the cooling load to be processed, the low-temperature side refrigerator is operated under a rated condition, and the high-temperature side refrigerator is operated under a partial cooling-load condition. That is, the refrigerators are not operated in an energy saving manner corresponding to the cooling load. In addition, the cold water pump, the cooling-water pump, and the cooling-tower fans in the conventional tandem-refrigerator type cold generation apparatuses are not operated in an energy saving manner corresponding to the condition of the outside air (e.g., the wet-bulb temperature).

[0005]

In the above situation, establishment of an operation control system for operating the tandem-refrigerator type cold generation apparatus in an energy saving manner corresponding to the cooling load and the condition of the outside air is demanded.

[0006]

Embodiments of tThe present invention havechas been developed in view of the above circumstances. EmbodimentsThe object of the present invention seekis to provide an operation control system for operating the tandem-refrigerator type cold generation apparatus, which can reduce the total energy consumption in the cold generation apparatus according to the cooling load and the condition of the outside air.

MEANS FOR SOLVING THE PROBLEMS

[0007]

According to the first aspect of the present invention~~ (as indicated in the appended claim 1)~~, there is provided an operation control system for a cold generation apparatus ~~is provided for achieving the aforementioned object. The cold generation apparatus~~ includesing: cold-water piping through which cold water is supplied to an external load apparatus; a plurality of heat-pump type refrigerators which are arranged in series along the cold-water piping, and each has an evaporator and a condenser for cooling the cold water; a cold-water pump which supplies the cold water returned from the external load apparatus, to the external load apparatus through the refrigerators so that the cold water is cooled in the evaporator in each of the refrigerators; cooling-water pumps which are respectively arranged in correspondence with the refrigerators for supplying cooling water to the condenser in the refrigerators through cooling-water piping; and cooling towers which are respectively arranged for the refrigerators, and respectively have cooling-tower fans for cooling the cooling water with outside air. The operation control system includes: acquisition means which acquires a wet-bulb temperature of

the outside air taken into the cooling towers by the cooling-tower fans, a refrigeration load ratio as a ratio of an actual refrigeration load to a sum of preset values of refrigeration performance of the refrigerators, and a cold-water flow ratio as a ratio of an actual flow rate of the cold-water to a rated flow rate of the cold water; a simulator which performs a simulation for determining an optimum value of a cooling-water flow ratio as a flow ratio between the cooling-water pumps corresponding to the refrigerators, an optimum value of an air flow ratio as a ratio between flow rates in the cooling-tower fans in the cooling towers, and an optimum value of a load sharing ratio as a ratio in which the refrigeration load ratio is shared (i.e., the actual refrigeration load is shared) by the refrigerators, by calculating a coefficient of performance of the entire cold generation apparatus on the basis of arbitrary load sharing ratios inputted as a variable, under a condition determined by the wet-bulb temperature, the refrigeration load ratio, and the cold-water flow ratio which are acquired by the acquisition means, where the optimum value of the cooling-water flow ratio, the optimum value of the air flow ratio, and the optimum value of the load sharing ratio maximize a coefficient of performance (COP) of the cold generation apparatus; and control means which controls the cold-water pump on the basis of the cold-water flow ratio, controls temperatures of the cold water at outlets of the refrigerators on the basis of the optimum value of the load sharing ratio, and controls the cooling-water pumps and the cooling-tower fans in the cooling towers on the basis of the optimum value of the cooling-water flow ratio and the optimum value of the air flow ratio.

[0008]

As described above, in the above cold generation apparatus to which the operation control system according to the first aspect of the present invention is applied, a cooling-water pump and a cooling-tower fan are provided for each of the refrigerators.

[0009]

In the above operation control system, the control means controls the cold-water pump of each refrigerator on the basis of the cold-water flow ratio. In addition, the simulator performs a simulation for determining an optimum value of the cooling-water flow ratio, an optimum value of the air flow ratio, and an optimum value of the load sharing ratio which maximize the COP of the entire cold generation apparatus, where the cooling-water flow ratio is a flow ratio between the cooling-water pumps corresponding to the refrigerators, the air flow ratio is a ratio between air flow rates in the cooling-tower fans in the cooling towers, and the load sharing ratio is a ratio in which the actual refrigeration load is shared by the refrigerators. Herein, the cooling-water flow ratio, the air flow ratio, and the load sharing ratio are variables in

the control table, so that the simulation load can be remarkably reduced.

[0018]

Further, in the operation control system for the cold generation apparatus according to the first aspect of the present invention, it is preferable that the operation control system further include a first inverter which enables change of a rotational frequency of the cold-water pump, second inverters which enable change of rotational frequencies of the cooling-water pumps, and third inverters which enable change of rotational frequencies of the cooling-tower fans, and the control means control through the first inverter, the second inverters, the third inverters the rotational frequencies of the cold-water pump, the cooling-water pumps, and the cooling-tower fans by converting the optimum value of the cold-water flow ratio, the optimum value of the cooling-water flow ratio, and the optimum value of the air flow ratio into inverter frequencies, and outputting the inverter frequencies to the first inverter, the second inverters, and the third inverters.

[0019]

In this case, it is possible to further reduce the power consumption in the cold generation apparatus by controlling the rotational frequencies of the cold-water pump, the cooling-water pumps and the cooling-tower fans through the invertors.

[0020]

Furthermore, in the operation control system for the cold generation apparatus according to the first aspect of the present invention, it is preferable that when one or more of the refrigerators shares 0% of the actual refrigeration load according to the optimum value of the load sharing ratio, the control means stop operation of the one or more of the refrigerators, and operation of one or more of the cooling-water pumps and one or more of the cooling-tower fans corresponding to the one or more of the refrigerators. In this case, the power consumption in the cold generation apparatus can be further reduced.

[0021]

According to the second aspect of the present invention ~~(as indicated in the appended claim 5)~~, there is provided an operation control system for a cold generation apparatus ~~is provided for achieving the aforementioned object. The cold generation apparatus~~ includ~~e~~sing: cold-water piping through which cold water is supplied to an external load apparatus; a plurality of heat-pump type refrigerators which are arranged in series along the cold-water piping, and each have an evaporator and a condenser for cooling the cold water; a cold-water pump which supplies the cold water returned from the external load apparatus, to the external load apparatus through the refrigerators so that the cold

water is cooled in the evaporator in each of the refrigerators; at least one cooling tower which is arranged for the refrigerators, having a cooling-tower fan for cooling cooling water with outside air; and cooling-water pumps which are respectively arranged in correspondence with the refrigerators for distributing the cooling water cooled in the cooling tower, to the refrigerators through cooling-water piping, so that the cooling water cooled in the cooling tower is supplied to the condenser in each of the refrigerators. The operation control system includes: acquisition means which acquires a wet-bulb temperature of the outside air taken into the cooling tower by the cooling-tower fan, a refrigeration load ratio as a ratio of an actual refrigeration load to a sum of preset values of refrigeration performance of the refrigerators, and a cold-water flow ratio as a ratio of an actual flow rate of the cold-water to a rated flow rate of the cold water; a simulator which performs a simulation for determining an optimum value of a cooling-water flow ratio as a flow ratio between the cooling-water pumps corresponding to the refrigerators, an optimum value of an air flow rate in the cooling-tower fan in the cooling tower, and an optimum value of a load sharing ratio as a ratio in which the actual refrigeration load is shared by the refrigerators, by calculating a coefficient of performance of the entire cold generation apparatus on the basis of arbitrary load sharing ratios inputted as a variable, under a condition determined by the wet-bulb temperature, the refrigeration load ratio, and the cold-water flow ratio which are acquired by the acquisition means, where the optimum value of the cooling-water flow ratio, the optimum value of the air flow rate, and the optimum value of the load sharing ratio maximize a coefficient of performance of the cold generation apparatus; and control means which controls the cold-water pump on the basis of the cold-water flow ratio, controls temperatures of the cold water at outlets of the refrigerators on the basis of the optimum value of the load sharing ratio, and controls the cooling-water pumps and the cooling-tower fan in the cooling tower on the basis of the optimum value of the cooling-water flow ratio and the optimum value of the air flow rate.

[0022]

As described above, in the above cold generation apparatus to which the operation control system according to the second aspect of the present invention is applied, at least one cooling tower is provided for multiple refrigerators, and the cooling water cooled by the cooling-tower fan in the cooling tower is distributed to the multiple refrigerators by using the cooling-water pumps corresponding to the multiple refrigerators. In this case, the simulator in the operation control system according to the second aspect of the present invention can perform the simulation in a similar manner to the simulator in the operation control system according to the first aspect of the present invention, except that "the air flow ratio between the cooling-tower fans"

in the first aspect of the present invention should be replaced with "the air flow rate in the cooling-tower fan".

[0023]

According to the third aspect of the present invention ~~(as indicated in the appended claim 6)~~, there is provided an operation control system for a cold generation apparatus ~~is provided for achieving the aforementioned object. The cold generation apparatus~~ includesing: cold-water piping through which cold water is supplied to an external load apparatus; a plurality of heat-pump type refrigerators which are arranged in series along the cold-water piping, and each have an evaporator and a condenser for cooling the cold water; a cold-water pump which supplies the cold water returned from the external load apparatus, to the external load apparatus through the refrigerators so that the cold water is cooled in the evaporator in each of the refrigerators; a cooling tower which is arranged for the refrigerators, and has a cooling-tower fan for cooling cooling water with outside air; and a cooling-water pump which is arranged for supplying the cooling water cooled in the cooling tower, to the refrigerators from a high-temperature side to a low-temperature side in succession through cooling-water piping, so that the cooling water cooled in the cooling tower is supplied to the condenser in each of the refrigerators. The operation control system includes: acquisition means which acquires a wet-bulb temperature of the outside air taken into the cooling tower by the cooling-tower fan, a refrigeration load ratio as a ratio of an actual refrigeration load to a sum of preset values of refrigeration performance of the refrigerators, and a cold-water flow ratio as a ratio of an actual flow rate of the cold-water to a rated flow rate of the cold water; a simulator which performs a simulation for determining an optimum value of a cooling-water flow rate in the cooling-water pump, an optimum value of an air flow rate in the cooling-tower fan in the cooling tower, and an optimum value of a load sharing ratio as a ratio in which the actual refrigeration load is shared by the refrigerators, by calculating a coefficient of performance of the entire cold generation apparatus on the basis of arbitrary load sharing ratios inputted as a variable, under a condition determined by the wet-bulb temperature, the refrigeration load ratio, and the cold-water flow ratio which are acquired by the acquisition means, where the optimum value of the cooling-water flow rate, the optimum value of the air flow rate, and the optimum value of the load sharing ratio maximize a coefficient of performance of the cold generation apparatus; and control means which controls the cold-water pump on the basis of the cold-water flow ratio, controls temperatures of the cold water at outlets of the refrigerators on the basis of the optimum value of the load sharing ratio, and controls the cooling-water pump and the cooling-tower fan in the cooling tower on the basis of the optimum value of the cooling-water flow rate and the optimum value of the air flow rate.

can be reduced.

EFFECT OF THE INVENTION

[0028]

According to embodiments of the present invention, the tandem-refrigerator type cold generation apparatus can be controlled in such a manner that the power consumption in the entire cold generation apparatus is reduced in correspondence with the cooling load and the condition of the outside air. Therefore, it is possible to provide an operation control system for a cold generation apparatus, the system capable of more remarkably reducing the power consumption than conventional systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 is a diagram illustrating configurations of a cold generation apparatus and an operation control system for the cold generation apparatus according to a first embodiment of the present invention;

FIG. 2 is a diagram illustrating configurations of a cold generation apparatus and an operation control system A for the cold generation apparatus as a first variation of the first embodiment of the present invention;

FIG. 3 is a diagram illustrating configurations of a cold generation apparatus and an operation control system for the cold generation apparatus as a second variation of the first embodiment of the present invention;

FIG. 4 is a diagram illustrating configurations of a cold generation apparatus and an operation control system for the cold generation apparatus as a third variation of the first embodiment of the present invention;

FIG. 5 is a diagram indicating a sequence of operations for a simulation performed by a simulator;

FIG. 6 is a diagram illustrating an example of a part of a control table, in which the optimum value of the relative cooling-water flow rate in a high-temperature side cooling-water pump is indicated in correspondence with the refrigeration load ratio and the wet-bulb temperature;

FIG. 7 is a diagram illustrating an example of a part of the control table, in which the optimum value of the relative air flow rate in a high-temperature side cooling-tower fan is indicated in correspondence with the refrigeration load ratio and the wet-bulb temperature;

FIG. 8 is a diagram illustrating an example of a part of the control table, in