

DESCRIPTION

Title of Invention

AIR CONDITIONING SYSTEM AND METHOD FOR CONTROLLING AIR CONDITIONING SYSTEM

Technical Field

[0001]

The present disclosure relates to an air conditioning system and a method for controlling an air conditioning system. The present application claims priority based on Japanese Patent Application No. 2024-012749 filed in Japan on January 31, 2024, the contents of which are incorporated herein by reference.

Background Art

[0002]

In a server room (data center), a building, or the like, an air conditioning system including a heat source unit, such as an air-cooled heat pump chiller or a centrifugal chiller, and an air conditioner that cools indoor air with a heat medium supplied from the heat source unit is used. For example, PTL 1 discloses a technique for controlling an operating rate of each of a plurality of air conditioners such that a sum of power consumption of the respective air conditioners is minimized. In addition, NPLs 1 and 2 disclose a technique for controlling the number of operating heat source units to maximize a coefficient of performance (COP) of a heat source system including a plurality of heat source units.

Citation List

Patent Literature

[0003]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2011-257062

Non Patent Literature

[0004]

[NPL 1] Satoshi Nikaido, Kenji Ueda, Yoshie Togano, Minoru Matsuo, and Koki Tateishi, "'Ene-Conductor' The Optimum Controller for a Heat Source System that Consists of Centrifugal Chillers", Mitsubishi Heavy Industries Technical Review, Vol. 51, No. 2 (2014)

[NPL 2] Hiroshige Kikuchi, Yuji Miyajima, Fumihiro Ito, and Akira Maeyama, "Optimal Control System for Heat Source Facility for CO2 Reduction and Energy Saving", Hitachi Review Archives, Vol. 96, No. 12 (2014)

Summary of Invention

Technical Problem

[0005]

In the related art, the air conditioners and the heat source unit each perform control to aim at an optimum point independently without cooperation. In general, for example, in a cooling operation of a server room, when a set value (setting temperature) of a room temperature is increased, a load of the air conditioners may be reduced, and the power consumption may be reduced. Therefore, an administrator of the server room tends to set the setting temperature to a value close to an upper limit of an establishment range of an environmental requirement. However, in a case where the setting temperature is given in this way, it is possible to minimize the power consumption of the air conditioners, but it may be difficult to minimize power consumption of the heat source unit.

[0006]

An object of the present disclosure is to provide an air conditioning system and a method for controlling an air conditioning system, which can minimize power consumption of an entire air conditioning system while satisfying an environmental requirement.

Solution to Problem

[0007]

According to an aspect of the present disclosure, an air conditioning system is an air conditioning system including: an air conditioner controller that controls an air conditioner provided in an air conditioning target space; a heat source unit controller that controls a heat source unit and an auxiliary unit that supply a heat source to the air conditioner; and an integrated controller that outputs a control command to the air conditioner controller and the heat source unit controller, in which the integrated controller includes a first prediction unit that predicts a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables, and a command unit that outputs, based on a power consumption prediction value of the air conditioner for each setting temperature predicted by the air conditioner controller and a power consumption prediction value of the heat source unit and the auxiliary unit for each setting temperature predicted by the heat source unit controller, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command, the air conditioner controller

includes a second prediction unit that predicts power consumption of the air conditioner for each setting temperature included in the establishment range by using a second model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable, and the heat source unit controller includes a third prediction unit that predicts power consumption of the heat source unit and the auxiliary unit for each setting temperature included in the establishment range by using a third model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

[0008]

According to an aspect of the present disclosure, a method for controlling an air conditioning system is a method for controlling an air conditioning system including an air conditioner controller that controls an air conditioner provided in an air conditioning target space, a heat source unit controller that controls a heat source unit and an auxiliary unit that supply a heat source to the air conditioner, and an integrated controller that outputs a control command to the air conditioner controller and the heat source unit controller, the method including: a step of, via the integrated controller, predicting a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables; a step of, via the integrated

controller, outputting, based on a power consumption prediction value of the air conditioner for each setting temperature predicted by the air conditioner controller and a power consumption prediction value of the heat source unit and the auxiliary unit for each setting temperature predicted by the heat source unit controller, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command; a step of, via the air conditioner controller, predicting power consumption of the air conditioner for each setting temperature included in the establishment range by using a second model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable; and a step of, via the heat source unit controller, predicting power consumption of the heat source unit and the auxiliary unit for each setting temperature included in the establishment range by using a third model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

Advantageous Effects of Invention

[0009]

According to the aspect, it is possible to minimize the power consumption of the entire air conditioning system while satisfying the environmental requirement.

Brief Description of Drawings

[0010]

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

FIG. 2 is a block diagram showing a functional configuration of an integrated

controller according to the first embodiment.

FIG. 3 is a diagram showing an example of a first model according to the first embodiment.

FIG. 4 is a block diagram showing a functional configuration of an air conditioner controller according to the first embodiment.

FIG. 5 is a diagram showing an example of second and third models according to the first embodiment.

FIG. 6 is a block diagram showing a functional configuration of a heat source unit/auxiliary unit controller according to the first embodiment.

FIG. 7 is a sequence diagram showing an example of processing of the air conditioning system according to the first embodiment.

FIG. 8 is a diagram showing an example of a power consumption prediction value according to the first embodiment.

FIG. 9 is a flowchart showing an example of processing of the integrated controller according to the first embodiment.

FIG. 10 is a flowchart showing an example of processing of the air conditioner controller and the heat source unit/auxiliary unit controller according to the first embodiment.

FIG. 11 is a schematic diagram showing an overall configuration of an air conditioning system according to a second embodiment.

FIG. 12 is a diagram showing an example of a first model according to the second embodiment.

FIG. 13 is a schematic diagram showing an overall configuration of an air conditioning system according to a third embodiment.

FIG. 14 is a block diagram showing a functional configuration of a server

controller according to the third embodiment.

FIG. 15 is a sequence diagram showing an example of processing of the air conditioning system according to the third embodiment.

FIG. 16 is a schematic diagram showing an overall configuration of an air conditioning system according to a fourth embodiment.

FIG. 17 is a block diagram showing a functional configuration of a power generation controller according to the fourth embodiment.

FIG. 18 is a flowchart showing an example of processing of the power generation controller according to the fourth embodiment.

FIG. 19 is a schematic diagram showing an overall configuration of an air conditioning system according to a fifth embodiment.

Description of Embodiments

[0011]

<First Embodiment>

Hereinafter, a first embodiment will be described in detail with reference to FIGS. 1 to 11.

[0012]

(Overall Configuration of Air Conditioning System)

FIG. 1 is a schematic diagram showing an overall configuration of an air conditioning system according to a first embodiment. In the present embodiment, an example in which an air conditioning system 100 performs air conditioning (cooling) of a server room as shown in FIG. 1 will be described. In other embodiments, the air conditioning system 100 may perform air conditioning (cooling and heating) of a building, a factory, a warehouse, or the like.

[0013]

As shown in FIG. 1, the air conditioning system 100 includes an air conditioner 2, a heat source unit 3, an auxiliary unit 4, an integrated controller 10, an air conditioner controller 20, and a heat source unit/auxiliary unit controller 30.

[0014]

The air conditioner 2 is an indoor unit provided inside the server room, which is an air conditioning target space. The air conditioner 2 draws air from the server room, performs heat exchange with a heat medium of the heat source unit 3, and discharges the air to the server room. A plurality of air conditioners 2 may be installed according to a size of the server room and the number of servers.

[0015]

The heat source unit 3 supplies a heat source to the air conditioner 2. The heat source unit 3 is, for example, an air-cooled heat pump chiller, a centrifugal chiller, or the like. In the present embodiment, an example in which the heat source unit 3 is a centrifugal chiller and supplies chilled water as a heat source will be described. A plurality of heat source units 3 may be installed according to the size of the server room and the number of servers.

[0016]

In the present embodiment, the auxiliary unit 4 is a chilled water pump 4A. In addition, the auxiliary unit 4 may include a cooling water pump 4B and an outdoor unit 4C (cooling tower) of the centrifugal chiller. In the other embodiments, in a case where the heat source unit 3 is an air-cooled heat pump chiller, the outdoor unit 4C may be configured as a part of the heat source unit 3.

[0017]

The integrated controller 10 controls an operation of the entire air conditioning system 100 to reduce total power consumption of an air conditioner side (Range. 1)

and a heat source unit side (Range. 2) of the air conditioning system 100 while satisfying an environmental requirement of the server room. In a case where the air conditioning system 100 is used for cooling the server room as in the present embodiment, the environmental requirement is an upper limit value of a room temperature, and is designated by an administrator of the server room. In the other embodiments, the air conditioning system 100 may be used for cooling and heating of a building or the like, and in this case, the environmental requirement may be designated in a range from a lower limit value to the upper limit value of the room temperature.

[0018]

The air conditioner controller 20 controls an operation of the air conditioner 2 such that the room temperature of the server room approaches a setting temperature commanded by the integrated controller 10.

[0019]

The heat source unit/auxiliary unit controller 30 controls an operation of the heat source unit 3 and the auxiliary unit 4 (chilled water pump 4A) based on the setting temperature commanded by the integrated controller 10. In the following description, the heat source unit/auxiliary unit controller 30 will also be referred to simply as a "heat source unit controller".

[0020]

(Functional Configuration of Integrated Controller)

FIG. 2 is a block diagram showing a functional configuration of an integrated controller according to the first embodiment. As shown in FIG. 2, the integrated controller 10 includes a processor 11, a memory 12, a storage 13, and a communication interface 14.

[0021]

The processor 11 functions as a first acquisition unit 101, a first prediction unit 102, a command unit 103, and a first learning unit 104 by operating according to a predetermined program.

[0022]

The first acquisition unit 101 acquires a measurement value of a sensor of each unit of the air conditioning system 100. For example, the first acquisition unit 101 acquires a measurement value of a temperature (room temperature Ta_{act}) [$^{\circ}C$] of the server room from a temperature sensor T1 provided in the server room. The first acquisition unit 101 acquires a measurement value of an outside air temperature Tf from a temperature sensor T2 provided outside the server room (in a vicinity of the outdoor unit 4C, or the like). The first acquisition unit 101 may acquire measurement values of power consumption E1 and E2 [kW] of the respective units from power meters WM1, WM2, and WM3 provided in a power line (not shown) that supplies power to each unit of the air conditioner 2, the heat source unit 3, and the auxiliary unit 4. In addition, the first acquisition unit 101 acquires a power consumption prediction value, an operation state, and the like of the air conditioner 2, the heat source unit 3, and the auxiliary unit 4 from each of the controllers 20 and 30. Details of the power consumption prediction value will be described later.

[0023]

The first prediction unit 102 predicts a future heat load of the server room and an establishment range of a setting temperature satisfying the environmental requirement of the server room, by using a first model M1 (FIG. 3). As shown in FIG. 3, the first model M1 is a prediction model that uses the room temperature Ta_{act} measured in the server room as an explanatory variable and that uses a future heat load

prediction value of the server room as an objective variable. The future heat load prediction value is, for example, the room temperature [$^{\circ}\text{C}$] of the server room n minutes after a current time. The establishment range of the setting temperature is a setting range of the room temperature (discharge temperature of cooling air of the air conditioner 2) of the server room that is equal to or lower than the environmental requirement (upper limit value of the room temperature). The first model M1 may be trained to output a discharge flow rate of the cooling air, a chilled water temperature and flow rate, a cooling water temperature and flow rate, and the like. In addition, the first model M1 may further use current outside air temperature T_f , date and time, weather forecast, and the like as explanatory variables. By increasing the number of explanatory variables, the first model M1 can improve prediction accuracy of the future room temperature by taking into account an influence of an outside air temperature, a time of day, a season, the weather, and the like.

[0024]

The command unit 103 outputs, to each of the controllers 20 and 30, a setting temperature T_a at which a sum of the power consumption prediction values is minimized, as a control command, based on the power consumption prediction value for each setting temperature predicted by each of the controllers 20 and 30.

[0025]

The first learning unit 104 performs machine learning on the first model M1 by using, as learning data, a time series of the measurement values of the room temperature T_{a_act} and the outside air temperature T_f , a time series of the setting temperatures T_a commanded by the command unit 103, the weather, and the like. The first learning unit 104 trains the first model M1 using a predetermined amount of learning data in a learning phase and records the first model M1 in the storage 13. In

addition, in an operation phase of the integrated controller 10, the first learning unit 104 sequentially collects the learning data and trains (updates) the first model M1.

[0026]

The memory 12 has a memory region necessary for an operation of the processor 11.

[0027]

The storage 13 is a so-called auxiliary storage device and is, for example, a hard disk drive (HDD), a solid-state drive (SSD), or the like. The storage 13 stores data that is acquired, generated, and referred to by each unit of the processor 11 during processes.

[0028]

The communication interface 14 is an interface for transmitting and receiving data, a control signal, a measurement, and the like between the respective controllers 20, 30, and 40 and various sensors.

[0029]

(Functional Configuration of Air Conditioner Controller)

FIG. 4 is a block diagram showing a functional configuration of an air conditioner controller according to the first embodiment. As shown in FIG. 4, the air conditioner controller 20 includes a processor 21, a memory 22, a storage 23, and a communication interface 24.

[0030]

The processor 21 functions as a second acquisition unit 201, a second prediction unit 202, an air conditioner control unit 203, and a second learning unit 204 by operating according to a predetermined program.

[0031]

The second acquisition unit 201 acquires the measurement value of the sensor of each unit of the air conditioning system 100. For example, the second acquisition unit 201 acquires the measurement value of the temperature (room temperature T_{a_act} [°C]) of the server room from the temperature sensor T1 provided in the server room. The second acquisition unit 201 acquires the measurement value of the power consumption $E1$ [kW] of the air conditioner 2 from the power meter WM1 of the air conditioner 2. The second acquisition unit 201 acquires the measurement value of the outside air temperature T_f from the temperature sensor T2 outside the server room. The second acquisition unit 201 may acquire the measurement values via the integrated controller 10 instead of directly acquiring the measurement values from the sensors. In addition, the second acquisition unit 201 acquires the control command from the integrated controller 10. The control command includes a request for the power consumption prediction value, a command for the setting temperature T_a of the server room, and the like.

[0032]

The second prediction unit 202 predicts the power consumption $E1$ or an operating point of the air conditioner 2 by using a second model M2 (FIG. 5). As shown in FIG. 5, the second model M2 is a prediction model that uses a range of the setting temperature and the future heat load prediction value of the server room as explanatory variables and that uses the power consumption prediction value of the air conditioner 2 for each setting temperature as an objective variable. In addition, the second model M2 may further use measurement values of a current room temperature T_{a_act} or the current outside air temperature T_f as an explanatory variable. By increasing the number of explanatory variables, the second model M1 can more accurately predict the power consumption $E1$ by taking into account a difference

between the current room temperature or the current outside air temperature and a prediction value of the future room temperature.

[0033]

The range of the setting temperature includes at least a part of a temperature range that satisfies the environmental requirement. In a case where the upper limit value (for example, 15°C) of the room temperature is designated by the environmental requirement, the second prediction unit 202 inputs a temperature (for example, 10°C or higher and 15°C or lower) in a predetermined range equal to or lower than the upper limit value to the second model M2 as the range of the setting temperature. In a case where the lower limit value is further designated by the environmental requirement, the second prediction unit 202 inputs a temperature from the lower limit value to the upper limit value to the second model M2 as the range of the setting temperature. The range of the setting temperature may be set by the administrator of the server room, and may be output to the air conditioner controller 20 together with the heat load prediction value by the integrated controller 10.

[0034]

The air conditioner control unit 203 optimizes an operating condition (the number of air conditioners 2 to be operated, an air flow rate of the air conditioners 2 to be operated, and the like) such that the power consumption of the air conditioner 2 is minimized, based on the setting temperature T_a commanded by the integrated controller 10, and controls the air conditioner 2. Since processing of optimizing the operating condition based on the setting temperature is the same as existing processing (for example, refer to PTL 1), a detailed description thereof will be omitted.

[0035]

The second learning unit 204 performs machine learning on the second model

M2 by using a time series of temperature measurement values (room temperature Ta1 and outside air temperature Tf), a time series of the setting temperatures Ta, and a time series of the measurement values of the power consumption E1 of the air conditioner 2 as learning data. The second learning unit 204 trains the second model M2 using a predetermined amount of learning data in a learning phase and records the second model M2 in the storage 23. In addition, in an operation phase of the air conditioner controller 20, the second learning unit 204 sequentially collects the learning data and trains (updates) the second model M2.

[0036]

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

[0037]

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

[0038]

The communication interface 24 is an interface for transmitting and receiving data, a control signal, a measurement, and the like between the integrated controller 10 and various sensors.

[0039]

(Functional Configuration of Heat Source Unit/Auxiliary Unit Controller)

FIG. 6 is a block diagram showing a functional configuration of a heat source unit controller according to the first embodiment. As shown in FIG. 6, the heat source unit controller 30 includes a processor 31, a memory 32, a storage 33, and a

communication interface 34.

[0040]

The processor 31 functions as a third acquisition unit 301, a third prediction unit 302, a heat source unit/auxiliary unit control unit 303, and a third learning unit 304 by operating according to a predetermined program.

[0041]

The third acquisition unit 301 acquires the measurement value of the sensor of each unit of the air conditioning system 100. For example, the third acquisition unit 301 acquires the measurement value of the temperature (room temperature T_{a_act}) [°C] of the server room from the temperature sensor T1 provided in the server room. The third acquisition unit 301 acquires the measurement value of the power consumption $E2$ [kW] of the heat source unit 3 and the auxiliary unit 4 from the power meter WM2 of the heat source unit 3. The third acquisition unit 301 acquires the measurement value of the outside air temperature T_f from the temperature sensor T2 outside the server room. The third acquisition unit 301 may acquire the measurement values via the integrated controller 10 instead of directly acquiring the measurement values from the sensors. In addition, the third acquisition unit 301 acquires the control command from the integrated controller 10. The control command includes a request for the power consumption prediction value, a command for the setting temperature T_a of the server room, and the like.

[0042]

The third prediction unit 302 predicts the power consumption $E2$ of the heat source unit 3 and the auxiliary unit 4 by using a third model M3 (FIG. 5). As shown in FIG. 5, the third model M3 is a prediction model similar to the second model M2, and uses the range of the setting temperature and the future heat load prediction value

of the server room as explanatory variables and uses the power consumption prediction value of the heat source unit 3 for each setting temperature as an objective variable. The range of the setting temperature input to the third model M3 is the same as the range of the setting temperature input to the second model M2.

[0043]

The heat source unit/auxiliary unit control unit 303 optimizes an operating condition (the number of heat source units 3 to be operated, a rotation speed of a compressor of the heat source units 3 to be operated, a rotation speed of the auxiliary unit 4, and the like) such that the power consumption of the heat source unit 3 and the auxiliary unit 4 is minimized, based on the setting temperature T_a commanded by the integrated controller 10, and controls the heat source unit 3 and the auxiliary unit 4. Since processing of optimizing the operating condition based on the setting temperature is the same as existing processing (for example, refer to NPLs 1 and 2), a detailed description thereof will be omitted. In the following description, the heat source unit/auxiliary unit control unit 303 will also be simply referred to as a "heat source unit control unit".

[0044]

The third learning unit 304 performs machine learning on the third model M3 by using a time series of temperature measurement values (room temperature T_{a1} and outside air temperature T_f), a time series of the setting temperatures T_a , and a time series of the measurement values of the power consumption E_2 of the heat source unit 3 and the auxiliary unit 4 as learning data. The third learning unit 304 trains the third model M3 using a predetermined amount of learning data in a learning phase and records the third model M3 in the storage 33. In addition, in an operation phase of the heat source unit controller 30, the third learning unit 304 sequentially collects the

learning data and trains (updates) the third model M3.

[0045]

The memory 32 has a memory region necessary for an operation of the processor 31.

[0046]

The storage 33 is a so-called auxiliary storage device and is, for example, a hard disk drive (HDD), a solid-state drive (SSD), or the like. The storage 33 stores data that is acquired, generated, and referred to by each unit of the processor 31 during processes.

[0047]

The communication interface 34 is an interface for transmitting and receiving the data, the control signal, the measurement, and the like between the integrated controller 10 and various sensors.

[0048]

(Processing of Air Conditioning System)

FIG. 7 is a sequence diagram showing an example of processing of the air conditioning system according to the first embodiment. Here, a flow of the processing of the air conditioning system 100 will be described in detail with reference to FIG. 7. It is assumed that, at a point in time in FIG. 7, the learning phases of the respective controllers 10, 20, and 30 are completed, and the trained models M1 to M3 are recorded in the storage of each controller. Therefore, FIG. 7 shows processing in the operation phase of each controller.

[0049]

First, the first acquisition unit 101 of the integrated controller 10 acquires the measurement values (the room temperature T_{a_act} of the server room, the outside air

temperature T_f , and the like) at the current time from each sensor (step S101). The first acquisition unit 101 may acquire weather forecast data from an external server (not shown) at this time.

[0050]

When the measurement values are acquired, the first prediction unit 102 of the integrated controller 10 predicts the future heat load and an establishment range of a future setting temperature by using the first model M1 (steps S102 and S103). Specifically, the first prediction unit 102 reads out the first model M1 from the storage 13. The first prediction unit 102 inputs the measurement values (the room temperature T_{a_act} of the server room and the outside air temperature T_f) at the current time acquired in step S101 to the readout first model M1, and obtains the future heat load prediction value and the establishment range of the future setting temperature as outputs (steps S102 and S103). In addition, the first prediction unit 102 may further input a current date and time or the weather forecast data to the first model M1. The heat load prediction value is, for example, a predicted room temperature [$^{\circ}\text{C}$] of the server room after n minutes. The establishment range of the setting temperature is, for example, a range of the setting temperature (cooling air discharge temperature) of the air conditioner 2 in which the server room after n minutes can satisfy the environmental requirement (the room temperature is equal to or lower than the upper limit value).

[0051]

In addition, the command unit 103 of the integrated controller 10 requests each of the controllers 20 and 30 to predict the power consumption of the air conditioner 2, the heat source unit 3, and the chilled water pump 4A (auxiliary unit) at each setting temperature included in the establishment range of the setting temperature

of the air conditioner 2 based on the heat load prediction value (step S104).

[0052]

When the request by the integrated controller 10 is received, the second prediction unit 202 of the air conditioner controller 20 optimizes the operating condition to minimize the power consumption of the air conditioner 2 at each setting temperature (step S105). The second prediction unit 202 inputs the heat load prediction value and the establishment range of the setting temperature which are acquired from the integrated controller 10 to the second model M2 read out from the storage 23, and obtains a prediction value of the power consumption E1 of the air conditioner 2 for each setting temperature as an output. For example, as shown in (a) of FIG. 8, it is assumed that the room temperature of the server room is designated to be 15°C or lower as the environmental requirement. In addition, it is assumed that the establishment range of the setting temperature (establishment range of the operating condition of the air conditioner 2) is 10°C or higher and 15°C or lower. The second prediction unit 202 predicts the power consumption E1 of the air conditioner 2 for each setting temperature from 10°C to 15°C by the second model M2. (a) of FIG. 8 is a graph showing an example of the prediction value of the power consumption E1 of the air conditioner 2 with respect to the setting temperature. In addition, the second prediction unit 202 outputs the power consumption prediction value of the air conditioner 2 at each setting temperature and the operating condition at that time to the integrated controller 10 (step S106).

[0053]

When the request by the integrated controller 10 is received, the third prediction unit 302 of the heat source unit controller 30 optimizes the operating condition to minimize the power consumption of the heat source unit 3 and the

auxiliary unit 4 at each setting temperature (step S107). For example, the third prediction unit 302 inputs the heat load prediction value and the establishment range of the setting temperature which are acquired from the integrated controller 10 to the third model M3 read out from the storage 33, and obtains a prediction value of the power consumption E2 of the heat source unit 3 and the auxiliary unit 4 for each setting temperature as an output. For example, in (b) of FIG. 8, a broken line graph is a graph in which a vertical axis represents the power consumption E2 and a horizontal axis represents the operating condition of the heat source unit 3 and the auxiliary unit 4, and shows a transition of the power consumption E2 when the operating condition (the number of operating units, the rotation speed of the compressor) of the heat source unit 3 is changed at a certain setting temperature Ta. A solid line graph in (b) of FIG. 8 is a graph in which a vertical axis represents the power consumption E2 and a horizontal axis represents the setting temperature Ta. The solid line graph is a graph connecting optimum points (operating points at which the power consumption E2 is minimized) of the broken line graph corresponding to each setting temperature Ta, and shows a transition of the power consumption E2 when the heat source unit 3 is most efficiently controlled at each setting temperature Ta. As represented by the solid line graph, a power consumption characteristic of the heat source unit 3 and the auxiliary unit 4 for the setting temperature Ta is different from a power consumption characteristic of the air conditioner 2 ((a) of FIG. 8). The third model M3 learns the power consumption characteristic of the heat source unit 3 and the auxiliary unit 4 and outputs the prediction value of the power consumption of the heat source unit 3 and the auxiliary unit 4 corresponding to each temperature within the establishment range of the setting temperature. In addition, the third prediction unit 302 outputs the power consumption prediction value of the heat source unit 3 at each setting temperature and

the operating condition at that time to the integrated controller 10 (step S108).

[0054]

Next, when the command unit 103 of the integrated controller 10 acquires the power consumption prediction values from each of the controllers 20 and 30, the command unit 103 selects the setting temperature at which the sum of the power consumption prediction values is minimized (step S110). For example, as shown in (c) of FIG. 8, it is assumed that the sum of the prediction value of the power consumption E1 of the air conditioner 2 and the prediction value of the power consumption E2 of the heat source unit 3 and the auxiliary unit 4 is minimized (optimum point P3) when the setting temperature is 13°C. In this case, the command unit 103 selects the optimum point P3 = 13°C as the setting temperature of the server room in the establishment range of the setting temperature (10°C to 15°C). The command unit 103 outputs, to each of the controllers 20 and 30, the selected setting temperature (13°C) as the control command (step S110).

[0055]

The air conditioner control unit 203 of the air conditioner controller 20 changes the operating condition of the air conditioner 2 to the operating condition corresponding to the setting temperature (13°C in an example of FIG. 8) commanded by the integrated controller 10 among the operating conditions obtained in step S105 (step S111). In addition, similarly, the heat source unit control unit 303 of the heat source unit controller 30 changes the operating condition of the heat source unit 3 and the auxiliary unit 4 (chilled water pump 4A) to the operating condition corresponding to the setting temperature commanded by the integrated controller 10 among the operating conditions obtained in step S107 (step S112).

[0056]

Each controller repeatedly executes a series of processing of FIG. 7 at a regular interval. In this way, it is possible to operate each unit of the air conditioning system 100 such that the power consumption of the entire air conditioning system 100 is minimized while satisfying the environmental requirement of the server room in response to the room temperature and the outside air temperature that change from moment to moment.

[0057]

(Training Processing)

In addition, each controller sequentially performs training and updating of the models in parallel with the processing shown in FIG. 7. Here, training processing will be described with reference to FIGS. 9 and 10.

[0058]

FIG. 9 is a flowchart showing an example of processing of the integrated controller according to the first embodiment. The integrated controller 10 performs the training processing shown in FIG. 9 in parallel with the series of processing shown in FIG. 7.

[0059]

First, the first acquisition unit 101 of the integrated controller 10 acquires a measurement value (room temperature of the server room) of a heat load at the current time (step S201).

[0060]

Next, the first learning unit 104 of the integrated controller 10 reads out the heat load prediction value predicted by the first prediction unit 102 in the past from the storage 13 (step S202). It is assumed that the first prediction unit 102 predicts a heat load after n minutes in step S102 of FIG. 7. In this case, the first learning unit 104

reads out a heat load prediction value predicted n minutes before the current time.

[0061]

In addition, the first learning unit 104 learns an error between an actual heat load (measurement value) at a current time t and a heat load prediction value at the time t predicted n minutes before, and updates the first model M1 (step S203). The first learning unit 104 learns a weight to minimize an evaluation function based, for example, on the error between the actual measurement value and the prediction value, and updates the first model M1.

[0062]

Although FIG. 9 shows an example in which the first model M1 learns the heat load, the present disclosure is not limited thereto. In the other embodiments, the first model M1 may further learn the operating points such as the discharge temperature and flow rate of the cooling air of the air conditioner 2, the chilled water temperature and flow rate, and the cooling water temperature and flow rate. In this case, in steps S201 to S203, the first learning unit 104 learns the error between the measurement value and the prediction value of these operating points in addition to the heat load, and updates the first model M1.

[0063]

FIG. 10 is a flowchart showing an example of processing of the air conditioner controller, the heat source unit controller, and an auxiliary unit controller according to the first embodiment. Each controller performs the training processing shown in FIG. 10 in parallel with the series of processing shown in FIG. 7. Since the processing of each controller is the same, the air conditioner controller 20 will be described as an example.

[0064]

First, the second acquisition unit 201 of the air conditioner controller 20 acquires a measurement of the power consumption E1 of the air conditioner 2 (step S211).

[0065]

Next, the second learning unit 204 of the air conditioner controller 20 reads out the power consumption prediction value of the air conditioner 2 predicted by the second prediction unit 202 in the past from the storage 23 (step S212). It is assumed that the second prediction unit 202 predicts power consumption after n minutes in step S105 of FIG. 7. In this case, the second learning unit 204 reads out a power consumption prediction value predicted n minutes before the current time.

[0066]

In addition, the second learning unit 204 learns an error between actual power consumption E1 (measurement value) of the air conditioner 2 at the current time t and a power consumption prediction value at the time t predicted n minutes before, and updates the second model M2 (step S213). The second learning unit 204 learns a weight to minimize an evaluation function based, for example, on the error between the actual measurement value and the prediction value, and updates the second model M2. The third learning unit 304 of the heat source unit controller 30 updates the third model M3 in the same manner based on the error with an actual measurement value of the power consumption E2 of the heat source unit 3 and the auxiliary unit 4 (chilled water pump 4A).

[0067]

Although FIG. 10 shows an example in which the second model M2 and the third model M3 learn the power consumption, the present disclosure is not limited thereto. In the other embodiments, the second model M2 and the third model M3

may learn the operating points such as the discharge temperature and flow rate of the cooling air of the air conditioner 2, the chilled water temperature and flow rate, and the cooling water temperature and flow rate. In this case, the second learning unit 204 and the third learning unit 304 each learn the error between the measurement values and the prediction values of these operating points in addition to the power consumption in steps S211 to S213, and update the second model M2 and the third model M3.

[0068]

(Operations and Effects)

As described above, the air conditioning system 100 includes the air conditioner controller 20, the heat source unit controller 30, and the integrated controller 10. The integrated controller 10 includes the first prediction unit 102 that predicts the future heat load (room temperature) of the server room and the establishment range of the setting range based on the first model M1 that uses the heat load (room temperature T_{a_act}) measured in the server room (air conditioning target space) as an explanatory variable and that uses the future heat load prediction value of the server room and the establishment range of the setting temperature satisfying the environmental requirement of the server room as objective variables, and the command unit 103 that outputs, based on the power consumption prediction value of the air conditioner 2 for each setting temperature predicted by the air conditioner controller 20 and the power consumption prediction value of the heat source unit 3 and the auxiliary unit 4 for each setting temperature predicted by the heat source unit controller 30, the setting temperature at which the sum of the power consumption prediction values is minimized as the control command. The air conditioner controller 20 includes the second prediction unit 202 that predicts the power

consumption E1 of the air conditioner 2 for each setting temperature by using the second model M2 that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable. The heat source unit controller 30 includes the third prediction unit 302 that predicts the power consumption E2 of the heat source unit 3 and the auxiliary unit 4 for each setting temperature by using the third model M3 that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

[0069]

As described above, in the related art, the administrator of the server room tends to determine the setting temperature of the server room (air conditioner) such that the power consumption of the air conditioner is minimized. However, as shown in (a) and (b) of FIG. 8, since the air conditioner and the heat source unit and the auxiliary unit have different power consumption characteristics, it is difficult to minimize the power consumption of the heat source unit in a case where the setting temperature of the server room is set based on the optimum point of the air conditioner. On the other hand, the air conditioning system 100 according to the present embodiment can minimize the power consumption of the entire air conditioning system 100 while satisfying the environmental requirement by searching for and determining the setting temperature at which the sum of the power consumption prediction values of the air conditioner 2, the heat source unit 3, and the auxiliary unit 4 is minimized from among a plurality of setting temperatures. In addition, compared to the related art, since the setting temperature of the server room can be

appropriately set, temperatures of server components (CPU, GPU) can be more effectively lowered, and a failure probability of the server components can be reduced. In addition, since an operating rate of a cooling fan provided in the server is reduced as the temperatures of the server components are lowered, power consumption of the server can be reduced.

[0070]

In addition, a heat load of the server room (air conditioning target space) is the room temperature of the server room, and the first prediction unit 102 of the integrated controller 10 predicts the future room temperature of the server room as the heat load prediction value.

[0071]

In this way, the air conditioning system 100 can measure the room temperature T_{a_act} , which is a current heat load of the server room, with a simple configuration in which only the temperature sensor T1 is provided in the server room.

[0072]

<Second Embodiment>

A second embodiment will be described below with reference to FIGS. 11 and 12. Among 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.

[0073]

FIG. 11 is a schematic diagram showing an overall configuration of an air conditioning system according to the second embodiment. As shown in FIG. 11, in the present embodiment, a plurality of temperature sensors T3 are further provided in the server room. Each temperature sensor T3 is provided adjacent to each of a

plurality of servers 5, and measures temperatures (CPU temperature, GPU temperature) Tp1, Tp2, Tp3, ... of the respective servers 5.

[0074]

In addition, in the present embodiment, the first acquisition unit 101 of the integrated controller 10 acquires measurement values of the temperatures Tp1, Tp2, Tp3, ... of the respective servers 5 at the current time from the temperature sensors T3 in step S101 of FIG. 7. In step S102 of FIG. 7, the first prediction unit 102 further inputs the measurement values of the temperatures Tp1, Tp2, Tp3, ... of the respective servers 5 to the first model M1, and obtains the future heat load prediction value as an output. As shown in FIG. 12, the first model M1 of the present embodiment outputs a predicted temperature [°C] of each server 5 after n minutes as the heat load prediction value.

[0075]

In addition, in the present embodiment, the environmental requirement is a maximum allowable temperature of each server, and the setting temperature is the temperature of each server. The maximum allowable temperature is, for example, a value defined as a specification of the server (CPU, GPU). In step S105 of FIG. 7, the second prediction unit 202 of the air conditioner controller 20 inputs a temperature (for example, 40°C to 70°C) in a predetermined range equal to or lower than the maximum allowable temperature to the second model M2 as the range of the setting temperature. The same applies to the processing in step S107 of FIG. 7.

[0076]

In this way, the air conditioning system 100 can minimize the power consumption of the entire air conditioning system 100 while preventing each server 5 from exceeding the maximum allowable temperature. In addition, by monitoring and

cooling the temperature of each server 5 in this way, it is possible to cool the server components more effectively than in the first embodiment, so that a failure probability of the server (CPU, GPU) can be further reduced. In addition, by cooling the server components, the operating rate of the cooling fan of the server can be reduced, and an effect of reducing the power consumption of the server can be improved.

[0077]

<Third Embodiment>

A third embodiment will be described below with reference to FIGS. 13 to 15. Among configurations of the third embodiment, the same configurations as those of the above-described embodiments will be described using the same reference numerals as those of the above-described embodiments.

[0078]

FIG. 13 is a schematic diagram showing an overall configuration of an air conditioning system according to the third embodiment. As shown in FIG. 13, the air conditioning system 100 according to the present embodiment further includes a server controller 50.

[0079]

FIG. 14 is a block diagram showing a functional configuration of the server controller according to the third embodiment. As shown in FIG. 14, the server controller 50 includes a processor 51, a memory 52, a storage 53, and a communication interface 54.

[0080]

The processor 51 functions as a fifth acquisition unit 501 and an allocation unit 502 by operating according to a predetermined program.

[0081]

The fifth acquisition unit 501 acquires a job request for the server 5 from a higher-level device.

[0082]

The allocation unit 502 allocates the job to each server 5 such that a processing amount of each server 5 is balanced.

[0083]

The memory 52 has a memory region necessary for an operation of the processor 51.

[0084]

The storage 53 is a so-called auxiliary storage device and is, for example, a hard disk drive (HDD), a solid-state drive (SSD), or the like. The storage 53 stores data that is acquired, generated, and referred to by each unit of the processor 51 during processes.

[0085]

The communication interface 54 is an interface for transmitting and receiving data, a control signal, a measurement, and the like between the integrated controller 10, the higher-level device, and various sensors.

[0086]

In addition, in a case where there is a server in which a margin of the server temperature is less than a threshold value, the command unit 103 of the integrated controller 10 commands the air conditioner controller 20 such that a setting temperature of an air conditioner for which the server is an air conditioning target is to be lower than a setting temperature of another air conditioner.

[0087]

The air conditioner control unit 203 of the air conditioner controller 20

performs control of lowering the setting temperature for the designated air conditioner.

[0088]

FIG. 15 is a sequence diagram showing an example of processing of the air conditioning system according to the third embodiment. Here, a flow of processing of the integrated controller 10, the air conditioner controller 20, and the server controller 50 according to the present embodiment will be described with reference to FIG. 15.

[0089]

First, the fifth acquisition unit 501 of the server controller 50 acquires the job request from the higher-level device (step S301). In this case, the allocation unit 502 of the server controller 50 changes allocation of the job to each server 5 to balance a processing load of each server 5. As a result, the server controller 50 can suppress concentration of a load on some servers 5 and an increase in the server temperature.

[0090]

In parallel with the processing of the server controller 50, the first acquisition unit 101 of the integrated controller 10 acquires the measurement values of the temperatures Tp1, Tp2, Tp3, ... of the respective servers 5 at the current time from the temperature sensor T3 (step S303).

[0091]

In addition, the command unit 103 of the integrated controller 10 determines whether there is a server in which the margin of the server temperature is less than the threshold value (step S304). The margin is a difference between the maximum allowable temperature and a current server temperature (maximum allowable temperature - current server temperature). In a case where there is a server 5 in which the margin is less than the threshold value (for example, 5°C) (step S304), the

command unit 103 identifies the air conditioner 2 for which the server 5 is an air conditioning target, as a target air conditioner. In addition, information in which each air conditioner 2 is associated with a corresponding server 5 as the air conditioning target is recorded in advance in the storage 13 of the integrated controller 10, and the command unit 103 identifies the target air conditioner with reference to the information. In addition, the command unit 103 changes a setting temperature of the target air conditioner to be lower than a setting temperature of another air conditioner 2 (step S305), and outputs identification information (air conditioner ID) of the target air conditioner and a setting temperature after change to the air conditioner controller 20 as the control command (step S306).

[0092]

The air conditioner control unit 203 of the air conditioner controller 20 performs control to optimize the operating condition based on the setting temperature after the change for the target air conditioner designated by the integrated controller 10 (step S307).

[0093]

The air conditioning system 100 repeatedly executes a series of processing of FIG. 15 at a regular interval. In this way, the air conditioning system 100 can suppress a bias of the processing load of the servers 5 and prevent the temperature of each server 5 from exceeding the maximum allowable temperature by the processing of the server controller 50. In addition, even in a case where the processing load is concentrated on some servers 5 and the temperature is increased despite an attempt of the server controller 50 to perform balancing processing, the integrated controller 10 can change the setting temperatures of some air conditioners 2 to cool only those servers 5. In this manner, it is possible to suppress an increase in the power

consumption of the entire air conditioning system 100 while preventing the temperature of each server 5 from exceeding the maximum allowable temperature.

[0094]

<Fourth Embodiment>

A fourth embodiment will be described below with reference to FIGS. 16 to 18. Among configurations of the fourth embodiment, the same configurations as those of the above-described embodiments will be described using the same reference numerals as those of the above-described embodiments.

[0095]

FIG. 16 is a schematic diagram showing an overall configuration of an air conditioning system according to the fourth embodiment. As shown in FIG. 16, the air conditioning system 100 according to the present embodiment further includes a power generation facility 6 and a power generation controller 60.

[0096]

The power generation facility 6 is, for example, a solar power generation facility or the like, and supplies generated power to the air conditioning system 100. The power generation facility 6 includes a storage battery 6A, and may charge the storage battery 6A with surplus power in a case where the generated power (supply amount) is larger than power consumption (demand amount) of the air conditioning system 100. In addition, in a case where the generated power is smaller than the power consumption of the air conditioning system 100, a shortfall may be covered by discharging power from the storage battery 6A, or power may be purchased from a power system.

[0097]

FIG. 17 is a block diagram showing a functional configuration of a power

generation controller according to the fourth embodiment. As shown in FIG. 17, the power generation controller 60 includes a processor 61, a memory 62, a storage 63, and a communication interface 64.

[0098]

The processor 61 functions as a supply and demand prediction unit 601 and a power generation control unit 602 by operating according to a predetermined program.

[0099]

The supply and demand prediction unit 601 predicts a power demand amount of the air conditioning system 100 and a power supply amount of the power generation facility 6.

[0100]

The power generation control unit 602 adjusts a power generation amount of the power generation facility 6 based on the power demand amount and the power supply amount.

[0101]

The memory 62 has a memory region necessary for an operation of the processor 61.

[0102]

The storage 63 is a so-called auxiliary storage device and is, for example, a hard disk drive (HDD), a solid-state drive (SSD), or the like. The storage 63 stores data that is acquired, generated, and referred to by each unit of the processor 61 during processes.

[0103]

The communication interface 64 is an interface for transmitting and receiving the data, the control signal, the measurement, and the like between the integrated

controller 10 and various sensors.

[0104]

FIG. 18 is a flowchart showing an example of processing of the power generation controller according to the fourth embodiment. Here, a flow of processing of the power generation controller 60 will be described with reference to FIG. 18.

[0105]

First, the supply and demand prediction unit 601 of the power generation controller 60 predicts the power demand amount of the air conditioning system 100 and the power supply amount of the power generation facility 6 (step S401). For example, the supply and demand prediction unit 601 acquires the sum of the power consumption prediction values of the respective units with respect to the setting temperature from the integrated controller 10, and sets the sum as a prediction value of the power demand amount after n minutes. In addition, the supply and demand prediction unit 601 predicts a power generation amount (power supply amount) of the power generation facility 6 after n minutes from statistical data or the like accumulated in advance.

[0106]

Next, in a case where the predicted power supply amount is larger than the power demand amount (step S402; YES), the power generation control unit 602 of the power generation controller 60 determines that the generated power is surplus. In this case, the power generation control unit 602 performs control of reducing surplus generated power or control of charging the storage battery (step S403). For example, in a case where surplus can be stored in the storage battery 6A, the power generation control unit 602 outputs a control command to store the surplus in the storage battery 6A to the power generation facility 6. In addition, in a case where an amount of

power stored in the storage battery 6A is large and a part or all of the surplus cannot be stored in the storage battery 6A, a control command to reduce the generated power may be output to the power generation facility 6. In this way, the power generation control unit 602 can suppress the excessive power generation of the power generation facility 6. In addition, by storing the surplus power in the storage battery 6A, it is possible to provide for a case where the power demand amount is high.

[0107]

In addition, in a case where the predicted power supply amount is smaller than the power demand amount (step S402; NO and step S404; YES), the power generation control unit 602 performs control of increasing the power generation amount of the power generation facility 6, control of discharging power corresponding to the shortfall from the storage battery 6A, control of purchasing power from the power system, or control of suppressing the jobs of the servers (step S405). For example, in a case where the amount of power stored in the storage battery 6A is sufficient, the power generation control unit 602 outputs a control command to discharge the shortfall from the storage battery 6A and supply the discharged power to the air conditioning system 100, to the power generation facility 6. In addition, in a case where the amount of power stored in the storage battery 6A cannot cover the shortfall or in a case where the power generation amount of the power generation facility 6 can be increased (that is, the power supply amount < a potential power generation amount), the power generation control unit 602 may output a control command to increase the power generation amount to the power generation facility 6. In a case where the amount of power stored in the storage battery 6A is not sufficient and the power generation amount of the power generation facility cannot be increased any further, the power generation facility 6 requests the server controller 50 to suppress the jobs of the

servers through the integrated controller 10. In this case, the command unit 103 of the integrated controller 10 receives the request by the power generation controller 60 and commands the server controller 50 to suppress job input. In a case where the server controller 50 receives the command to suppress job input, the server controller 50 restricts acceptance of new jobs from the higher-level device. In addition, in a case where the power demand amount exceeds the power supply amount even in a case where the power generation control unit 602 attempts to suppress job input, the power generation control unit 602 may purchase the shortfall from the power system. The power generation control unit 602 may first attempt to suppress job input, and in a case where a power demand is excessive even after the attempt, the power generation control unit 602 may perform other controls such as increasing the power generation amount. Priority of these controls may be optionally changed by the administrator. In this way, in a case where the power demand is predicted to be excessive in the air conditioning system 100, the power generation control unit 602 can suppress job input to the servers 5 and reduce the power demand. In addition, the power demand amount of the air conditioning system 100 can be covered by increasing the power generation amount of the power generation facility 6, discharging power from the storage battery 6A, or purchasing power.

[0108]

In a case where the predicted power demand amount and power supply amount match (step S403; NO and step S404; NO), the power generation control unit 602 does nothing and ends the processing.

[0109]

The power generation controller 60 repeatedly executes a series of processing in FIG. 18 at a regular interval.

[0110]

<Fifth Embodiment>

A fifth embodiment will be described below with reference to FIG. 19. Among configurations of the fifth embodiment, the same configurations as those of the above-described embodiments will be described using the same reference numerals as those of the above-described embodiments.

[0111]

FIG. 19 is a schematic diagram showing an overall configuration of an air conditioning system according to the fifth embodiment. FIG. 19 shows a flow of data such as a control command and a measurement value in the air conditioning system 100. As shown in FIG. 19, in the integrated controller 10 according to the present embodiment, the first model M1 includes a server room environment optimization AI (M1a) and an air conditioning system operating point optimization AI (M1b). The server room environment optimization AI (M1a) receives a current indoor environment (room temperature) and an outside air environment (outside air temperature) as inputs and predicts and outputs a state of a future heat load of a server room environment and an establishment range of the discharge temperature (setting temperature) and the flow rate of the cooling air of the air conditioner 2, in the same manner as the first model M1 in the above-described embodiments. In addition, the air conditioning system operating point optimization AI (M1b) predicts and outputs an optimal operating point of the air conditioning system that satisfies the establishment range of the discharge temperature and the flow rate of the cooling air. The optimal operating point includes, for example, cooling air discharge temperature and flow rate, cooling water inlet temperature and flow rate, chilled water outlet temperature and flow rate, and the like. The air conditioner control unit 203 of the air conditioner controller 20 outputs a

control signal for controlling a fan rotation speed to the air conditioner 2 based on the optimal operating point (cooling air discharge temperature and flow rate) output by the air conditioning system operating point optimization AI (M1b). The heat source unit controller 30 outputs control signals such as a cooling water pump rotation speed, a cooling tower fan rotation speed, the number of operating units and a load distribution of the heat source unit 3, and a chilled water pump rotation speed to each device based on the optimal operating point (cooling water temperature and flow rate, chilled water temperature and flow rate) output by the air conditioning system operating point optimization AI (M1b). Even in such an aspect, the same effect as that of the above-described embodiments can be obtained.

[0112]

<Other Embodiments>

The embodiments have been described in detail above with reference to the drawings. However, the specific configuration is not limited to the above description, and various design changes and the like can be made. That is, in the other embodiments, the order of the above processes may be changed as appropriate. In addition, some of the processes may be executed in parallel.

[0113]

<Supplementary Notes>

The air conditioning system and the method for controlling an air conditioning system described in the above-described embodiments are understood as follows, for example.

[0114]

(1) According to a first aspect, an air conditioning system 100 is an air conditioning system 100 including: an air conditioner controller 20 that controls an air

conditioner 2 provided in an air conditioning target space; a heat source unit controller 30 that controls a heat source unit 3 and an auxiliary unit 4 that supply a heat source to the air conditioner 2; and an integrated controller 10 that outputs a control command to the air conditioner controller 20 and the heat source unit controller 30, in which the integrated controller 10 includes a first prediction unit 102 that predicts a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model M1 that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables, and a command unit 103 that outputs, based on a power consumption prediction value of the air conditioner 2 for each setting temperature predicted by the air conditioner controller 20 and a power consumption prediction value of the heat source unit 3 and the auxiliary unit 4 for each setting temperature predicted by the heat source unit controller 30, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command, the air conditioner controller 20 includes a second prediction unit 202 that predicts power consumption of the air conditioner 2 for each setting temperature included in the establishment range by using a second model M2 that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable, and the heat source unit controller 30 includes a third prediction unit 302 that predicts power consumption of the heat source unit 3 and the auxiliary unit 4 for each setting temperature included in the establishment range by using a third model M3 that uses the establishment range of the setting temperature and the heat

load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

[0115]

The air conditioning system 100 can minimize the power consumption of the entire air conditioning system 100 while satisfying the environmental requirement by searching for and determining the setting temperature at which the sum $E1 + E2$ of the power consumption prediction values of the air conditioner 2, the heat source unit 3, and the auxiliary unit 4 is minimized from among a plurality of setting temperatures. In addition, compared to the related art, since the server room can be appropriately cooled, the temperatures of the server components (CPU, GPU) can be more effectively lowered, and the failure probability of the server components can be reduced. In addition, since an operating rate of a cooling fan provided in the server is reduced as the temperatures of the server components are lowered, power consumption of the server can be reduced.

[0116]

(2) According to a second aspect, in the air conditioning system 100 according to the first aspect, the heat load is a room temperature of the air conditioning target space, and the first prediction unit 102 of the integrated controller 10 predicts future room temperature of the air conditioning target space as the heat load prediction value.

[0117]

In this way, the air conditioning system 100 can measure the room temperature Ta_{act} , which is a current heat load of the server room, with a simple configuration in which only the temperature sensor T1 is provided in the server room.

[0118]

(3) According to a third aspect, in the air conditioning system 100 according to

the first aspect, a plurality of servers 5 are installed in the air conditioning target space, the heat load of the air conditioning target space is a server temperature of each of the servers 5, and the first prediction unit 102 of the integrated controller 10 predicts the future server temperature as the heat load prediction value.

[0119]

In this way, the air conditioning system 100 can minimize the power consumption of the entire air conditioning system 100 while preventing each server 5 from exceeding the maximum allowable temperature. In addition, by monitoring and cooling the temperature of each server 5 in this way, it is possible to cool the server components more effectively than in the first embodiment, so that a failure probability of the server (CPU, GPU) can be further reduced. In addition, by cooling the server components, the operating rate of the cooling fan of the server can be reduced, and an effect of reducing the power consumption of the server can be improved.

[0120]

(4) According to a fourth aspect, the air conditioning system 100 according to the third aspect further includes a server controller 50 that allocates jobs to the plurality of servers 5 such that a processing amount of each of the servers 5 is balanced, in which in a case where there is a server 5 in which a margin of the server temperature is less than a threshold value, the command unit 103 of the integrated controller 10 commands the air conditioner controller 20 such that a setting temperature of an air conditioner 2 for which the server 5 is an air conditioning target is to be lower than a setting temperature of another air conditioner 2.

[0121]

In this way, the air conditioning system 100 can suppress a bias of the processing load of the servers 5 and prevent the temperature of each server 5 from

exceeding the maximum allowable temperature by the processing of the server controller 50. In addition, even in a case where the processing load is concentrated on some servers 5 and the temperature is increased despite an attempt of the server controller 50 to perform balancing processing, the integrated controller 10 can change the setting temperatures of some air conditioners 2 to cool only those servers 5. In this manner, it is possible to suppress an increase in the power consumption of the entire air conditioning system 100 while preventing the temperature of each server 5 from exceeding the maximum allowable temperature.

[0122]

(5) According to a fifth aspect, the air conditioning system 100 according to any one of the first to fourth aspects further includes a power generation controller 60 that controls a power generation facility 6 supplying generated power to the air conditioning system 100, in which the power generation controller 60 includes a supply and demand prediction unit 601 that predicts a power demand amount of the air conditioning system 100 and a power supply amount of the power generation facility 6, and a power generation control unit 602 that adjusts a power generation amount of the power generation facility 6 based on the power demand amount and the power supply amount.

[0123]

In this way, the air conditioning system 100 can suppress the excessive power generation of the power generation facility 6.

[0124]

(6) According to a sixth aspect, the air conditioning system 100 according to the fifth aspect further includes a server controller 50 that allocates jobs to a plurality of servers 5 installed in the air conditioning target space such that a processing amount

of each of the servers 5 is balanced, in which in a case where the power demand amount is greater than the power supply amount, the power generation control unit 602 of the power generation controller 60 requests the server controller 50 to suppress job input through the integrated controller 10, and in a case where suppression of job input is requested, the server controller 50 restricts acceptance of new jobs.

[0125]

In this way, in a case where the power demand is predicted to be excessive, the air conditioning system 100 can suppress job input to the servers 5 and reduce the power demand.

[0126]

(7) According to a seventh aspect, a method for controlling an air conditioning system 100 is a method for controlling an air conditioning system 100 including an air conditioner controller 20 that controls an air conditioner 2 provided in an air conditioning target space, a heat source unit controller 30 that controls a heat source unit 3 and an auxiliary unit 4 that supply a heat source to the air conditioner 2, and an integrated controller 10 that outputs a control command to the air conditioner controller 20 and the heat source unit controller 30, the method including: a step of, via the integrated controller 10, predicting a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model M1 that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables; a step of, via the integrated controller 10, outputting, based on a power consumption prediction value of the air conditioner 2 for each setting temperature predicted by the air

conditioner controller 20 and a power consumption prediction value of the heat source unit 3 and the auxiliary unit 4 for each setting temperature predicted by the heat source unit controller 30, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command; a step of, via the air conditioner controller 20, predicting power consumption of the air conditioner 2 for each setting temperature included in the establishment range by using a second model M2 that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable; and a step of, via the heat source unit controller 30, predicting power consumption of the heat source unit 3 and the auxiliary unit 4 for each setting temperature included in the establishment range by using a third model M3 that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

Industrial Applicability

[0127]

According to the aspect, it is possible to minimize the power consumption of the entire air conditioning system while satisfying the environmental requirement.

Reference Signs List

[0128]

100: air conditioning system

2: air conditioner

3: heat source unit

4: auxiliary unit

4A: chilled water pump
4B: cooling water pump
4C: outdoor unit
5: server
6A: storage battery
10: integrated controller
101: first acquisition unit
102: first prediction unit
103: command unit
104: first learning unit
20: air conditioner controller
201: second acquisition unit
202: second prediction unit
203: air conditioner control unit
204: second learning unit
30: heat source unit controller
301: third acquisition unit
302: third prediction unit
303: heat source unit control unit
304: third learning unit
50: server controller
501: fifth acquisition unit
502: allocation unit
60: power generation controller
601: supply and demand prediction unit

602: power generation control unit

Claims

[Claim 1]

An air conditioning system comprising:

an air conditioner controller that controls an air conditioner provided in an air conditioning target space;

a heat source unit controller that controls a heat source unit and an auxiliary unit that supply a heat source to the air conditioner; and

an integrated controller that outputs a control command to the air conditioner controller and the heat source unit controller,

wherein the integrated controller includes

a first prediction unit that predicts a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables, and

a command unit that outputs, based on a power consumption prediction value of the air conditioner for each setting temperature predicted by the air conditioner controller and a power consumption prediction value of the heat source unit and the auxiliary unit for each setting temperature predicted by the heat source unit controller, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command,

the air conditioner controller includes a second prediction unit that predicts power consumption of the air conditioner for each setting temperature included in the

establishment range by using a second model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable, and

the heat source unit controller includes a third prediction unit that predicts power consumption of the heat source unit and the auxiliary unit for each setting temperature included in the establishment range by using a third model that uses an establishment range prediction value of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.

[Claim 2]

The air conditioning system according to Claim 1,

wherein the heat load is a room temperature of the air conditioning target space, and

the first prediction unit of the integrated controller predicts the future room temperature of the air conditioning target space as the heat load prediction value.

[Claim 3]

The air conditioning system according to Claim 1,

wherein a plurality of servers are installed in the air conditioning target space,

the heat load of the air conditioning target space is a server temperature of each of the servers, and

the first prediction unit of the integrated controller predicts the future server temperature as the heat load prediction value.

[Claim 4]

The air conditioning system according to Claim 3, further comprising:

a server controller that allocates jobs to the plurality of servers such that a processing amount of each of the servers is balanced,

wherein in a case where there is a server in which a margin of the server temperature is less than a threshold value, the command unit of the integrated controller commands the air conditioner controller such that a setting temperature of an air conditioner for which the server is an air conditioning target is to be lower than a setting temperature of another air conditioner.

[Claim 5]

The air conditioning system according to any one of Claims 1 to 4, further comprising:

a power generation controller that controls a power generation facility supplying generated power to the air conditioning system,

wherein the power generation controller includes

a supply and demand prediction unit that predicts a power demand amount of the air conditioning system and a power supply amount of the power generation facility, and

a power generation control unit that adjusts a power generation amount of the power generation facility based on the power demand amount and the power supply amount.

[Claim 6]

The air conditioning system according to Claim 5, further comprising:

a server controller that allocates jobs to a plurality of servers installed in the air conditioning target space such that a processing amount of each of the servers is balanced,

wherein in a case where the power demand amount is greater than the power supply amount, the power generation control unit of the power generation controller requests the server controller to suppress job input through the integrated controller, and

in a case where suppression of job input is requested, the server controller restricts acceptance of new jobs.

[Claim 7]

A method for controlling an air conditioning system including an air conditioner controller that controls an air conditioner provided in an air conditioning target space, a heat source unit controller that controls a heat source unit and an auxiliary unit that supply a heat source to the air conditioner, and an integrated controller that outputs a control command to the air conditioner controller and the heat source unit controller, the method comprising:

a step of, via the integrated controller, predicting a future heat load of the air conditioning target space and an establishment range of a setting range based on a first model that uses a heat load measured in the air conditioning target space as an explanatory variable and that uses a future heat load prediction value of the air conditioning target space and an establishment range of a setting temperature satisfying an environmental requirement of the air conditioning target space as objective variables;

a step of, via the integrated controller, outputting, based on a power consumption prediction value of the air conditioner for each setting temperature predicted by the air conditioner controller and a power consumption prediction value of the heat source unit and the auxiliary unit for each setting temperature predicted by the heat source unit controller, a setting temperature at which a sum of the power consumption prediction values is minimized as the control command;

a step of, via the air conditioner controller, predicting power consumption of the air conditioner for each setting temperature included in the establishment range by using a second model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable; and

a step of, via the heat source unit controller, predicting power consumption of the heat source unit and the auxiliary unit for each setting temperature included in the establishment range by using a third model that uses the establishment range of the setting temperature and the heat load prediction value as explanatory variables and that uses the power consumption prediction value for each setting temperature as an objective variable.