

【0048】

FIG. 5 is a flow chart illustrating how to determine an operation schedule (i.e., a cold-storage-and-release schedule) on which the energy-saving cold-storage-and-release-schedule-determining unit operates the cold source system by running the cold source machines at a load ratio selected from the optimal points and the low load points.

The energy-saving cold-storage-and-release-schedule-determining unit 34 calculates, for example, a cold-storage-and-release schedule from 0 to 23 o'clock with a two-hour interval according to a procedure illustrated in FIG. 5.

Note that the interval with which the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule is not limited to 2 hours. The cold-storage-and-release schedule may be calculated with an interval of 2 hours or less or with an interval of 2 hours or more.

【0049】

Note that the energy-saving cold-storage-and-release-schedule-determining unit 34 may calculate, for example, a whole-day cold-storage-and-release schedule at a fixed time (e.g., 0 am) everyday.

【0050】

Once starting calculation of the cold-storage-and-release schedule, the energy-saving cold-storage-and-release-schedule-determining unit 34 determines (at Step S1) a cold storage period and a cold release period based on data which predict a time course of the cold demand (i.e., data on cold demand prediction).

In addition, the data on cold demand prediction are data which predict a time course of the cold demand per hour, based on a change per hour in the cold demand during the same hour in the past.

At this time, the energy-saving cold-storage-and-release-schedule-determining unit 34 preferably sets the cold storage period to a period (e.g.,

nighttime) with a presumably smaller cold demand, and preferably sets the cold release period to a period (e.g., daytime) with a presumably larger cold demand.

【0051】

5 Next, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates an average ALOAD per unit time of the cold demand (Step S2). As used herein, the term "unit time" refers to an interval with which the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule. For
10 example, when the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule with a two-hour interval, the unit time is 2 hours.

 The energy-saving cold-storage-and-release-schedule-determining unit 34 sets an average per unit time of the cold demand specified by the
15 data on cold demand prediction to the average ALOAD per unit time of the cold demand. The average ALOAD as so calculated is an indicator for the cold demand when the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule.

【0052】

20 In addition, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a target level when the cold source system 1 conducts cold storage operation (i.e., a cold-storage-operation target level, STL) and a target level when the cold source system 1 conducts cold release operation (i.e., a cold-release-operation target level, RTL) (Step S3). Then,
25 the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold-storage-operation target level STL and the cold-release-operation target level RTL to the optimal point (PA1, PA2, or PA3) or the low load point (PL1, PL2, or PL3).

 For example, the energy-saving cold-storage-and-release-schedule-determining unit 34 first determines the cold-storage-operation target level
30 STL and the cold-release-operation target level RTL. At that time, the cold production when one cold source machine operates with a load ratio at the

optimal point PA1 is assigned to the cold-storage-operation target level STL and the cold-release-operation target level RTL.

In this way, hereinafter, the phrase "(STL: PA1, RTL: PA1)" is used to denote and describe a condition under which the cold production when one cold source machine operates with a load ratio at the optimal point PA1 is assigned to the cold-storage-operation target level STL and the cold-release-operation target level RTL.

【0053】

Also, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a target time (Step S4). Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 determines whether the above time is within a period for cold release operation (i.e., a cold release period) or a period for cold storage operation (i.e., a cold storage period). At Step S4, the energy-saving cold-storage-and-release-schedule-determining unit 34 can select any time in a day (0 to 23 o'clock). For example, the energy-saving cold-storage-and-release-schedule-determining unit 34 selects "0 am" when first selecting the time.

After that, when the above time is within the cold storage period as so defined, the energy-saving cold-storage-and-release-schedule-determining unit 34 determines that the above time is within a period for cold storage operation (Step S5 -> Yes). When the above time is within the other period (i.e., a cold release period), the energy-saving cold-storage-and-release-schedule-determining unit 34 determines that the above time is within a period for cold release operation (Step S5 -> No).

【0054】

When the above time is within a cold storage period (Step S5 -> Yes), the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates cold production per unit time (SUPPLYHEAT), a cold storage amount (SHEAT), and a cold storage amount left in the water storage tank (i.e., a cold storage ratio, RATIO) (Step S6). In contrast, when the above time is within a cold release period (Step S5 -> No), the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates cold production

per unit time (SUPPLYHEAT), a cold release amount (RHEAT), and a cold storage amount left in the water storage tank 20 (i.e., a cold storage ratio, RATIO) (Step S7).

【0055】

5 At Step S6, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold production (SUPPLYHEAT), the cold storage amount (SHEAT), and the cold storage ratio (RATIO) by using the following equations (4) to (6):

10
$$\text{SUPPLYHEAT} = \text{STL} \dots (4),$$
$$\text{SHEAT} = \text{SUPPLYHEAT} \cdot \text{LOAD} \dots (5), \text{ and}$$
$$\text{RATIO} = ((\text{RATIO}'' \times \text{SCAP} + \text{SHEAT}) / \text{SCAP}) \times 100 \dots (6),$$

 wherein LOAD: Cold Demand of Heat Load;

15 RATIO'': Cold Storage Ratio Calculated Just Before Present Time;

and

 SCAP: Cold Storage Capacity of Water Storage Tank.

【0056】

20 In the energy-saving cold-storage-and-release-schedule-determining unit 34, the average ALOAD as calculated in Step S2 is an indicator for the cold demand (LOAD) of the heat load 8. For example, at the time determined at Step S4, data on cold demand prediction are used to predict that the water storage tank 20 may have a large cold storage amount. In
25 this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 adopts a level lower than the average (ALOAD) per unit time including the above time as a cold demand (LOAD) of the heat load 8 at the above time so as to avoid excessive storage of cold energy. For example, the cold storage amount of the water storage tank 20 may be predicted to be
30 more than a predetermined upper threshold. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold demand (LOAD) of the heat load 8 as the value "ALOAD x a1 / 100" in which

the average ALOAD is multiplied by a predetermined decrease rate (a1%: a1 < 100).

The predetermined upper threshold and the predetermined decrease rate (a1) may be, for example, designed values specified by the

configuration, etc., of the cold source system 1.

【0057】

In addition, the data on cold demand prediction at the time determined at Step S4 are used to predict that the water storage tank 20 may have a small cold storage amount. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates a level higher than the average (ALOAD) per unit time including the above time as a cold demand (LOAD) of the heat load 8. For example, the cold storage amount of the water storage tank 20 may be predicted to be less than a predetermined lower threshold. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold demand of the heat load 8 as the value "ALOAD x a2 / 100" in which the average ALOAD is multiplied by a predetermined increase rate (a2%: a2 > 100).

The predetermined lower threshold and the predetermined increase rate (a2) may be, for example, designed values specified by the

configuration, etc., of the cold source system 1.

【0058】

In contrast, when the determined time is within a cold release period (Step S5 -> No), the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates, at Step S7, the cold production (SUPPLYHEAT), the cold release amount (RHEAT), and the cold storage ratio (RATIO) by using the following equations (7) to (9):

$$\text{SUPPLYHEAT} = \text{RTL} \quad \dots (7),$$

$$\text{RHEAT} = \text{LOAD} - \text{SUPPLYHEAT} \quad \dots (8), \text{ and}$$

$$\text{RATIO} = ((\text{RATIO}'' \times \text{SCAP} - \text{RHEAT}) / \text{SCAP}) \times 100 \quad \dots (9).$$

【0059】

In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 adopts an average (ALOAD) per unit time including the above time determined at Step S4 as a cold demand (LOAD) of the heat load 8. When the determined time is within a cold release period, however, it is taken into consideration that the determined time is a period with a high energy fee such as an electric power charge. Accordingly, the energy-saving cold-storage-and-release-schedule-determining unit 34 may set a level lower than the average (ALOAD) to the cold demand (LOAD) of the heat load 8. For example, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold demand (LOAD) of the heat load 8 to the value "ALOAD x a3 / 100" in which the average ALOAD is multiplied by a predetermined decrease rate (a3: a3 < 100).

In this case, the predetermined decrease rate (a3) may be a rate specified by the configuration, etc. of the cold source system 1 and/or an energy fee (i.e., an electric power charge) as obtained from data on an energy fee structure at the above time.

【0060】

Note that when the cold storage ratio (RATIO) of the water storage tank 20 exceeds "1" during the cold storage period, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule so as to stop the cold storage operation. At that time, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates a cold storage time (STIME) and a cold storage amount (cold storage ratio, RATIO) by using the following equations (10) to (12):

$$\text{SHEAT}' = \text{SHEAT} - \text{SCAP} \times (\text{RATIO} - 100) / 100 \quad \dots (10),$$

$$\text{STIME} = (\text{SHEAT}' / \text{SHEAT}) \times 100 \quad \dots (11), \text{ and}$$

$$\text{RATIO}' = 100 \quad \dots (12),$$

wherein SHEAT': Recalculated Cold Storage Amount; and
RATIO': Recalculated Cold Storage Rate.

【0061】

When the time determined at Step S4 is not the final time of the day (e.g., 22 o'clock) (Step S8 -> No), the energy-saving cold-storage-and-release-schedule-determining unit 34 returns the process to Step S4. Meanwhile,
5 when the determined time is the final time (Step S8 -> Yes), the energy-saving cold-storage-and-release-schedule-determining unit 34 ends the calculation of the cold-storage-and-release schedule if the cold storage ratio is from "0" to "1" at all the times (Step S9 -> Yes). In contrast, if the cold storage ratio is not from "0" to "1" at all the times (Step S9 -> No), the
10 energy-saving cold-storage-and-release-schedule-determining unit 34 returns the process to Step S3 and continues calculating the cold-storage-and-release schedule.

【0062】

For example, when the unit time is 2 hours, the energy-saving cold-storage-and-release-schedule-determining unit 34 executes 12 times the
15 process from Step S4 to Step S8, and calculates the whole-day cold-storage-and-release schedule.

【0063】

In this way, the energy-saving cold-storage-and-release-schedule-determining unit 34 returns the process to Step S3. When the cold
20 production of one cold source machine during operation with a load ratio at the optimal point PA1 is set to a cold-storage-operation target level STL and a cold-release-operation target level RTL, that is, in the case of the status (STL: PA1, RTL: PA1), the cold production of the one cold source machine
25 during operation with a load ratio at the low load point PL1 is set to the cold-release-operation target level RTL while keeping the cold-storage operation target level STL constant. That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the levels to the status (STL: PA1, RTL: PL1).

30 【0064】

Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 further returns the process to Step S3. When the

status is set to the status (STL: PA1, RTL: PL1), the cold production of two cold source machines during operation with a load ratio at the optimal point PA2 (referred to as the cold production at the optimal point PA2; hereinafter, the same applies to other optimal points and low load points) is set to the cold-release-operation target level RTL while keeping the cold-storage-operation target level STL constant. That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the levels to the status (STL: PA1, RTL: PA2).

【0065】

In such a manner, whenever the energy-saving cold-storage-and-release-schedule-determining unit 34 returns the process to Step S3, the cold-release-operation target level RTL is changed from the cold production at the optimal point PA1 to the cold production at the low load point PL3 while keeping the cold-storage-operation target level STL constant. That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 changes the state from the status (STL: PA1, RTL: PA1) to the status (STL: PA1, RTL: PL3).

In this course, if the cold storage ratio is from "0" to "1" at all the times (Step S9 -> Yes), the energy-saving cold-storage-and-release-schedule-determining unit 34 completes the calculation of the cold-storage-and-release schedule. Then, when the cold storage ratio is from "0" to "1" at all the times, the cold-storage-operation target level STL and the cold-release-operation target level RTL at each time are set to operation target levels (i.e., cold production) at each time.

【0066】

In contrast, when the cold-release-operation target level RTL is changed until the cold production at the low load point PL3, the cold storage ratio may not be from "0" to "1" at all the times (Step S9 -> No). In this case, when the process is returned to Step S3, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold-storage-operation target level STL to the cold production at the low load point PL1 and sets the cold-release-operation target level RTL to the cold production at

the optimal point PA1. That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the levels to the status (STL: PL1, RTL: PA1).

In such a manner, the energy-saving cold-storage-and-release-schedule-determining unit 34 changes the cold-release-operation target level RTL from the cold production at the optimal point PA1 to the cold production at the low load point PL3 until the cold storage ratio is from "0" to "1" at all the times.

In this course, if the cold storage ratio is from "0" to "1" at all the times (Step S9 -> Yes), the energy-saving cold-storage-and-release-schedule-determining unit 34 completes the calculation of the cold-storage-and-release schedule. Then, when the cold storage ratio is from "0" to "1" at all the times, the cold-storage-operation target level STL and the cold-release-operation target level RTL at each time are set to operation target levels (i.e., cold production) at each time.

【0067】

In such a manner, the energy-saving cold-storage-and-release-schedule-determining unit 34 sequentially changes the cold-storage-operation target level STL and the cold-release-operation target level RTL from the cold production at the optimal point PA1 to the cold production at the low load point PL3. That is, the energy-saving cold-storage-and-release-schedule-determining unit 34 sequentially changes the status (STL: PA1, RTL: PA1) to the status (STL: PL3, RTL: PL3). Then, when the cold storage ratio is from "0" to "1" at all the times (Step S9 -> Yes), the cold-storage-and-release-schedule-determining unit 34 completes the calculation of the cold-storage-and-release schedule.

Then, when the cold storage ratio is from "0" to "1" at all the times, the cold-storage-operation target level STL and the cold-release-operation target level RTL at each time are set to operation target levels (i.e., cold production) at each time.

Note that even if the status is changed to the status (STL: PL3, RTL: PL3), the cold storage ratio may not be from "0" to "1" at all the times (Step

S9 -> No). At that time, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets each of the cold-storage-operation target level STL and the cold-release-operation target level RTL to the cold production at the low load point PL3. That is, the status is set to the status (STL: PL3, RTL: PL3).

5 【0068】

In such a manner, whenever the energy-saving cold-storage-and-release-schedule-determining unit 34 returns the process to Step S3, the combination of the cold production defined by the cold-storage-operation target level STL and the cold-release-operation target level RTL is sequentially changed. That is, the combination defined by the optimal points (PA1, PA2, and PA3) and the low load points (PL1, PL2, and PL3) is sequentially changed to execute Step S4 and the subsequent steps.

10 Then, when the cold storage ratio is from "0" to "1" at all the times (Step S9 -> Yes), the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold-storage-operation target level STL and the cold-release-operation target level RTL to operation target levels (cold production) of the cold source machines.

15 【0069】

20 As described above, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates the cold-storage-and-release schedule according to the procedure illustrated in the flow chart of FIG. 5.

25 Then, when the cold storage ratio is from "0" to "1" at all the times, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold-storage-operation target level STL and the cold-release-operation target level RTL to operation target levels (cold production) of the cold source machines at each time. After that, the energy-saving cold-storage-and-release-schedule-determining unit 34 informs the cold-source-system-controlling unit of the determined cold-storage-operation target level STL and the cold-release-operation target level RTL.

30 The cold-source-system-controlling unit 31 calculates a controlling amount of each cold source machine (the first set 1a, the second set 1b, and

the third set 1c) based on the informed cold-storage-operation target level STL and the cold-release-operation target level RTL, and controls each cold source machine by using the controlling amount calculated. That is, in this embodiment, the cold-source-system-controlling unit 31 functions as an operation-controlling unit for operating each cold source machine.

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【0070】

FIG. 6 is a graph showing a time course of cold demand and an example of a cold-storage-operation target level STL and a cold-release-operation target level RTL which have been determined in accordance with the time course.

10

For example, the solid line in FIG. 6 denotes a prediction about a change in cold demand. In this case, the energy-saving cold-storage-and-release-schedule-determining unit 34 (see FIG. 2) determines the cold-storage-operation target level STL and the cold-release-operation target level RTL as indicated using the dashed lines.

15

The energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold storage period to the time before T1 and the time after T2, and sets a cold release period to the time between T1 and T2. Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets the cold-storage-operation target level during the cold storage period to the low load point PL2 which indicates operation of two cold source machines.

20

The cold-source-system-controlling unit 31 operates, with a load ratio at the low load point PL2, two cold source machines with a higher operation priority.

During the cold storage period, an amount of cold energy designated by oblique lines are stored in the water storage tank 20 (see FIG. 1) by operation of the cold source machines.

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【0071】

Note that FIG. 6 describes, as an example, that the cold-storage-operation target level STL is the same throughout the cold storage period. However, the cases are not limited to this example. The cold-storage-

30

operation target level STL may vary at each time during the cold storage period.

【0072】

During a cold release period (i.e., the time from T1 to T2), the
5 energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold-release-operation target level RTL, for example, during the time from T1 to T11 to cold production at the optimal point PA1 while operating one cold source machine. Next, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold-release-operation target level RTL
10 during the time from T11 to T12 to cold production at the optimal point PA2 while operating two cold source machines.

Then, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold-release-operation target level RTL during the time from T12 to T13 to cold production at the low load point PL3 while
15 operating three cold source machines. In addition, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold-release-operation target level RTL during the time from T13 to T15 to cold production at the optimal point PA2 while operating two cold source machines.

20 Further, the energy-saving cold-storage-and-release-schedule-determining unit 34 sets a cold-release-operation target level RTL during the time from T15 to T2 to cold production at the low load point PA1 while operating one cold source machine.

【0073】

25 During the time from T1 to T11, the cold-source-system-controlling unit 31 operates, with a load ratio at the optimal point PA1, one cold source machine with the highest operation priority. During the time from T11 to T12, the cold-source-system-controlling unit 31 operates, with a load ratio at the optimal point PA2, two cold source machines with a higher operation
30 priority.

In addition, during the time From T12 to T13, the cold-source-system-controlling unit 31 operates, with a load ratio at PL3, three cold source

machines. During the time from T13 to T15, the cold-source-system-controlling unit 31 operates, with a load ratio at the optimal point PA2, two cold source machines with a higher operation priority.

Further, during the time from T15 to T2, the cold-source-system-controlling unit 31 operates, with a load ratio at the optimal point PA1, one cold source machine with the highest operation priority.

【0074】

During the cold release period (from T1 to T2), cold energy corresponding to cold production generated during operation of the cold source machines is supplied to the heat load 8 (see FIG. 1), and is consumed as cold demand. Further, the controller 13 controls the cold source system 1 in such a manner that an amount of cold energy, by which the cold production is insufficient for the cold demand, is compensated by an amount of cold energy supplied through the water storage tank 20 (see FIG. 1) (i.e., a cold release amount of the water storage tank).

Specifically, the controller 13 (see FIG. 1) determines a supply amount of cold water W3 in such a manner that an amount of cold energy, by which the cold production is insufficient for the cold demand, is supplied from the water storage tank 20 to the heat load 8. Further, the controller 13 controls the cold supply pump 21 (see FIG. 1) so as to supply the determined amount of the cold water W3 from the water storage tank 20 to the heat load 8.

【0075】

An amount of cold energy (corresponding to cold production) generated during operation of the cold source machines and an amount of cold energy (corresponding to a cold release amount of the cold storage tank) stored in the water storage tank 20 (see FIG. 1) are supplied to the heat load 8 (see FIG. 1), and are consumed as cold demand.

【0076】

As described above, the cold source system 1 according to this embodiment includes three cold source machines of the first set 1a, the second set 1b, and the third set 1c as illustrated in FIG. 1. Depending on a

change in cold demand and an atmospheric wet-bulb temperature, the controller 13 included in the cold source system 1 determines a priority to operate the cold source machines so as to maximize the coefficient of performance (COP) of the cold source system 1.

5 In addition, based on the determined priority of the cold source machines and data on cold demand prediction which predicts a change in cold demand, the controller 13 determines an operation schedule (i.e., a cold-storage-and-release schedule) for operating the cold source system 1 (including three cold source machines) so as to maximize the coefficient of
10 performance (COP) of the whole cold source system 1. Further, the controller 13 runs the three cold source machines based on the cold-storage-and-release schedule determined.

【0077】

Such a configuration can be used to operate, with a high coefficient
15 of performance, the cold source system 1 including three cold source machines.

Specifically, in the cold source system 1 according to this embodiment, the cold-storage-and-release schedule for operating the cold source system 1 can be determined based on the data on cold demand
20 prediction. As a result, the cold source system 1 can be operated in accordance with a change in cold demand of the heat load 8 while keeping a high coefficient of performance.

【0078】

Note that the present invention is not limited to the above
25 embodiments and their modified embodiments. For example, the above embodiments detail the present invention for clarity purposes. The present invention is therefore not necessarily limited to embodiments having all the elements as described above.

In addition, parts of elements of one embodiment can be replaced by
30 those of another embodiment. Further, elements of one embodiment can be added to those of another embodiment.

【0079】

For example, the number of the cold source machines is not limited to 3. The present invention can apply to a cold source system 1 (see FIG. 1) having 4 or more cold source machines.

In this case, the controller 13 may calculate the evaluation function EF' for all the cold source machines by using the equation (3). Then, the controller 13 may determine a priority of operation of the cold source machines in ascending order of the evaluation function EF'.

【0080】

In addition, in the above embodiment, each cold source machine is provided with one additional low load point. Thus, three cold source machines have three low load points (i.e., PL1, PL2, and PL3). However, each cold source machine may be provided with two or more low load points.

Alternatively, without a low load point, each cold source machine may be operated with a load ratio based on each optimal point (i.e., PA1, PA2, or PA3).

【0081】

Meanwhile, in the above embodiment, the energy-saving cold-storage-and-release-schedule-determining unit 34 calculates a whole-day cold-storage-and-release schedule at a fixed time (e.g., 0 am) everyday. The present invention, however, is not limited to this configuration.

For example, the energy-saving cold-storage-and-release-schedule-determining unit 34 may calculate a whole-month cold-storage-and-release schedule at a fixed time (e.g., 0 am) on a particular day (e.g., the first day) every month.

In this configuration, the energy-saving cold-storage-and-release-schedule-determining unit 34 preferably repeats the procedure illustrated in the flow chart of FIG. 5 for the whole month.

【0082】

Note that the present invention is not limited to the above embodiments, and may be appropriately modified within an extent not departing from the scope of the present invention.

Description of Reference numerals

【0083】

- 1 Cold source system
- 1a First set (Cold source machine)
- 1b Second set (Cold source machine)
- 5 1c Third set (Cold source machine)
- 4a Inverter-driven turbo refrigerator (Refrigerator)
- 4b Turbo refrigerator (Refrigerator)
- 4c Waste-heat-utilizing absorption water heater-chiller
(Refrigerator)
- 10 13 Controller
- 20 Water storage tank (Cold storage tank)
- 21 Cold supply pump
- 31 Cold-source-system-controlling unit (Operation-controlling unit)
- 32 Simulation unit
- 15 33 Energy-saving-operation-ranking unit (Priority-determining
unit)
- 34 Energy-saving cold-storage-and-release-schedule-determining
unit (Schedule-determining unit)
- W3 Cold water
- 20

CLAIMS

1. A cold source system comprising:

at least two cold source machines having a refrigerator;

a simulation unit which calculates a coefficient of performance of
5 each of the cold source machines;

a priority-determining unit which determines an order of operation
in such a manner that the higher maximum coefficient of performance the
cold source machines have, the higher the priority of the operation is set to
be;

10 a schedule-determining unit which determines an operation
schedule in such a manner that the cold source machines with the higher
priority are preferentially operated based on a prediction of a change in cold
demand of a heat load; and

an operation-controlling unit which operates the cold source
15 machines based on the operation schedule.

2. The cold source system according to Claim 1, further comprising a
cold storage tank which stores cold energy produced by the cold source
machines,

20 wherein the schedule-determining unit determines the operation
schedule so as to operate the cold source machines at predetermined load
ratios including load ratios with the highest coefficient of performance and
so as to offset a difference between cold production of the cold source
machines and the cold demand of the heat load by using the cold energy
25 stored in the cold storage tank.

3. The cold source system according to Claim 2, wherein the schedule-
determining unit determines the operation schedule so as to operate the cold
source machines at the predetermined load ratios including the load ratios
30 with the highest coefficient of performance during each of a cold release
period when the cold demand is generated in the heat load and a cold
storage period when the cold production of the cold source machines are

stored in the cold storage tank.

4. The cold source system according to Claim 2, wherein the cold storage tank is a water storage tank which stores cold water cooled in the cold source machines.

5. The cold source system according to Claim 3, wherein the cold storage tank is a water storage tank which stores cold water cooled in the cold source machines.

6. The cold source system according to Claim 4 or 5, further comprising a cold supply pump which supplies the cold water stored in the water storage tank to the heat load,

wherein the cold supply pump can adjust a supply amount of the cold water supplied to the heat load.

7. The cold source system according to any one of Claims 1 to 5, wherein the schedule-determining unit determines the operation schedule based on predetermined prediction data which predict a change in the cold demand.

8. The cold source system according to Claim 6, wherein the schedule-determining unit determines the operation schedule based on predetermined prediction data which predict a change in the cold demand.