

DESCRIPTION

Title of Invention

CONTROL SYSTEM AND CONTROL METHOD

Technical Field

[0001]

The present disclosure relates to a control system and a control method. Priority is claimed on Japanese Patent Application No. 2024-010175, filed January 26, 2024, the content of which is incorporated herein by reference.

Background Art

[0002]

In a data center or the like in which a plurality of servers are provided, it is required to suppress power consumption of the servers and power consumption of cooling equipment for the servers. For example, PTL 1 discloses a technique in which workloads are sequentially assigned with priority given to information processing apparatuses having high power efficiency so that the workload processing amount falls within a threshold range of each information processing apparatus.

Citation List

Patent Literature

[0003]

[PTL 1] Japanese Patent No. 4768082

Summary of Invention

Technical Problem

[0004]

When computational processing is performed using the plurality of servers in the data center or the like, it is common to cause some of the servers defined in advance to perform the computational processing. However, merely assigning the computational processing to the servers defined in advance or to the servers having high power efficiency may make it difficult to minimize the power consumption of the entire data center, including the power required for cooling the servers.

[0005]

An object of the present disclosure is to provide a control system and a control method capable of minimizing power consumption of the entire data center including a cooling system for servers.

Solution to Problem

[0006]

An aspect of the present disclosure relates to a control system including: in a facility in which a plurality of server groups, each composed of a plurality of servers arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction, a cooling system configured to cool the servers; and a control device configured to control the servers and the cooling system, in which the cooling system includes a cooling device configured to cool a primary-side refrigerant, a primary-side pipe provided with a primary-side pump configured to deliver the primary-side refrigerant cooled by the cooling device, a heat exchanger configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device and a secondary-side refrigerant used for cooling the servers, a secondary-side pipe provided with a secondary-side pump configured to deliver the secondary-side refrigerant cooled by the heat exchanger, the secondary-side pipe having, for each server group, a flow path composed of a main pipe, a plurality of first branch pipes branching

from the main pipe at branch positions corresponding to the respective server groups, and a plurality of second branch pipes branching from the first branch pipes to the respective servers, and on-off valves provided in each of the plurality of second branch pipes of the secondary-side pipe, the control device includes a first assignment unit configured to concentratedly assign, based on schedule information for jobs to perform computational processing on the servers and server information including arrangement of the servers, the jobs to the server groups in order from the server group having a shorter flow-path distance, and opening degrees of the on-off valves are changed in accordance with a processing load of the server.

[0007]

Another aspect of the present disclosure relates to a control method of controlling, in a facility in which a plurality of server groups, each composed of a plurality of servers arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction, a cooling system configured to cool the servers, and the servers, in which the cooling system includes a cooling device configured to cool a primary-side refrigerant, a primary-side pipe provided with a primary-side pump configured to deliver the primary-side refrigerant cooled by the cooling device, a heat exchanger configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device and a secondary-side refrigerant used for cooling the servers, a secondary-side pipe provided with a secondary-side pump configured to deliver the secondary-side refrigerant cooled by the heat exchanger, the secondary-side pipe having, for each server group, a flow path composed of a main pipe, a plurality of first branch pipes branching from the main pipe at branch positions corresponding to the respective server groups, and a plurality of second branch pipes branching from the first branch pipes to the respective servers, and

on-off valves provided in each of the plurality of second branch pipes of the secondary-side pipe, the control method including: a step of concentratedly assigning, based on schedule information for jobs to perform computational processing on the servers and server information including arrangement of the servers, the jobs to the server groups in order from the server group having a shorter flow-path distance; and a step of changing opening degrees of the on-off valves in accordance with a processing load of the server.

Advantageous Effects of Invention

[0008]

According to the above-described aspects, it is possible to minimize power consumption of the entire data center including the cooling system for servers.

Brief Description of Drawings

[0009]

FIG. 1 is a schematic diagram showing an overall configuration of a control system according to a first embodiment.

FIG. 2 is a diagram showing a configuration of a secondary-side pipe according to the first embodiment.

FIG. 3 is a block diagram showing a functional configuration of a control device according to the first embodiment.

FIG. 4 is a flowchart showing an example of processing of the control device according to the first embodiment.

FIG. 5 is a diagram showing an example of server information according to the first embodiment.

FIG. 6 is a diagram showing an example of a distribution of processing loads according to the first embodiment.

FIG. 7 is a block diagram showing a functional configuration of a control device

according to a second embodiment.

FIG. 8 is a flowchart showing an example of processing of the control device according to the second embodiment.

FIG. 9 is a graph showing an example of a relationship between a flow rate of a secondary-side refrigerant and power of a secondary-side pump according to the second embodiment.

FIG. 10 is a graph showing an example of a relationship between the flow rate of the secondary-side refrigerant and power of a cooling device according to the second embodiment.

FIG. 11 is a graph showing an example of a relationship between the flow rate of the secondary-side refrigerant and total power according to the second embodiment.

FIG. 12 is a diagram showing an example of a distribution of processing loads according to the second embodiment.

FIG. 13 is a diagram showing examples of a first predicted value and a second predicted value according to the second embodiment.

FIG. 14 is a first diagram showing an example of a distribution of processing loads according to a third embodiment.

FIG. 15 is a second diagram showing the example of the distribution of the processing loads according to the third embodiment.

Description of Embodiments

[0010]

<First Embodiment>

Hereinafter, a first embodiment will be described in detail with reference to FIGS. 1 to 6.

[0011]

(Overall Configuration)

FIG. 1 is a schematic diagram showing an overall configuration of a control system according to the first embodiment. A control system 1 includes, as shown in FIG. 1, a cooling system 10 and a control device 20.

[0012]

The cooling system 10 includes a cooling device 11, a primary-side pump 13, a heat exchanger 14, a primary-side pipe 15, a secondary-side pump 16, and a secondary-side pipe 17. The cooling system 10 is a system that cools, for example, servers 18 installed in a data center or the like. The server 18 includes a processor (heat generating body 19), such as a CPU or a GPU. In the present embodiment, an example will be described in which the heat generating body 19 is a CPU.

[0013]

The cooling device 11 is, for example, a free-cooling cooling tower, an air-cooled heat pump chiller, or the like. The cooling device 11 cools a primary-side refrigerant (for example, water) flowing through the primary-side pipe 15. The cooling device 11 includes a fan 12.

[0014]

The primary-side pump 13 is provided in the primary-side pipe 15, and draws in the primary-side refrigerant cooled by the cooling device 11 and delivers the primary-side refrigerant toward the heat exchanger 14. The primary-side pipe 15 is a pipe through which the primary-side refrigerant flows, the pipe being provided so that the primary-side refrigerant can circulate between the cooling device 11 and the heat exchanger 14.

[0015]

The secondary-side pipe 17 is a pipe through which a secondary-side refrigerant

flows, the pipe being provided so that the secondary-side refrigerant can circulate between the heat exchanger 14 and the server 18.

[0016]

The heat exchanger 14 exchanges heat between the primary-side refrigerant and the secondary-side refrigerant. In the heat exchanger 14, the secondary-side refrigerant is cooled by the primary-side refrigerant.

[0017]

The secondary-side refrigerant cools the CPU 19 by removing heat from the CPU 19, and is cooled by the primary-side refrigerant in the heat exchanger 14.

[0018]

FIG. 2 is a diagram showing a configuration of the secondary-side pipe according to the first embodiment. As shown in FIG. 2, the secondary-side pipe 17 allows the secondary-side refrigerant to circulate in each of a plurality of servers 18 installed in a facility R such as a data center, and thus each server 18 can be cooled. In the facility R, a plurality of server groups G, each composed of the plurality of servers 18 arranged in a first horizontal direction (left-right direction of the paper surface), are installed at intervals in a second horizontal direction (up-down direction of the paper surface) orthogonal to the first horizontal direction. FIG. 2 shows an example in which four server groups G, that is, groups A to D, are installed, but the number of server groups may be smaller or larger than this example. In addition, FIG. 2 shows an example in which each server group G has 15 servers 18, but the number of servers may be smaller or larger than this example.

[0019]

The secondary-side pipe 17 includes a main pipe 171, first branch pipes 172, and second branch pipes 173.

[0020]

The main pipe 171 is composed of a low-temperature-side main pipe 171a and a high-temperature-side main pipe 171b extending in the first horizontal direction. The low-temperature-side main pipe 171a is a flow path to which the secondary-side refrigerant (chilled water) cooled by the heat exchanger 14 is supplied, and the high-temperature-side main pipe 171b is a flow path through which the secondary-side refrigerant (warm water) heated by the heat removed from the server 18 (CPU 19) is discharged.

[0021]

The first branch pipes 172 branch from the main pipe 171 in the second horizontal direction at branch positions P1 to P4 corresponding to the respective server groups G (groups A to D) of the low-temperature-side main pipe 171a. In addition, the first branch pipes 172 join the main pipe 171 at merging positions P5 to P8 corresponding to the respective server groups G (groups A to D) of the high-temperature-side main pipe 171b. The first branch pipe 172 is composed of a low-temperature-side first branch pipe 172a and a high-temperature-side first branch pipe 172b. The low-temperature-side first branch pipe 172a is a flow path to which the secondary-side refrigerant (chilled water) cooled by the heat exchanger 14 is supplied, and the high-temperature-side first branch pipe 172b is a flow path through which the secondary-side refrigerant (warm water) heated by the heat removed from the server 18 (CPU 19) is discharged.

[0022]

The second branch pipes 173 branch from the low-temperature-side first branch pipe 172a, pass through the server 18, and then join the high-temperature-side first branch pipe 172b. The second branch pipe 173 is composed of a low-temperature-side

second branch pipe 173a and a high-temperature-side second branch pipe 173b. The low-temperature-side second branch pipe 173a is a flow path to which the secondary-side refrigerant (chilled water) cooled by the heat exchanger 14 is supplied, and the high-temperature-side second branch pipe 173b is a flow path through which the secondary-side refrigerant (warm water) heated by the heat removed from the server 18 (CPU 19) is discharged. Each of the low-temperature-side second branch pipe 173a and the high-temperature-side second branch pipe 173b is provided with on/off valves 174 and 175.

[0023]

The on/off valves 174 and 175 adjust a flow rate of the secondary-side refrigerant to the server 18 by changing the opening degrees thereof in accordance with the processing load of the server 18. In the present embodiment, the on/off valves 174 and 175 are automatic valves, and the opening degrees are automatically changed in accordance with a temperature difference between the secondary-side refrigerant on an inlet side (low-temperature-side second branch pipe 173a) of the server 18 and the secondary-side refrigerant on an outlet side (high-temperature-side second branch pipe 173b) of the server 18. When the temperature difference is within a predetermined range (close to 0), that is, when the processing load of the server 18 (CPU 19) is low and there is no heat generation, the on/off valves 174 and 175 are in a closed state, and the supply of the secondary-side refrigerant to the server 18 is stopped. On the other hand, the on/off valves 174 and 175 increase the opening degrees as the temperature difference increases, and increase the supply amount of the secondary-side refrigerant to the server 18. As a result, it is possible to suppress excessive or insufficient supply of the secondary-side refrigerant to the server 18.

[0024]

The control device 20 controls an operation of the cooling device 11 to adjust a

temperature of the primary-side refrigerant on the inlet side of the heat exchanger 14, controls a rotation speed of the primary-side pump 13 to adjust the flow rate of the primary-side refrigerant flowing through the primary-side pipe 15, controls a rotation speed of the secondary-side pump 16 to adjust the flow rate of the secondary-side refrigerant flowing through the secondary-side pipe 17, and controls a temperature of the CPU 19 to a desired range (equal to or lower than a predetermined allowable temperature). In addition, the control device 20 assigns jobs to the respective servers 18.

[0025]

(Functional Configuration of Control Device)

FIG. 3 is a block diagram showing a functional configuration of the control device according to the first embodiment. The control device 20 includes, as shown in FIG. 3, a processor 21, a memory 22, a storage 23, a communication interface 24, a display unit 25, and an operation unit 26.

[0026]

The processor 21 operates in accordance with a predetermined program to exhibit functions as an acquisition unit 211, a first assignment unit 212, a heat generation amount estimation unit 213, a power calculation unit 214, and a control unit 215.

[0027]

The acquisition unit 211 acquires schedule information of the job for performing computational processing in the server 18 and server information of the server 18. The schedule information of the job includes information on the job to be executed in a predetermined period of time. The server information includes information on the arrangement of the servers 18.

[0028]

The first assignment unit 212 concentratedly assigns the jobs to the server groups G in order from the server group G having a shorter flow-path distance, based on the schedule information of the job and the server information.

[0029]

The heat generation amount estimation unit 213 estimates a heat generation amount of each server based on the processing load of each server 18 (CPU 19) and information (table, function, or the like) that defines a relationship between the processing load and the heat generation amount of the CPU 19.

[0030]

The power calculation unit 214 determines operating parameters of the cooling device 11, the primary-side pump 13, and the secondary-side pump 16, for example, a rotation speed of the fan 12 (in a case where the cooling device 11 is of a free cooling type), a rotation speed of a compressor (not shown) (in a case where the cooling device 11 is a heat pump chiller), the rotation speeds of the primary-side pump 13 and the secondary-side pump 16, and the like, based on the estimated heat generation amount of the CPU 19 and the allowable temperature of the CPU 19.

[0031]

The control unit 215 controls the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 based on the operating parameters determined by the power calculation unit 214.

[0032]

In addition, the predetermined program executed by the processor 21 is stored in a computer-readable recording medium. Examples of the computer-readable recording medium include a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, and a semiconductor memory. The computer program may be distributed to a

computer via a communication line, and the computer that has received the distribution may execute the program. Further, the program may be a program for implementing some of the above-described functions. Furthermore, the above-described functions may be implemented by a so-called difference file (difference program) that can be implemented in combination with a program already stored in the computer system.

[0033]

In addition, in the present embodiment, the example has been described in which the on/off valves 174 and 175 are automatic valves, but the present disclosure is not limited thereto. In another embodiment, the on/off valves 174 and 175 may be controlled by the control unit 215. For example, the control unit 215 receives an operation of an administrator (user) of the data center, and adjusts the opening degree of each of the on/off valves 174 and 175. In addition, the control unit 215 may automatically adjust the opening degree of each of the on/off valves 174 and 175 in accordance with the heat generation amount of the server (CPU 19) estimated by the heat generation amount estimation unit 213.

[0034]

The memory 22 has a memory region necessary for the operation of the processor 21.

[0035]

The storage 23 is a so-called auxiliary storage device and is, for example, a hard disk drive (HDD) or a solid-state drive (SSD). The storage 23 stores data that is acquired, generated, and referred to by each unit of the processor 21 during the processing.

[0036]

The communication interface 24 is an interface for transmitting and receiving

data, control signals, measured values, and the like to and from the respective devices of the cooling system 10, various sensors, and the like.

[0037]

The display unit 25 has, for example, a display screen such as a liquid-crystal display, and displays text, an image, or the like represented by given data on the display screen.

[0038]

The operation unit 26 includes, for example, an input device such as a mouse or a keyboard, receives an operation of the administrator (user) of the data center, and outputs an operation signal corresponding to the received operation.

[0039]

(Processing Flow)

FIG. 4 is a flowchart showing an example of processing of the control device according to the first embodiment. Hereinafter, a flow of processing of the control device according to the present embodiment will be described in detail with reference to FIG. 4.

[0040]

First, the acquisition unit 211 acquires the schedule information of the job and the server information (step S101). For example, the storage 23 records information on the job (job name, start time, end time, and the like) input from a client. The acquisition unit 211 acquires the schedule information including information on the job to be executed in a predetermined period of time from the information on the job recorded in the storage 23. The predetermined period of time is, for example, a future period of time such as a 30-minute period starting five minutes after a current time, and may be arbitrarily set by the administrator (user) of the data center.

[0041]

FIG. 5 is a diagram showing an example of the server information according to the first embodiment. For example, the server information as shown in FIG. 5 is recorded in the storage 23 in advance. The server information includes information such as identification information (group ID or the like) of the server group G, a flow-path distance of the server group G, identification information (server ID or the like) of the server 18 belonging to each server group G, the allowable temperature of each server 18, and a load upper limit value. The server ID consists of, for example, a group ID of the server group G to which the server belongs and a number indicating an arrangement order within the group. In the example of FIG. 2, for example, the server ID of the first server 18 (the server 18 connected to the low-temperature-side second branch pipe 173a branching from a most upstream side of the low-temperature-side first branch pipe 172a) of the group A is denoted by "A1". That is, the arrangement of each server 18 can be known from the server ID. In addition, the flow-path distance of the server group is a distance of a flow path of the server group G composed of the main pipe 171 and the first branch pipes 172, and is based on design data of the cooling system 10, a value actually measured, or the like. For example, the flow-path distance of the group A is a distance obtained by adding up a distance from a start point (for example, an inlet of the facility R, an outlet of the heat exchanger 14, or the like) of the low-temperature-side main pipe 171a to the branch position P1 toward the group A, a distance of the first branch pipes 172 (low-temperature-side first branch pipe 172a and high-temperature-side first branch pipe 172b), and a distance from the merge position P5 toward the high-temperature-side main pipe 171b to an end point (for example, an outlet of the facility R, an inlet of the heat exchanger 14, or the like) of the high-temperature-side main pipe 171b. The load upper limit value is an upper limit value of a CPU utilization rate or a

maximum number of jobs that can be input.

[0042]

Next, the first assignment unit 212 assigns the job included in the schedule information of the job so that the processing load is concentrated on the server of the server group G having a shorter flow-path distance (step S102). In the examples of FIGS. 2 and 5, the server group G having a shortest flow-path distance is the group A. Therefore, the first assignment unit 212 assigns the job to each server 18 (A1 to A15) of the group D up to the load upper limit value. In addition, when the job is assigned to each server 18 (A1 to A15) of the group A up to the load upper limit value and there is an unassigned job, the first assignment unit 212 assigns the job to the server of the server group G having a next shortest flow-path distance. In the examples of FIGS. 2 and 5, the group B has the next shortest flow-path distance after the group A. Therefore, when all the jobs cannot be processed by the servers 18 (A1 to A15) of the group A, the first assignment unit 212 assigns the jobs to the servers 18 (B1 to B15) of the group B.

[0043]

FIG. 6 is a diagram showing an example of a distribution of the processing loads according to the first embodiment. In step S102, as shown in FIG. 6, the first assignment unit 212 concentratedly assigns all the jobs to the respective servers 18 (A1 to A15) of the group A, and does not assign the jobs to the servers 18 of the other groups B to D. As shown in FIG. 6, the first assignment unit 212 may display, for example, a diagram showing a distribution of the processing loads (CPU utilization rates) of the servers 18 by hatching, color, text information, or the like on the display unit 25 so that the user can check the distribution.

[0044]

Next, the operating parameters of the units (cooling device 11, primary-side

pump 13, and secondary-side pump 16) of the cooling system 10 are determined to control the cooling system 10 (step S103). For example, the heat generation amount estimation unit 213 calculates the heat generation amount of the server 18 based on the processing load of the server 18 (CPU 19). Further, the heat generation amount estimation unit 213 acquires the allowable temperature of the server 18 from the server information recorded in the storage 23. The power calculation unit 214 determines the operating parameters of the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 based on the estimated heat generation amount of the CPU 19 and the allowable temperature of the CPU 19. A known technique may be used as the method for determining the operating parameters. The control unit 215 controls the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 based on the operating parameters determined by the power calculation unit 214.

[0045]

In addition, the on/off valves 174 and 175 of each server group G automatically switch between an open state and a closed state (step S103). For example, when the opening degree is automatically changed by the temperature difference between the inlet and the outlet of the server 18, each server 18 (A1 to A15) of the group A has a high processing load and the temperature difference becomes large, so that each of the on/off valves 174 and 175 is in an open state. On the other hand, since each server of the groups B to D has a small processing load and the temperature difference becomes close to zero, each of the on/off valves 174 and 175 is in a closed state. In another embodiment, the user may give an opening and closing instruction for each of the on/off valves 174 and 175 through the operation unit 26 of the control device 20 while checking the distribution of the processing loads displayed on the display unit 25. In addition, in still another embodiment, the control unit 215 may control each of the on/off valves

174 and 175 to be in an open state and a closed state based on the temperature difference between the inlet and the outlet of the server 18.

[0046]

The control device 20 repeatedly executes the series of processing in FIG. 4 at each predetermined timing.

[0047]

(Operation and Effect)

As described above, in the control system 1 according to the present embodiment, the control device 20 includes the first assignment unit 212 that concentratedly assigns the jobs to the server groups G in order from the server group G having a shorter flow-path distance, based on the schedule information of the job and the server information. In addition, the opening degrees of the on/off valves 174 and 175 provided in the second branch pipe 173 of the secondary-side pipe 17 are changed in accordance with the processing load of the server 18.

[0048]

In the related art, since the job has been assigned to the server designated by the client, the processing loads have been distributed to the groups A to D, and it has been necessary to cause the secondary-side refrigerant to circulate in all of the groups A to D. On the other hand, in the present embodiment, the control device 20 can cause the secondary-side refrigerant to circulate only in the group A by concentrating the processing load on the group A having a shorter flow-path distance. In this case, since a distance through which the secondary-side refrigerant flows is only a flow-path distance of the group A, a circulation path of the secondary-side refrigerant can be shortened as compared with a case where the secondary-side refrigerant circulates to the group D. Accordingly, in a case where the flow rate of the secondary-side refrigerant

in the main pipe 171 is the same, it is possible to suppress a pressure loss of the main pipe and to reduce the power (power consumption) of the secondary-side pump 16. Therefore, the power consumption of the entire data center, including the cooling system 10 of the server 18, can be minimized.

[0049]

Further, the opening degrees of the on/off valves 174 and 175 are automatically changed based on the temperature difference of the secondary-side refrigerant at the inlet and the outlet of the server 18 of the second branch pipe 173.

[0050]

As a result, for the server 18 having no job assignment (processing load) and a small temperature difference, the on/off valves 174 and 175 can be automatically closed to stop the circulation of the secondary-side refrigerant without the user performing monitoring or operation.

[0051]

The control device 20 further includes the control unit 215 that performs control of changing opening degrees based on the operation instruction from the user or based on the temperature difference of the secondary-side refrigerant at the inlet and the outlet of the server 18 of the second branch pipe 173.

[0052]

As a result, even in a case where the on/off valves 174 and 175 that are not automatic valves are provided, for the server 18 having no job assignment (processing load) and having a small temperature difference, the on/off valves 174 and 175 can be closed to stop the circulation of the secondary-side refrigerant by the operation of the user or by the automatic control of the control unit 215.

[0053]

<Second Embodiment>

Hereinafter, a second embodiment will be described with reference to FIGS. 7 to 13. In the configurations of the second embodiment, the same configurations as those of the first embodiment will be described using the same reference numerals as those of the first embodiment.

[0054]

(Functional Configuration of Control Device)

FIG. 7 is a block diagram showing a functional configuration of the control device according to the second embodiment. As shown in FIG. 7, the control device 20 according to the present embodiment further includes a second assignment unit 216 and a determination unit 217. The function of the power calculation unit 214 is different from that of the first embodiment.

[0055]

The second assignment unit 216 assigns the jobs to all the servers 18 of all the server groups G so that the processing loads are equalized, based on the schedule information of the job and the server information. In the present embodiment, the equalization of the processing loads indicates that a difference in the processing load (CPU utilization rate) is within a predetermined value (within $\pm X\%$).

[0056]

The power calculation unit 214 calculates a first predicted value of power of the cooling system 10 corresponding to the job assignment of the first assignment unit 212 and a second predicted value of power of the cooling system 10 corresponding to the job assignment of the second assignment unit 216, based on information indicating a relationship between the allowable temperature of the server 18, the heat generation amount, the flow rates of the primary-side refrigerant and the secondary-side refrigerant,

and total power of the cooling system 10 for supplying the primary-side refrigerant and the secondary-side refrigerant to the server 18.

[0057]

The determination unit 217 determines whether to adopt the job assignment by the first assignment unit 212 or the job assignment by the second assignment unit 216, based on the first predicted value and the second predicted value.

[0058]

(Processing Flow)

FIG. 8 is a flowchart showing an example of processing of the control device according to the second embodiment. Hereinafter, a flow of processing of the control device according to the present embodiment will be described in detail with reference to FIG. 8.

[0059]

First, the acquisition unit 211 acquires the schedule information of the job and the server information (step S201). This processing is the same as the processing of step S101 in the first embodiment (FIG. 4).

[0060]

Next, first processing of steps S202 to S206 and second processing of steps S207 to S211 are executed in parallel. Further, in another embodiment, the first processing and the second processing may be executed in order.

[0061]

First, the first processing (steps S202 to S206) will be described. The first assignment unit 212 assigns the job included in the schedule information of the job so that the processing load is concentrated on the server of the server group G having a shorter flow-path distance (step S202). This processing is the same as the processing

of step S102 in the first embodiment (FIG. 4).

[0062]

Then, the power calculation unit 214 sets the flow rate of the primary-side refrigerant (step S203). The flow rate of the primary-side refrigerant may be set by, for example, the user through the operation unit 26, or a set value recorded in advance may be read from the storage 23.

[0063]

The heat generation amount estimation unit 213 confirms a constraint condition of the heat generating body (step S204). For example, the heat generation amount estimation unit 213 calculates the heat generation amount of the server 18 based on the processing load of the server 18 (CPU 19). Further, the heat generation amount estimation unit 213 acquires the allowable temperature of the server 18 from the server information recorded in the storage 23. In the processing from step S205 onward, an optimum operating point under the constraint condition is determined, with the flow rate of the primary-side refrigerant set in step S203 and the heat generation amount of the server 18 and the allowable temperature thereof confirmed in step S204 being used as the constraint condition.

[0064]

Next, the power calculation unit 214 determines the flow rate of the secondary-side refrigerant for satisfying the constraint condition (step S205).

[0065]

FIG. 9 is a graph showing an example of a relationship between the flow rate of the secondary-side refrigerant and power of the secondary-side pump according to the second embodiment. As shown in FIG. 9, when the flow rate of the secondary-side refrigerant increases, the power of the secondary-side pump 16 also increases.

According to the graph of FIG. 9, the power of the secondary-side pump 16 can be obtained by determining the flow rate of the secondary-side refrigerant.

[0066]

FIG. 10 is a graph showing an example of a relationship between the flow rate of the secondary-side refrigerant and the power of the cooling device according to the second embodiment. The graph of FIG. 10 shows, for example, a relationship between the flow rate of the secondary-side refrigerant and the power of the cooling device 11 in a case where the flow rate of the primary-side refrigerant and the heat generation amount of the server 18 (CPU 19) are assumed to be constant at a certain value. As shown in the drawing, the power of the cooling device 11 on the primary side can be reduced by increasing the flow rate of the secondary-side refrigerant. When combined with the graph of FIG. 9, it is possible to determine the power of the secondary-side pump 16 and the power of the cooling device 11 in accordance with the flow rate of the secondary-side refrigerant.

[0067]

FIG. 11 is a graph showing an example of a relationship between the flow rate of the secondary-side refrigerant and total power according to the second embodiment. The graph of FIG. 11 shows, for example, a relationship between the flow rate of the secondary-side refrigerant and the total power when the flow rate of the primary-side refrigerant and the heat generation amount of the server 18 (CPU 19) are assumed to be constant at a certain value. The total power is the sum of the power of the cooling device 11, the power of the primary-side pump 13, and the power of the secondary-side pump 16. By combining the graphs of FIGS. 9 and 10, the power of the cooling device 11, the power of the primary-side pump 13, and the power of the secondary-side pump 16 can be determined by determining the flow rate of the secondary-side refrigerant.

Here, when a power usage effectiveness (PUE) optimum value at which the total power is minimized is selected and the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 can be operated at this operating point, the cooling system 10 can be operated with minimum power (energy consumption), thereby contributing to improvement of the energy efficiency of the data center.

[0068]

For example, the storage 23 stores a graph (for example, FIG. 11) or the like showing a relationship between the flow rate of the secondary-side refrigerant and the total power for a combination of the flow rate of the primary-side refrigerant set in step S105 and the heat generation amount of the server 18 and the allowable temperature of the server 18 calculated in step S204. The power calculation unit 214 calculates the flow rate of the secondary-side refrigerant at which the total power is minimized based on the graph, and determines the calculated value as the flow rate of the secondary-side refrigerant of the cooling system 10 corresponding to the job assignment by the first assignment unit 212 (step S205).

[0069]

When the flow rate of the secondary-side refrigerant is determined, the power (rotation speed) of the secondary-side pump 16 is determined. For example, the power calculation unit 214 calculates the power of the secondary-side pump 16 based on the graph of FIG. 9 and the flow rate of the secondary-side refrigerant, and converts the power of the secondary-side pump 16 into the rotation speed. In addition, the power calculation unit 214 determines the temperature of the secondary-side refrigerant necessary for cooling the server 18 to be equal to or lower than the allowable temperature, based on the heat generation amount of the server 18 and the allowable temperature thereof, and on the flow rate of the secondary-side refrigerant. For

example, the storage 23 stores a table that defines a correspondence relationship between the heat generation amount of the server 18, the allowable temperature of the server 18, the flow rate of the secondary-side refrigerant, and the temperature of the secondary-side refrigerant (the temperature of the secondary-side refrigerant on the inlet side of the server 18). The power calculation unit 214 determines the secondary-side refrigerant temperature corresponding to the job assignment by the first assignment unit 212, based on the heat generation amount and the allowable temperature estimated in step S204, the flow rate of the secondary-side refrigerant determined in step S205, and the table. When the temperature of the secondary-side refrigerant is determined, the temperature of the primary-side refrigerant on the inlet side of the heat exchanger 14 is also determined because the flow rate of the primary-side refrigerant has already been set. For example, the storage 23 stores a table that defines a correspondence relationship between the flow rate of the primary-side refrigerant, the temperature of the primary-side refrigerant, the flow rate of the secondary-side refrigerant, and the temperature of the secondary-side refrigerant. The power calculation unit 214 calculates the temperature of the primary-side refrigerant corresponding to the job assignment by the first assignment unit 212, based on the table, the previously determined flow rate of the primary-side refrigerant, and the flow rate of the secondary-side refrigerant and the refrigerant temperature.

[0070]

The temperatures at the inlet and the outlet of the primary side of the heat exchanger 14 are determined under each of the above conditions, and the power (first predicted value) of the cooling device 11 corresponding to the job assignment by the first assignment unit 212 is determined (step S206). The power calculation unit 214 calculates, by a predetermined calculation formula, the temperature of the primary-side

refrigerant at the outlet side of the heat exchanger 14 from the temperature of the primary-side refrigerant at the inlet side of the heat exchanger 14 and the flow rate and temperature of the secondary-side refrigerant, and calculates the power (power consumption) of the cooling device 11 from the temperatures of the primary-side refrigerant at the inlet and the outlet of the primary side of the heat exchanger 14. For example, when the cooling device 11 is a free-cooling cooling tower, the power calculation unit 214 calculates the power (power consumption) of the fan 12. For example, when the cooling device 11 is an air-cooled heat pump chiller, the power calculation unit 214 calculates the power (power consumption) of the fan 12, the compressor (not shown), and the like. In addition, when the cooling device 11 includes both the free-cooling cooling tower and the air-cooled heat pump chiller, and the constraint condition is satisfied by only the free-cooling cooling tower, the power calculation unit 214 calculates only the power of the fan 12 of the cooling tower. On the other hand, when the constraint condition cannot be satisfied unless both the free-cooling cooling tower and the air-cooled heat pump chiller are operated, the power calculation unit 214 calculates the total value of the power of the fan 12 of the cooling tower and the power of the fan 12 of the heat pump chiller or the compressor (not shown).

[0071]

Next, the second processing (steps S207 to S211) will be described. The second assignment unit 216 assigns the job included in the schedule information of the job so that the processing loads of all the servers of all the server groups G are substantially equalized (step S207).

[0072]

FIG. 12 is a diagram showing an example of a distribution of the processing loads according to the second embodiment. In step S207, the second assignment unit

216 assigns the jobs to the respective servers 18 of all the groups A to D so that the jobs are substantially equalized, as shown in FIG. 12.

[0073]

In addition, the processing of steps S208 to S211 are the same as the processing of steps S203 to S206. In step S211, the power calculation unit 214 determines the power (second predicted value) of the cooling device 11 corresponding to the job assignment by the second assignment unit 216.

[0074]

Then, the determination unit 217 compares the first predicted value with the second predicted value (step S212).

[0075]

FIG. 13 is a diagram showing examples of the first predicted value and the second predicted value according to the second embodiment. For example, as in the example of FIG. 13, when the second predicted value is smaller than the first predicted value (step S212; NO), the determination unit 217 adopts the job assignment by the second assignment unit 216 (for example, FIG. 12) (step S214). In addition, the control unit 215 controls the respective units of the cooling system 10 based on the second predicted value. For example, the control unit 215 controls the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 based on values obtained by converting the power of the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 determined in step S211 into the rotation speed of the fan 12 (or/and the rotation speed of the compressor), the rotation speed of the primary-side pump 13, and the rotation speed of the secondary-side pump 16.

[0076]

In addition, when the first predicted value is smaller than the second predicted

value (step S212; YES), the determination unit 217 adopts the job assignment by the first assignment unit 212 (for example, FIG. 6) (step S213). In addition, the control unit 215 controls the respective units of the cooling system 10 based on the first predicted value. For example, the control unit 215 controls the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 based on values obtained by converting the power of the cooling device 11, the primary-side pump 13, and the secondary-side pump 16 determined in step S206 into the rotation speed of the fan 12 (or/and the rotation speed of the compressor), the rotation speed of the primary-side pump 13, and the rotation speed of the secondary-side pump 16.

[0077]

The control device 20 repeatedly executes the series of processing in FIG. 4 at each predetermined timing.

[0078]

(Operation and Effect)

As described above, in the control system 1 according to the present embodiment, the control device 20 further includes a second assignment unit 216 configured to assign, based on the schedule information and the server information, the jobs to all the servers 18 of all the server groups G so that the processing loads are equalized, a power calculation unit 214 configured to calculate, based on information indicating a relationship among an allowable temperature of the servers 18, a heat generation amount, flow rates of the primary-side refrigerant and the secondary-side refrigerant, and total power of the cooling system 10 for supplying the primary-side refrigerant and the secondary-side refrigerant to the servers 18, a first predicted value of power of the cooling system 10 corresponding to job assignment by the first assignment unit 212 and a second predicted value of power of the cooling system 10 corresponding

to job assignment by the second assignment unit 216, and a determination unit 217 configured to determine, based on the first predicted value and the second predicted value, whether to adopt the job assignment by the first assignment unit 212 or the job assignment by the second assignment unit 216.

[0079]

As a result, the control device 20 can control the system by selecting the condition (job assignment) in which the power can be further reduced. Therefore, the power consumption of the cooling system 10 can be further effectively reduced.

[0080]

For example, in a configuration in which the cooling device 11 includes both the free-cooling cooling tower and the air-cooled heat pump chiller, there is a case where the constraint condition can be satisfied by only operating the free-cooling cooling tower without using the air-cooled heat pump, depending on the condition. For example, in the job assignment by the second assignment unit 216 (the jobs are substantially equally assigned to all the servers 18), the heat load per server is reduced, and thus there is a possibility that each server 18 can be sufficiently cooled even when the refrigerant temperature is relatively high. In addition, during periods when the outside air temperature is low, such as in winter, a sufficient cooling effect may be obtained using only a free-cooling cooling tower. In such a case, the air-cooled heat pump chiller is stopped, and only the free-cooling cooling tower having smaller power is operated, so that the server 18 can be cooled, and the effect of reducing the power consumption can be further enhanced.

[0081]

<Third Embodiment>

Hereinafter, a second embodiment will be described with reference to FIG. 13.

In the configurations of the second embodiment, the same configurations as those of the first embodiment will be described using the same reference numerals as those of the first embodiment.

[0082]

The facility R according to the present embodiment has a plurality of floors. The plurality of server groups G are set in each floor.

[0083]

In addition, the first assignment unit 212 according to the present embodiment concentratedly assigns the jobs to the server group G of some of the floors so that the number of floors in operation is minimized in step S102 of FIG. 4 or step S202 of FIG. 8. The first assignment unit 212 assigns the jobs, for example, in order from a floor 1 until the processing load of each server 18 of each server group G reaches the load upper limit value. In addition, when the floor 1 alone is insufficient, the jobs are assigned until the processing load of each server 18 of a floor 2 reaches the load upper limit value.

[0084]

FIG. 14 is a first diagram showing an example of a distribution of the processing loads according to the third embodiment. FIG. 15 is a second diagram showing the example of the distribution of the processing loads according to the third embodiment. FIG. 14 shows an example in which the second assignment unit 216 substantially equally assigns the jobs to all the servers 18 of all the floors. On the other hand, FIG. 15 shows an example in which the first assignment unit 212 according to the present embodiment concentratedly assigns the jobs to the server group G of some of the floors (floors 1 and 2) so that the number of floors in operation is minimized. As shown in FIG. 14, in the assignment method of the second assignment unit 216, it is necessary to operate three floors, and thus the power consumption of the cooling system 10 increases accordingly.

On the other hand, as shown in FIG. 15, in the assignment method of the first assignment unit 212, since only the minimum number (two) of floors need to be operated, the circulation of the secondary-side refrigerant may be stopped for a floor 3 that is not operated (no job assignment). Therefore, since the cooling of the floor 3 is not necessary, there is a possibility that the power consumption of the entire facility R can be reduced. Since it is possible to input the jobs of another client to the server 18 of the floor 3, the data center can handle more jobs of the clients.

[0085]

<Other Embodiments>

Although the embodiments have been described in detail above with reference to the accompanying drawings, the specific configuration is not limited to the above description, and various design changes and the like can be made. That is, in another embodiment, the order of the above-described processing may be changed as appropriate. In addition, a part of processing may be executed in parallel.

[0086]

<Supplementary Notes>

A control system and a control method described in the above-described embodiments are understood as follows, for example.

[0087]

(1) A first aspect relates to a control system 1 including: in a facility R in which a plurality of server groups G, each composed of a plurality of servers 18 arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction, a cooling system 10 configured to cool the servers 18; and a control device 20 configured to control the servers 18 and the cooling system 10, in which the cooling system 10 includes a cooling device 11 configured to

cool a primary-side refrigerant, a primary-side pipe 15 provided with a primary-side pump 13 configured to deliver the primary-side refrigerant cooled by the cooling device 11, a heat exchanger 14 configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device 11 and a secondary-side refrigerant used for cooling the servers 18, a secondary-side pipe 17 provided with a secondary-side pump 16 configured to deliver the secondary-side refrigerant cooled by the heat exchanger 14, the secondary-side pipe 17 having, for each server group G, a flow path composed of a main pipe 171, a plurality of first branch pipes 172 branching from the main pipe 171 at branch positions corresponding to the respective server groups G, and a plurality of second branch pipes 173 branching from the first branch pipes 172 to the respective servers 18, and on-off valves 174 and 175 provided in each of the plurality of second branch pipes 173 of the secondary-side pipe 17, the control device 20 includes a first assignment unit 212 configured to concentratedly assign, based on schedule information for jobs to perform computational processing on the servers 18 and server information including arrangement of the servers 18, the jobs to the server groups G in order from the server group G having a shorter flow-path distance, and opening degrees of the on-off valves 174 and 175 are changed in accordance with a processing load of the server 18.

[0088]

In the related art, since the job has been assigned to the server designated by the client, the processing loads have been distributed to the groups A to D, and it has been necessary to cause the secondary-side refrigerant to circulate in all of the groups A to D. On the other hand, in the present embodiment, the control device 20 can cause the secondary-side refrigerant to circulate only in the group A by concentrating the processing load on the group A having a shorter flow-path distance. In this case, since

a distance through which the secondary-side refrigerant flows is only a flow-path distance of the group A, a circulation path of the secondary-side refrigerant can be shortened as compared with a case where the secondary-side refrigerant circulates to the group D. Accordingly, in a case where the flow rate of the secondary-side refrigerant in the main pipe 171 is the same, it is possible to suppress a pressure loss of the main pipe and to reduce the power (power consumption) of the secondary-side pump 16. Therefore, the power consumption of the entire data center, including the cooling system 10 of the server 18, can be minimized.

[0089]

(2) A second aspect relates to the control system 1 according to the first aspect, in which the opening degrees of the on-off valves 174 and 175 are automatically changed based on a temperature difference of the secondary-side refrigerant between an inlet and an outlet of the server 18 in the second branch pipe 173.

[0090]

As a result, for the server 18 having no job assignment (processing load) and a small temperature difference, the on/off valves 174 and 175 can be automatically closed to stop the circulation of the secondary-side refrigerant without the user performing monitoring or operation.

[0091]

(3) A third aspect relates to the control system 1 according to the first aspect, in which the control device 20 further includes a control unit 215 configured to perform control of changing opening degrees based on an operation instruction from a user or based on a temperature difference of the secondary-side refrigerant between an inlet and an outlet of the server 18 in the second branch pipe 173.

[0092]

As a result, even in a case where the on/off valves 174 and 175 that are not automatic valves are provided, for the server 18 having no job assignment (processing load) and having a small temperature difference, the on/off valves 174 and 175 can be closed to stop the circulation of the secondary-side refrigerant by the operation of the user or by the automatic control of the control unit 215.

[0093]

(4) A fourth aspect relates to the control system 1 according to any one of the first to third aspects, in which the control device 20 further includes a second assignment unit 216 configured to assign, based on the schedule information and the server information, the jobs to all the servers 18 of all the server groups G so that the processing loads are equalized, a power calculation unit 214 configured to calculate, based on information indicating a relationship among an allowable temperature of the servers 18, a heat generation amount, flow rates of the primary-side refrigerant and the secondary-side refrigerant, and total power of the cooling system 10 for supplying the primary-side refrigerant and the secondary-side refrigerant to the servers 18, a first predicted value of power of the cooling system 10 corresponding to job assignment by the first assignment unit 212 and a second predicted value of power of the cooling system 10 corresponding to job assignment by the second assignment unit 216, and a determination unit 217 configured to determine, based on the first predicted value and the second predicted value, whether to adopt the job assignment by the first assignment unit 212 or the job assignment by the second assignment unit 216.

[0094]

As a result, the control device 20 can control the system by selecting the condition (job assignment) in which the power can be further reduced. Therefore, the power consumption of the cooling system 10 can be further effectively reduced.

[0095]

(5) A fifth aspect relates to the control system 1 according to any one of the first to fourth aspects, in which the facility R has a plurality of floors on which the server groups G are installed, and the first assignment unit 212 is configured to concentratedly assign the jobs to the server groups G on some of the floors so that the number of floors in operation is minimized.

[0096]

As a result, the number of operating floors can be minimized, so that it is possible to further reduce the power consumption of the entire facility R. Further, since it is possible to input the job of another client to the server 18 on the non-operating floor, the data center can handle more jobs of the clients.

[0097]

(6) A sixth aspect relates to a control method of controlling, in a facility R in which a plurality of server groups G, each composed of a plurality of servers 18 arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction, a cooling system 10 configured to cool the servers 18, and the servers 18, in which the cooling system 10 includes a cooling device 11 configured to cool a primary-side refrigerant, a primary-side pipe 15 provided with a primary-side pump 13 configured to deliver the primary-side refrigerant cooled by the cooling device 11, a heat exchanger 14 configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device 11 and a secondary-side refrigerant used for cooling the servers 18, a secondary-side pipe 17 provided with a secondary-side pump 16 configured to deliver the secondary-side refrigerant cooled by the heat exchanger 14, the secondary-side pipe 17 having, for each server group G, a flow path composed of a main pipe 171, a plurality of first branch pipes 172 branching

from the main pipe 171 at branch positions corresponding to the respective server groups G, and a plurality of second branch pipes 173 branching from the first branch pipes 172 to the respective servers 18, and on-off valves 174 and 175 provided in each of the plurality of second branch pipes 173 of the secondary-side pipe 17, the control method including: a step of concentratedly assigning, based on schedule information for jobs to perform computational processing on the servers 18 and server information including arrangement of the servers 18, the jobs to the server groups G in order from the server group G having a shorter flow-path distance; and a step of changing opening degrees of the on-off valves 174 and 175 in accordance with a processing load of the server 18.

Industrial Applicability

[0098]

According to the above-described aspects, it is possible to minimize power consumption of the entire data center including the cooling system for servers.

Reference Signs List

[0099]

1: control system

10: cooling system

11: cooling device

12: fan

13: primary-side pump

14: heat exchanger

15: primary-side pipe

16: secondary-side pump

17: secondary-side pipe

171: main pipe

172: first branch pipe
173: second branch pipe
174, 175: on/off valve
18: server
19: CPU (heat generating body)
20: control device
21: processor
211: acquisition unit
212: first assignment unit
213: heat generation amount estimation unit
214: power calculation unit
215: control unit
216: second assignment unit
217: determination unit
22: memory
23: storage
24: communication interface
25: display unit
26: operation unit
G: server group

Claims

[Claim 1]

A control system comprising:

in a facility in which a plurality of server groups, each composed of a plurality of servers arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction,

a cooling system configured to cool the servers; and

a control device configured to control the servers and the cooling system,

wherein the cooling system includes

a cooling device configured to cool a primary-side refrigerant,

a primary-side pipe provided with a primary-side pump configured to deliver the primary-side refrigerant cooled by the cooling device,

a heat exchanger configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device and a secondary-side refrigerant used for cooling the servers,

a secondary-side pipe provided with a secondary-side pump configured to deliver the secondary-side refrigerant cooled by the heat exchanger, the secondary-side pipe having, for each server group, a flow path composed of a main pipe, a plurality of first branch pipes branching from the main pipe at branch positions corresponding to the respective server groups, and a plurality of second branch pipes branching from the first branch pipes to the respective servers, and

on-off valves provided in each of the plurality of second branch pipes of the secondary-side pipe,

the control device includes a first assignment unit configured to concentratedly

assign, based on schedule information for jobs to perform computational processing on the servers and server information including arrangement of the servers, the jobs to the server groups in order from the server group having a shorter flow-path distance, and opening degrees of the on-off valves are changed in accordance with a processing load of the server.

[Claim 2]

The control system according to claim 1,
wherein the opening degrees of the on-off valves are automatically changed based on a temperature difference of the secondary-side refrigerant between an inlet and an outlet of the server in the second branch pipe.

[Claim 3]

The control system according to claim 1,
wherein the control device further includes a control unit configured to perform control of changing opening degrees based on an operation instruction from a user or based on a temperature difference of the secondary-side refrigerant between an inlet and an outlet of the server in the second branch pipe.

[Claim 4]

The control system according to any one of claims 1 to 3,
wherein the control device further includes
a second assignment unit configured to assign, based on the schedule information and the server information, the jobs to all the servers of all the server groups so that the processing loads are equalized,

a power calculation unit configured to calculate, based on information indicating a relationship among an allowable temperature of the servers, a heat generation amount, flow rates of the primary-side refrigerant and the secondary-side refrigerant, and total power of the cooling system for supplying the primary-side refrigerant and the secondary-side refrigerant to the servers, a first predicted value of power of the cooling system corresponding to job assignment by the first assignment unit and a second predicted value of power of the cooling system corresponding to job assignment by the second assignment unit, and

a determination unit configured to determine, based on the first predicted value and the second predicted value, whether to adopt the job assignment by the first assignment unit or the job assignment by the second assignment unit.

[Claim 5]

The control system according to any one of claims 1 to 3,
wherein the facility has a plurality of floors on which the server groups are installed, and
the first assignment unit is configured to concentratedly assign the jobs to the server groups on some of the floors so that the number of floors in operation is minimized.

[Claim 6]

A control method of controlling, in a facility in which a plurality of server groups, each composed of a plurality of servers arranged in a first horizontal direction, are installed at intervals in a second horizontal direction orthogonal to the first horizontal direction, a cooling system configured to cool the servers, and the servers,

in which the cooling system includes

- a cooling device configured to cool a primary-side refrigerant,
- a primary-side pipe provided with a primary-side pump configured to deliver the primary-side refrigerant cooled by the cooling device,
- a heat exchanger configured to perform heat exchange between the primary-side refrigerant cooled by the cooling device and a secondary-side refrigerant used for cooling the servers,
- a secondary-side pipe provided with a secondary-side pump configured to deliver the secondary-side refrigerant cooled by the heat exchanger, the secondary-side pipe having, for each server group, a flow path composed of a main pipe, a plurality of first branch pipes branching from the main pipe at branch positions corresponding to the respective server groups, and a plurality of second branch pipes branching from the first branch pipes to the respective servers, and
- on-off valves provided in each of the plurality of second branch pipes of the secondary-side pipe,

the control method comprising:

- a step of concentratedly assigning, based on schedule information for jobs to perform computational processing on the servers and server information including arrangement of the servers, the jobs to the server groups in order from the server group having a shorter flow-path distance; and
- a step of changing opening degrees of the on-off valves in accordance with a processing load of the server.