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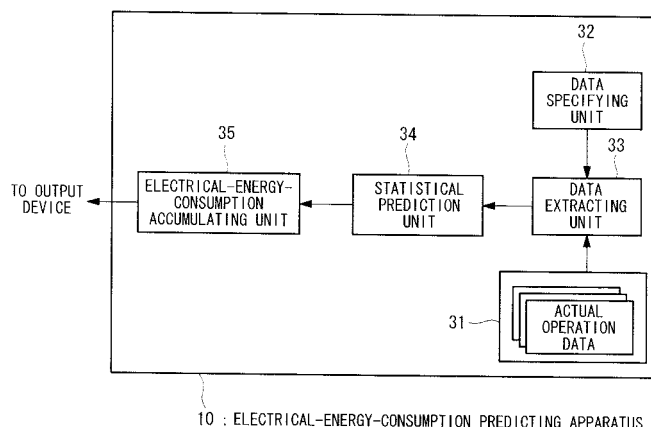
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(54) **AIR CONDITIONING SYSTEM AND DEVICE FOR PREDICTING BUILDING AIR CONDITIONING FACILITY POWER CONSUMPTION AMOUNT**

(57) It is an object to keep an electrical energy consumption per predetermined period within a target electrical energy. Provided is a building-air-conditioning-equipment electrical-energy-consumption predicting apparatus including a database (31) that stores actual operation data in association with the day, hour, and minute, the actual operation data including the electrical energy consumption of building air-conditioning equipment during a predetermined unit time, etc., a data specifying unit (32) that specifies actual operation data to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during a pre-

diction target period, a data extracting unit (33) that extracts the specified actual operation data from the database (31), a statistical prediction unit (34) that predicts the electrical energy consumptions during individual prediction target times in the prediction target period by using a statistical method on the basis of the extracted actual operation data, and an electrical-energy-consumption accumulating unit (35) that calculates the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions during the individual prediction target times.

FIG. 3



Description

Technical Field

5 **[0001]** The present invention relates to, for example, an air-conditioning system that performs centralized management of a plurality of air conditioners installed in a building and to a building-air-conditioning-equipment electrical-energy-consumption predicting apparatus used in the air-conditioning system.

Background Art

10 **[0002]** Air-conditioning systems that perform centralized management of the operation of a plurality of air conditioners installed in a building have hitherto been known. For example, Patent Citations 1 and 2 disclose air-conditioning systems in which a host computer and an air-conditioning controlling and monitoring apparatus are connected via a building-management communication network, the air-conditioning controlling and monitoring apparatus and a plurality of air
15 conditioners are connected via an air-conditioning control network, and the air-conditioning controlling and monitoring apparatus controls the individual air conditioners on the basis of operation control instructions from the host computer.

Patent Citation 1: Japanese Unexamined Patent Application, Publication No. 2005-291610

Patent Citation 2: Japanese Unexamined Patent Application, Publication No. 2005-308278

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Disclosure of Invention

[0003] In a building in which a large number of air conditioners is installed, the electrical energy consumption relating to air-conditioning equipment occupies a large part of the electrical energy consumption of the building as a whole.
25 Furthermore, depending on the contract with a power company, for example, there are cases where the base charge is automatically raised when the electrical energy consumption per defined period (e.g., per 30 minutes) exceeds a contract limit value even once. In such cases, it is necessary to constantly monitor the electrical energy consumption per defined period and to manage the operation so that the electrical energy consumption is kept within the contract limit value.

[0004] It is an object of the present invention to provide an air-conditioning system and an air-conditioning-equipment electrical-energy-consumption predicting apparatus with which, by predicting the electrical energy consumption of building air-conditioning equipment per predetermined period, it is possible to keep the electrical energy consumption per
30 predetermined period within a target electrical energy.

[0005] In order to solve the above problem, the present invention employs the following solutions.
A first aspect of the present invention is a building-air-conditioning-equipment electrical-energy-consumption predicting
35 apparatus that calculates electrical energy consumption of building air-conditioning equipment during a prediction target period, including a storage unit that stores actual operation data of building air-conditioning equipment, in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time; a data specifying unit that specifies actual operation data to be used for predicting the
40 cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period; a data extracting unit that extracts the actual operation data specified by the data specifying unit from the storage unit; a statistical prediction unit that predicts the electrical energy consumptions during individual prediction target times in the prediction target period by using time-series analysis on the basis of the actual operation data extracted by the data extracting unit; and an electrical-energy-consumption accumulating unit that calculates the electrical energy consumption
45 of the building air-conditioning equipment during the prediction target period by using the electrical energy consumptions during the individual prediction target times predicted by the statistical prediction unit and the actual operation data stored in the storage unit and relevant to the prediction target period.

[0006] With this configuration, the statistical prediction unit predicts the electrical energy consumptions during the individual prediction target times in the prediction target period by using the actual operation data stored in the storage
50 unit, and the electrical-energy-consumption accumulating unit calculates cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions.

Thus, the cumulative electrical energy consumption during the prediction target period is calculated by using actual operation data for times at which actual operation data already exists in the prediction target period while using the
55 electrical energy consumptions predicted by the statistical prediction unit for future times at which actual operation data does not exist yet.

[0007] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the prediction target period may be set on a per-30-minute basis.

[0008] Contracts with power companies are often determined on the basis of the electrical energy consumption per 30 minutes. Thus, by setting the prediction target period in accordance with the contract with the power company, it becomes possible to manage the operation in consideration of the cost of power.

[0009] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the data specifying unit may specify actual operation data for a predetermined duration in the past belonging to the prediction target period.

[0010] By using the actual operation data of the predetermined duration in the past belonging to the prediction target period, it becomes possible to perform prediction that better reflects the actual situation.

[0011] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the statistical prediction unit may calculate, for each piece of the actual operation data extracted by the data extracting unit, an electrical energy consumption of the air-conditioning equipment during the predetermined unit time, an average outside air temperature during predetermine unit time, an average intake temperature during the predetermined unit time weighted by the capacities of indoor units, and an average temperature setting during the predetermined unit time weighted by the capacities of the indoor units, obtains a state variable vector having these items as elements for each piece of the actual operation data, and predicts the electrical energy consumptions during the individual prediction target times from an autoregressive model representing a linear combination of the state variable vectors.

[0012] With this configuration, since the electrical energy consumption, the average outside air temperature, the weighted-average intake temperature (average room temperature), and the weighted-average temperature setting, which are important parameters for ascertaining the air-conditioning operation status, are used, it becomes possible to improve the reliability of prediction of the electrical energy consumption during the prediction target period.

[0013] The building-air-conditioning-equipment electrical-energy-consumption predicting apparatus may include an operating-level limiting unit that outputs a limitation signal for limiting the operation of the air conditioners installed in the building when the electrical energy consumption of the building air-conditioning equipment during the prediction target period, calculated by the electrical-energy-consumption accumulating unit, exceeds a preset target electrical energy consumption.

[0014] With this configuration, it possible to limit the operation of the air conditioners installed in the building when the cumulative electrical energy consumption during the prediction target period exceeds the target electrical energy consumption. Thus, it is possible to restrict the actual electrical energy consumption during the prediction target period, so that it becomes possible to keep the actual cumulative electrical energy consumption close to the target electrical energy consumption or within the target electrical energy consumption, depending on the situation.

[0015] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, an order of priority of air conditioners whose operation is to be limited may be set in advance, and the operating-level limiting unit may limit operation in order from air conditioners with higher priority levels.

[0016] Accordingly, it becomes possible to keep important air conditioners operating normally. Thus, it becomes possible to perform restricted operation of air-conditioning equipment in consideration of the usage status.

[0017] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the operating-level limiting unit may output the limitation signal for limiting at least one of temperature settings of the air conditioners, compressor rotation speeds, and degrees of opening of electronic expansion valves provided in refrigerator pipes.

[0018] The building-air-conditioning-equipment electrical-energy-consumption predicting apparatus may include a data correcting unit that corrects by a predetermined amount the actual operation data used for prediction by the statistical prediction unit when the electrical energy consumptions of the building air-conditioning equipment during the prediction target period, calculated by electrical-energy-consumption accumulating unit, exceeds a preset target electrical energy consumption, the statistical prediction unit may re-predict electrical energy consumptions for the individual prediction target times by using the actual operation data corrected by the data correcting unit, and the electrical-energy-consumption accumulating unit may calculate the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the re-predicted electrical energy consumptions.

[0019] With this configuration, when the cumulative electrical energy consumption during the prediction target period exceeds the target electrical energy consumption, the data correcting unit corrects an element relating to the operating level (e.g., the weighted-average temperature setting or the like), thereby correcting the actual operation data. The element corrected at this time is an element relating to the operating level, and the other elements, for example, elements relating to observed quantities, are not corrected but are maintained as they are. Then, the statistical prediction unit re-predicts the electrical energy consumptions during the individual prediction target times in the prediction target period by using the corrected actual operation data, and the cumulative electrical energy consumption during the prediction target period is re-calculated by using the re-calculated electrical energy consumptions. Thus, it becomes possible to ascertain how much the cumulative electrical energy consumption is reduced during the prediction target period by correcting a certain parameter by a certain amount in the subsequent operation of the air-conditioning equipment.

[0020] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the date correcting unit may correct by the predetermined amount at least one of temperature settings of the actual operation data

and compressor rotation speeds if the compressor rotation speeds are included in the actual operation data.

[0021] Since the electrical energy consumption is restricted by restricting at least one of the temperature settings and compressor rotation speeds in the actual operation data, it is possible to alleviate discomfort for people in the building compared with the case where the air conditioners are stopped.

[0022] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the data correcting unit may repeat correction of the actual operation data until the electrical energy consumption calculated by the electrical-energy-consumption accumulating unit comes to fall within the target electrical energy consumption.

[0023] With this configuration, it becomes possible to ascertain the amount of correction with which the cumulative electrical energy consumption during the prediction target period falls within the target electrical energy consumption.

[0024] In the building-air-conditioning-equipment electrical-energy-consumption predicting apparatus, the operating-level limiting unit may generate and output the limitation signal on the basis of an amount of correction by the data correcting unit when the electrical energy consumption calculated by the electrical-energy-consumption accumulating unit comes to fall within the target electrical energy consumption.

[0025] Accordingly, it becomes possible to reliably keep the actual cumulative electrical energy consumption during the prediction target period within the target electrical energy consumption.

[0026] A second aspect of the present invention is an air-conditioning system including any one of the above building-air-conditioning-equipment electrical-energy-consumption predicting apparatuses.

[0027] A third aspect of the present invention is a building-air-conditioning-equipment electrical-energy-consumption predicting method of calculating the electrical energy consumption of building air-conditioning equipment during a prediction target period, including a step of specifying actual operation data to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period from a storage unit that stores actual operation data of the building air-conditioning equipment in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time; a step of extracting the specified actual operation data from the storage unit; a step of predicting the electrical energy consumptions during individual prediction target times in the prediction target period by using a statistical method on the basis of the extracted actual operation data; and a step of calculating the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions during the individual prediction target times and the actual operation data stored in the storage unit and relevant to the prediction target period.

[0028] A fourth aspect of the present invention is a computer-readable recording medium having recorded thereon a building-air-conditioning-equipment electrical-energy-consumption predicting program for calculating the electrical energy consumption of building air-conditioning equipment during a prediction target period, the program causing a computer to execute processing for specifying actual operation data to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period from a storage unit that stores actual operation data of the building air-conditioning equipment in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time; processing for extracting the specified actual operation data from the storage unit; processing for predicting the electrical energy consumptions during individual prediction target times in the prediction target period by using a statistical method on the basis of the extracted actual operation data; and processing for calculating the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions during the individual prediction target times and the actual operation data stored in the storage unit and relevant to the prediction target period.

[0029] According to the present invention, since the electrical energy consumptions of building air-conditioning equipment per predetermined period is predicted, an advantage is afforded in that it is possible to keep the electrical energy consumption per predetermined period within the target electrical energy.

Brief Description of Drawings

[0030]

[FIG. 1] Fig. 1 is a diagram showing the overall configuration of an air-conditioning system according to a first embodiment of the present invention.

[FIG. 2] Fig. 2 is a diagram showing the hardware configuration of an electrical-energy-consumption predicting apparatus according to the first embodiment of the present invention.

[FIG. 3] Fig. 3 is a functional block diagram showing an overview of the functions of the electrical-energy-consumption predicting apparatus according to the first embodiment of the present invention.

[FIG. 4] Fig. 4 is a diagram showing an example of the output displayed on a display monitor.

[FIG. 5] Fig. 5 is a functional block diagram showing an overview of the functions of an electrical-energy-consumption predicting apparatus according to a second embodiment of the present invention.

Explanation of Reference:

[0031]

- 1: Host computer
- 2: Building-management communication network
- 3: Air-conditioning controlling and monitoring apparatus
- 4: Air-conditioning control network
- 5: Air conditioners
- 10: Electrical-energy-consumption predicting apparatus
- 21: CPU
- 22: Main storage device
- 23: Auxiliary storage device
- 24: input device
- 25: Output device
- 31: Database
- 32: Data specifying unit
- 33: Data extracting unit
- 34: Statistical prediction unit
- 35: Electrical-energy-consumption accumulating unit
- 36: Data correcting unit
- 37: Operating-level limiting unit

Best Mode for Carrying Out the Invention

[First Embodiment]

[0032] Hereinafter, an air-conditioning system and an electrical-energy-consumption predicting apparatus for air-conditioning equipment according to a first embodiment of the present invention will be described with reference to the drawings.

[0033] Fig. 1 is a block diagram showing the overall configuration of the air-conditioning system according to this embodiment of the present invention. As shown in Fig. 1, the air-conditioning system according to this embodiment includes a host computer 1, an air-conditioning controlling and monitoring apparatus 3 connected to the host computer 1 via a building-management communication network 2, a plurality of air conditioners 5 connected to the air-conditioning controlling and monitoring apparatus 3 via an air-conditioning control network 4, and an electrical-energy-consumption predicting apparatus 10 connected to the host computer 1 and the air-conditioning controlling and monitoring apparatus 3 via the building-management communication network 2.

[0034] The host computer 1 is, for example, a building computer including a CPU (Central Processing Unit), a ROM (Read Only Memory), a RAM (Random Access Memory), an input device, a display device, and so forth, and performs operational management of equipment provided in a building.

[0035] The building-management communication network 2 is a network that uses a communication protocol adopted as a standard for building management (e.g., TCP/IP), for example, a LAN (Local Area Network), an intranet, the Internet, or the like.

[0036] The air-conditioning controlling and monitoring apparatus 3 is an apparatus for performing operation control and operation management of the air conditioner 5 installed in individual rooms in the building, and it monitors the operation status of the individual air conditioners 5 and provides the host computer 1 and the electrical-energy-consumption predicting apparatus 10 with operation status information representing the results of the monitoring.

[0037] For example, the operation status information includes information indicating an operation type, such as cooling operation, warming operation, or operation stopped, and also includes a temperature setting, a room temperature (the temperature of air intaken by an indoor unit), an outside air temperature, an operation time, a compressor rotation speed, and so forth.

The air-conditioning control network 4 is a network that uses a communication protocol adopted as a standard for control and monitoring of the air conditioners 5.

[0038] The electrical-energy-consumption predicting apparatus 10 is, for example, an apparatus that is capable of predicting the electrical energy consumption of all the air conditioners 5 installed in the building on a per-predetermined-

period basis, for example, on a per-30-minute basis.

[0039] Fig. 2 is a block diagram showing an example hardware configuration of electrical-energy-consumption predicting apparatus 10 according to this embodiment.

As shown in Fig. 2, the electrical-energy-consumption predicting apparatus 10 according to this embodiment includes a computer system (computing system) that is configured of a CPU (Central Processing Unit) 21, a main storage device 22 such as a RAM (Random Access Memory), an auxiliary storage device 23 such as a ROM (Read Only Memory), an input device 24 such as a keyboard or a mouse, and an output device 25 such as a display device or a printer, and so forth. Furthermore, the electrical-energy-consumption predicting apparatus 10 includes a communication device (not shown) for exchanging data via the building-management communication network 2 with the host computer 1, the building-management communication network 3, and so forth shown in Fig. 1.

[0040] The auxiliary storage device 23 stores various programs, and the CPU 21 reads the programs from the auxiliary storage device 23 into the main storage device 22 such as a RAM and executes the programs, whereby various processing is performed.

[0041] Fig. 3 is a functional block diagram showing an overview of functions of the electrical-energy-consumption predicting apparatus 10. As shown in Fig. 3, the electrical-energy-consumption predicting apparatus 10 includes a database (storage unit) 31, a data specifying unit 32, a data extracting unit 33, a statistical prediction unit 34, and an electrical-energy-consumption accumulating unit 35.

[0042] The database 31 stores actual operation data of the building air-conditioning equipment in association with the day, hour, minute, including the electrical energy consumption, the outside air temperature, and temperature settings, compressor intake temperatures, and compressor rotation speeds of the individual air conditioners installed in the building, during a predetermined unit time. These pieces of actual operation data are created from the operation status information supplied from the air-conditioning controlling and monitoring apparatus 3, electric-energy-consumption information regarding the air-conditioning equipment in the building, supplied from an electrical-power monitoring apparatus (not shown) that monitors the power consumption of the air-conditioning equipment installed in the building, and so forth.

[0043] In this embodiment, the "actual operation data" refers to a collection of various data collected in one minute, such as the electrical energy consumption, the outside air temperature, temperature settings, compressor intake temperatures, and compressor rotation speeds. As described above, in this embodiment, actual operation data composed of a collection of the above pieces of data (elements) is created on a per-minute basis, and the actual operation data is stored in the database 31 in association with the day, hour, and minute of data collection.

[0044] The data specifying unit 32 specifies actual operation data that is to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during a prediction target period. For example, as shown in Fig. 4, when a period from 13:00 to 13:30 is specified as the prediction target period, the data specifying unit 32 specifies actual operation data of a predetermined duration in the past belonging to this prediction target period. The predetermined duration in the past is a duration that can be set arbitrarily: it is set to be, for example, 5 minutes, the entire period, or the like. Alternatively, the configuration, may be such that a user can specify actual operation data from the past actual operation data stored in the database 31. In this case, the user can specify actual operation data by operating the input device 24 (see Fig. 2).

[0045] For example, as shown in Fig. 4, when 13:00 to 13:30 is specified as the prediction target period and the current time is 13:15, the data specifying unit 32 specifies a part or the entirety of the actual operation data for 13:00 to 13:15.

[0046] The data extracting unit 33 extracts a plurality of pieces of actual operation data (a time series of state vectors) specified by the data specifying unit 32 from the database 31. Thus, N pieces of actual operation data going back in the past from 13:15 are extracted from the database 31.

[0047] The statistical prediction unit 34 predicts the electrical energy consumptions on a prediction target day by using a statistical analysis method on the basis of the plurality of pieces of actual operation data (i.e., the time series of state vectors) extracted by the data extracting unit 33. For example, by using the N pieces of actual operation data extracted by the data extracting unit 33, for each piece of actual operation data, the statistical prediction unit 34 calculates a per-minute electrical energy consumption of the building air-conditioning equipment, a per-minute average outside air temperature, a per-minute average intake temperature weighted by the capacities of the indoor units, and a per-minute average temperature setting weighted by the capacities of the indoor units, obtains N state variable vectors having these items as elements for the individual pieces of actual operation data, predicts the electrical energy consumption on a per-minute basis from an autoregressive model representing a linear combination of the time series of the state variable vectors.

[0048] Specifically, the statistical prediction unit 34 generates an autoregressive model expressed by equation (1) below by using N state vectors and solves this autoregressive model by a known method, such as the minimum AIC (Akaike's Information Criterion) method, thereby predicting the electrical energy consumption on a per-minute basis during, for example, a period from 13:16 to 13:30, for which actual operation data does not exist, among 13:00 to 13:30 specified as the prediction target period.

[Formula 1]

$$\begin{aligned}
& [Whm(k), Tom(k), Tam(k), Tsm(k)]^T \\
& = \sum_{i=1}^N A(i) \cdot [Whm(k-i), Tom(k-i), Tam(k-i), Tsm(k-i)]^T + U(k)
\end{aligned}
\tag{1}$$

[0049] In equation (1) above, $A(i)$ is $N \times 4$ coefficient matrices ($i = 1, 2, \dots, N$), which is called an autoregressive model, and system identification is performed online by the AIC method or the like on the basis of the actual operation data. The order of the coefficient matrices is determined in accordance with the number of elements of the state vectors. That is, in this embodiment, state vectors are created by using four elements consisting of the electrical energy consumption of the building air-conditioning equipment, the average outside air temperature, a weighted-average intake temperature, and a weighted-average temperature setting, so that the coefficient matrices are 4×4 . Furthermore, if the compressor rotation speed is added as an element, $A(i)$ becomes 5×5 coefficient matrices.

[0050] $U(k)$ is a k -th white noise error. $Whm(k)$ is the per-minute electrical energy consumption of the building air-conditioning equipment related to the k -th actual operation data, $Tom(k)$ is the per-minute average outside air temperature related to the k -th actual operation data, $Tam(k)$ is the per-minute average intake temperature (room temperature) related to the k -th actual operation data, weighted by the capacities of the indoor units, and $Tsm(k)$ is the per-minute average temperature setting related to the k -th actual operation data, weighted by the capacities of the indoor units.

[0051] Regarding the intake temperature (room temperature), since the electrical energy consumption varies depending on the ability of the air conditioners, etc., weighting is performed in consideration of the capacities of the indoor units in calculating an average value.

Similarly, regarding the temperature setting, since the contribution to the electrical energy consumption varies depending on the magnitude of the capacities of the indoor units of the individual air conditioners, weighting is performed in consideration of the capacities of the indoor units in calculating an average value.

[0052] The statistical prediction unit 34 obtains a matrix $A(i)$ that minimizes $U(k)$ in equation (1) given above, and predicts the per-minute electrical energy consumption during each prediction target time in the prediction target period, i.e., 13:16 to 13:30 in this embodiment. As described earlier, the matrix $A(i)$ that minimizes $U(k)$ can be obtained by the minimum AIC method or the like.

[0053] Furthermore, "N" representing the number of pieces of actual operation data is also determined by solving the autoregressive model. For example, an optimal number N of pieces of actual operation data may be obtained by first solving the autoregressive model, and the above calculation may be performed again after N is determined by using the determined N pieces of actual operation data. This serves to improve the accuracy of prediction of electrical energy consumptions on the prediction target day.

[0054] The electrical-energy-consumption accumulating unit 35 calculates the electrical energy consumption of the building air-conditioning equipment from 13:00 to 13:30, which is the prediction target period, by using the electrical energy consumptions predicted by the statistical prediction unit 34 and the actual operation data stored in the database 31, and outputs the result of the calculation to, for example, the output device 25 (see Fig. 2) or the like.

[0055] Next, processing executed in the air-conditioning system configured as described above, particularly the units of the electrical-energy-consumption predicting apparatus 10, will be described with reference to Figs. 1 to 3. The various processing described below, performed by the units shown in Fig. 3, is performed by the CPU 21 shown in Fig. 2 reading an electrical-energy-consumption predicting program stored in the auxiliary storage device 23 into the main storage device 22 and executing the program.

[0056] First, on the basis of control instructions from the host computer 1 or the like, the air-conditioning controlling and monitoring apparatus 3 controls the operation of the air conditioners 5 installed in the building, whereby operation status information of the individual air conditioners 5 is accumulated in the air-conditioning controlling and monitoring apparatus 3, and the operation status information is sent from the air-conditioning controlling and monitoring apparatus 3 to the electrical-energy-consumption predicting apparatus 10 via the building-management communication network 2. Furthermore, the electrical energy consumption of the air conditioners 5 and so forth in the building is monitored by an electrical-power monitoring apparatus (not shown), and information regarding the electrical energy consumptions is

sent from the electrical-power monitoring apparatus to the electrical-energy-consumption predicting apparatus 10.

[0057] Thus, in the database 31 in the electrical-energy-consumption predicting apparatus 10, actual operation data is generated on a per-minute basis on the basis of these pieces of information, and the actual operation data is stored sequentially in association with the day and hour.

[0058] Then, the electrical-energy-consumption predicting apparatus 10 predicts electrical energy consumptions in the prediction target period to which the current time belongs by using the actual operation data accumulated in the database 31 on a per-something basis.

[0059] For example, when the current time is 13:15, the prediction target period is 13:00 to 13:30. Thus, the electrical-energy-consumption predicting apparatus 10 predicts the electrical energy consumption on a per-minute basis in the period of 13:16 to 13:30, for which actual operation data does not exist, and obtains the cumulative electrical energy consumption during the prediction target period by using the prediction results.

[0060] First, of the actual operation data for 13:00 to 13:15, the data specifying unit 32 specifies N pieces for 13:15, 13:14, 13:13, ..., 13:(15-N+1), and the data extracting unit 33 extracts the specified actual operation data from the database 31. The extracted N pieces of actual operation data are output to the statistical prediction unit 34.

[0061] By using the N pieces of actual operation data extracted by the data extracting unit 33, the statistical prediction unit 34 creates a time series of state vectors whose elements are, for each piece of the actual operation data, the per-minute electrical energy consumption Whm of the building air-conditioning equipment, the per-minute average outside air temperature Tom, the per-minute average intake temperature Tam weighted by the capacities of the indoor units, and the per-minute average temperature setting Tsm weighted by the capacities of the indoor units. Then, by using the autoregressive model (i.e., the coefficient matrices A(i)) expressed in equation (1) given earlier, the statistical prediction unit 34 sequentially performs predictive calculation of per-minute state vectors for 13:16, 13:17, ..., 13:30, thereby calculating per-minute electrical energy consumptions Whm(k) from 13:16 to 13:30, and outputs the predicted electrical energy consumptions Whm(k) in the individual prediction target times during the 15-minute period to the electrical-energy-consumption accumulating unit 35.

[0062] The electrical-energy-consumption accumulating unit 35 uses actual electrical energy consumptions stored in the database 31 as electrical energy consumptions up to 13:15 and uses the electrical energy consumptions predicted by the statistical prediction unit 34 as electrical energy consumptions on and after 13:16 and accumulates these values, thereby calculating a predicted cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period of 13:00 to 13:30. The electrical-energy-consumption accumulating unit 35 outputs the calculation result and information about the electrical energy consumptions used for the calculation to the output device (see Fig. 2). Thus, by displaying the predicted cumulative electrical energy consumption during the prediction target period of 13:00 to 13:30 on the output device, for example, a monitor of a display device or the like, it is possible to report the information to the user.

[0063] The manner of display regarding the display device is not particularly limited. For example, the predicted electrical energy consumptions during the prediction target period may be just displayed in the form of numerical values, or may be displayed, for example, in the form of a graph as shown in Fig. 4.

[0064] Fig. 4 is a diagram showing an example display that is displayed on the display device. In the graph shown in Fig. 4, per-minute cumulative electrical energy consumptions are shown in the form of a line graph. In the line graph, the line graph up to 13:15, for which actual operation data exists, is represented as filled in black, whereas the line graph on and after 13:16, for which actual operation data does not exist and prediction has been performed, is represented as outlined in white.

[0065] By varying the manner of display between the case where actual operation data exists and the case where prediction has been performed as described above, the user can readily tell whether the data is predicted data. Furthermore, by repeatedly executing the prediction processing for the prediction target period every minute, the predicted cumulative electrical energy consumption during the prediction target period is every minute, so that the latest predicted cumulative electrical energy consumption is presented to the user.

[0066] As described hereinabove, with the air-conditioning system and the electrical-energy-consumption predicting apparatus according to this embodiment, it becomes possible to predict the cumulative electrical energy consumption on a per-predetermined-period basis, for example, on a 30-minute basis. Accordingly, the user can grasp the approximate electrical energy consumption at 30-minute intervals, and thus, for example, it becomes possible to control the operation of the building air-conditioning equipment so that the cumulative electrical energy consumption during 30 minutes does not exceed a contract electrical energy (target electrical energy consumption).

[Second Embodiment]

[0067] Next, an air-conditioning system and an electrical-energy-consumption predicting apparatus according to a second embodiment of the present invention will be described with reference to Fig. 5.

In the air-conditioning system according to this embodiment, the configuration of the electrical-energy-consumption

predicting apparatus differs from that in the first embodiment described above.

Hereinafter, regarding the electrical-energy-consumption predicting apparatus according to this embodiment, descriptions of commonalities with the first embodiment will be omitted, and differences will be mainly described.

[0068] Fig. 5 is a functional block diagram of the electrical-energy-consumption predicting apparatus according to this embodiment. As shown in Fig. 5, an electrical-energy-consumption predicting apparatus 10' according to this embodiment includes a data correcting unit 36 and an operating-level limiting unit 37.

The data correcting unit 36 corrects, by a predetermined amount, the temperature settings of the actual operation data used by the statistical prediction unit 34 for prediction of electrical energy consumptions if the cumulative electrical energy consumption calculated by the electrical-energy-consumption accumulating unit 35 exceeds a preset target electrical energy consumption.

[0069] The operating-level limiting unit 37 generates a limitation signal for limiting the operation of the air conditioners 5 installed in the building on the basis of the amount of correction by the data correcting unit 36 when the cumulative electrical energy consumption calculated by the electrical-energy-consumption accumulating unit 35 comes to fall within the target electrical energy consumption, and outputs the limitation signal to the host computer 1.

[0070] Hereinafter, the operation of the electrical-energy-consumption predicting apparatus 10' according to this embodiment will be described.

Now, assuming that the predicted cumulative electrical energy consumption during the prediction target period has been calculated by the electrical-energy-consumption accumulating unit 35, the predicted cumulative electrical energy consumption is output to the output device 25 (see Fig. 2) as described earlier and is also output to the data correcting unit 36. The data correcting unit 36 determines whether the predicted cumulative electrical energy consumption exceeds the target electrical energy consumption, and if it does, corrects by a predetermined amount an element relating to the operating level, for example, the temperature settings, among the actual operation data used by the statistical prediction unit 34 for prediction of electrical energy consumptions. For example, the data correcting unit 36 corrects the temperature settings of the actual operation data as in equation (2) below.

[0071]

$$Tsm'(k-i) = Tsm(k-i) + \Delta Tsm \quad (2)$$

[0072] In equation (2) above, $Tsm'(k-i)$ is the corrected temperature setting in the k-th actual operation data, $Tsm(k-i)$ is the temperature setting in the k-th actual operation data before the correction, and ΔTsm is the amount of correction, which is set to be, for example, $\Delta Tsm = +0.5^\circ\text{C}$ for cooling mode and $\Delta Tsm = -0.5^\circ\text{C}$ for heating mode. The amount of correction is a value that can be set arbitrarily, and, for example, the configuration may be such that the user can input an arbitrary value from the input device 24 (see Fig. 2).

[0073] When the corrected temperature settings $Tsm'(k-i)$ have been calculated by the data correcting unit 36 as described above and have been provided to the statistical prediction unit 34, the statistical prediction unit 34 recreates a time series of state vectors by using the corrected temperature settings $Tsm'(k-i)$ and using the actual operation data for elements regarding observed quantities other than the operating level, such as the electrical energy consumptions, room temperatures, and outside air temperatures. Then, an autoregressive model based on (1) above is generated, and electrical energy consumptions during the individual prediction target times in the prediction target period are predicted by solving the autoregressive model.

Specifically, on the basis of equation (3) bellow, electrical energy consumptions during the individual prediction target times in the prediction target period are calculated again.

[0074]

[Formula 2]

$$\begin{aligned}
& [Whm'(k), Tom'(k), Tam'(k), Tsm'(k)]^T \\
& = \sum_{i=1}^N A(i) \cdot [Whm(k-i), Tom(k-i), Tam(k-i), Tsm'(k-i)]^T + U(k)
\end{aligned}
\tag{3}$$

[0075] Upon again predicting the electrical energy consumptions from 13:16 to 13:30 by using the corrected temperature settings, the statistical prediction unit 34 outputs the predicted electrical energy consumptions to the electrical-energy-consumption accumulating unit 35.

[0076] The electrical-energy-consumption accumulating unit 35 calculates the predicted cumulative electrical energy consumption of the air-conditioning equipment during the prediction target period by using the electrical energy consumptions during the individual prediction target times predicted on the basis of the corrected actual operation data, and outputs the predicted cumulative electrical energy consumption to the output device 25 (see Fig. 2) and the data correcting unit 36.

[0077] The data correcting unit 36 determines whether the predicted cumulative electrical energy consumption input again exceeds the target electrical energy consumption, and if the target electrical energy consumption is exceeded, further corrects the actual operation by the predetermined amount and outputs the corrected actual operation data to the statistical prediction unit 34. Thus, the statistical prediction unit 34 performs re-prediction on the basis of the corrected actual operation data, and the electrical-energy-consumption accumulating unit 35 further calculates the predicted cumulative electrical energy consumption by using the results of prediction. The, the correction of actual operation data is performed repeatedly until the predicted cumulative electrical energy consumptions comes to fall within the target electrical energy consumption.

[0078] When the predicted cumulative electrical energy consumption comes to fall within the target electrical energy consumption as described above, the data correcting unit 36 outputs the current amount of correction to the operating-level limiting unit 37. On the basis of the amount of correction input from the data correcting unit 36, the operating-level limiting unit 37 generates a limitation signal for limiting the operation control of the air conditioners 5 and output the limitation signal to the host computer 1. Upon receiving the limitation signal, the host computer 1 generates a control instruction based on the limitation signal and outputs the control instruction to the air-conditioning controlling and monitoring apparatus 3. Thus, the operation of the air conditioners 5 is restricted, so that the actual electrical energy consumption during the prediction target period becomes closer to the target electrical energy.

[0079] Then, by repeatedly executing the above-described prediction processing for the prediction target period on a per-minute basis, the predicted cumulative electrical energy consumption during the prediction target period is updated every minute.

[0080] As described above, with air-conditioning system and the electrical-energy-consumption predicting apparatus according to this embodiment, until the predicted cumulative electrical energy consumption calculated by the electrical-energy-consumption accumulating unit 35 comes to fall within the target electrical energy consumption, correction of actual operation data, statistical re-prediction using the corrected actual operation data, and re-calculation of the cumulative electrical energy consumption are performed repeatedly. Then, when the predicted cumulative electrical energy consumption comes to fall within the target electrical energy consumption, the operating-level limiting unit 37 generates a limitation signal on the basis of the amount of correction at that time, and the operation of the air conditioners 5 is restricted on the basis of the limitation signal.

Accordingly, it becomes possible to reliably keep the actual cumulative electrical energy consumption during the prediction target period within the target electrical energy consumption.

[0081] In the restricted operation of the air conditioners 5, for example, an order of priority of the air conditioners 5 whose operation is to be limited may be set in advance so that the operating-level limiting unit 37 generates and outputs such a limitation signal that limits operation of air conditioners starting from the ones having higher priority levels. By setting in advance an order of priority of the air conditioners 5 whose operation is to be restricted as described above, it becomes possible to sequentially restrict the operation from the ones that cause less inconvenience even when their operation is restricted. As a result, it becomes possible to minimize discomfort for people inside the building.

[0082] Furthermore, although a case where the data correcting unit 36 corrects the temperature settings, as an example

of an element relating to the operating level among actual operation data, has been described in this embodiment, alternatively, the compressor rotation speeds may be corrected.

Alternatively, both the temperature settings and the compressor rotation speeds may be corrected. In the case where both the temperature settings and the compressor rotation speeds are corrected, the data correcting unit 36 corrects the compressor rotation speeds on the basis of equation (4) below. The correction of the temperature settings has been described earlier so will not be described.

[0083]

$$Rcm'(k-i) = Rcm(k-i) + \Delta Rcm \quad (4)$$

[0084] In equation (4) above, $Rcm'(k-i)$ is the corrected compressor rotation speed in the k -th actual operation data, $Rcm(k-i)$ is the compressor rotation speed in the k -th actual operation data before the correction, and ΔRcm is the amount of correction, which is a value with which the current rotation speed is reduced by, for example, 10%.

When the compressor rotation speeds have been corrected as described above, the statistical prediction unit 34 again performs predictive calculation for the individual prediction target times on the basis of equation (5) below.

[Formula 3]

$$\begin{aligned} & [Whm'(k), Tom'(k), Tam'(k), Tsm'(k), Rcm'(k)]^T \\ &= \sum_{i=1}^N A(i) \cdot [Whm(k-i), Tom(k-i), Tam(k-i), Tsm(k-i), Rcm(k-i)]^T + U(k) \end{aligned} \quad (5)$$

[0085] Furthermore, in addition to or instead of the temperature settings and compressor rotation speeds described above, the degrees of opening of electronic expansion valves provided in refrigerator pipes, which are other operating levels, may be adjusted.

[0086] Furthermore, in the embodiment described above, as a result of restricted operation, if the predicted cumulative electrical energy consumption predicted after the restricted operation exhibits a value less than the target electrical energy consumption by a predetermined amount, the restricted operation may be stopped, returning to normal operation. This makes it possible to control the operation of the air-conditioning equipment just within the target electrical energy consumption while reducing discomfort for users.

[0087] Although the embodiments of the present invention have been described hereinabove in detail with reference to the drawings, specific configurations are not limited to the embodiments, and design modifications or the like within the spirit of the present invention are encompassed.

Claims

1. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus that calculates the electrical energy consumption of building air-conditioning equipment during a prediction target period, comprising:

a storage unit that stores actual operation data of the building air-conditioning equipment in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time;

a data specifying unit that specifies actual operation data to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period;

a data extracting unit that extracts the actual operation data specified by the data specifying unit from the storage unit;

a statistical prediction unit that predicts the electrical energy consumptions during individual prediction target times in the prediction target period by using time-series analysis on the basis of the actual operation data extracted by the data extracting unit; and

an electrical-energy-consumption accumulating unit that calculates the electrical energy consumptions of the building air-conditioning equipment during the prediction target period by using the electrical energy consumptions during the individual prediction target predicated by the statistical prediction unit and the actual operation data stored in the storage unit relevant to prediction target period.

2. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 1, wherein the prediction target period is set on a per-30-minute basis.
3. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 1 or 2, wherein the data specifying unit specifies actual operation, data for a predetermined duration in the past belonging to the prediction target period.
4. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to any one of Claims 1 to 3, wherein the statistical prediction unit calculates, for each piece of the actual operation data extracted by the data extracting unit, an electrical energy consumption of the air-conditioning equipment during the predetermined unit time, an average outside air temperature during the predetermined unit time, an average intake temperature during the predetermined unit time weighted by the capacities of indoor units, and an average temperature setting during the predetermined unit time weighted by the capacities of the indoor units, obtains a state variable vector having these items as elements for each piece of the actual operation data, and predicts the electrical energy consumptions during the individual prediction target times from an autoregressive model representing a linear combination of the state variable vectors.
5. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to any one of Claims 1 to 4, comprising an operating-level limiting unit that outputs a limitation signal for limiting the operation of the air conditioners installed in the building when the electrical energy consumption of the building air-conditioning equipment during the prediction target period, calculated by the electrical-energy-consumption accumulating unit, exceeds a preset target electrical energy consumption.
6. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 5, wherein an order of priority of air conditioners whose operation is to be limited is set in advance, and the operating-level limiting unit limits operation in order from air conditioners with higher priority levels.
7. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 5 or 6, wherein the operating-level limiting unit outputs the limitation signal for limiting at least one of temperature settings of the air conditioners, compressor rotation speeds, and degrees of opening of electronic expansion valves provided in refrigerator pipes.
8. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to any one of Claims 1 to 7, comprising a data correcting unit that corrects by a predetermined amount the actual operation data used for prediction by the statistical prediction unit when the electrical energy consumption of the building air-conditioning equipment during the prediction target period, calculated by the electrical-energy-consumption accumulating unit, exceeds a preset target electrical energy consumption, wherein the statistical prediction unit re-predicts electrical energy consumptions for the individual prediction target times by using the actual operation data corrected by the data correcting unit, and wherein the electrical-energy-consumption accumulating unit calculates the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the re-predicted electrical energy consumptions.
9. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 8, wherein the data correcting unit corrects by the predetermined amount at least one of temperature settings of the actual operation data and compressor rotation speeds if the compressor rotation speeds are included in the actual operation data.
10. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 8 or 9, wherein the data correcting unit repeats correction of the actual operation data until the electrical energy con-

sumption calculated by the electrical-energy-consumption accumulating unit comes to fall within the target electrical energy consumption.

5 11. A building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to Claim 10, wherein the operating-level limiting unit generates and outputs the limitation signal on the basis of an amount of correction by the data correcting unit when the electrical energy consumption calculated by the electrical-energy-consumption accumulating unit comes to fall within the target electrical energy consumption.

10 12. An air-conditioning system comprising a building-air-conditioning-equipment electrical-energy-consumption predicting apparatus according to any one of Claims 1 to 11.

13. A building-air-conditioning-equipment electrical-energy-consumption predicting method of calculating the electrical energy consumption of building air-conditioning equipment during a prediction target period, comprising:

15 a step of specifying actual operation data to be used for predicting the cumulative electrical energy consumptions of the building air-conditioning equipment during the prediction target period from a storage unit that stores actual operation data of the building air-conditioning equipment in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time;

20 a step of extracting the specified actual operation data from the storage unit;

a step of predicting the electrical energy consumptions during individual prediction target times in the prediction target period by using a statistical method on the basis of the extracted actual operation data; and

25 a step of calculating the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions during the individual prediction target times and the actual operation data stored in the storage unit and relevant to the prediction target period.

30 14. A computer-readable recording medium; having recorded thereon a building-air-conditioning-equipment electrical-energy-consumption predicting program for calculating the electrical energy consumption of building air-conditioning equipment during a prediction target period, the program causing a computer to execute:

35 processing for specifying actual operation data to be used for predicting the cumulative electrical energy consumption of the building air-conditioning equipment during the prediction target period from a storage unit that stores actual operation data of the building air-conditioning equipment in association with the day, hour, and minute, the actual operation data including an electrical energy consumption, an outside air temperature, a room temperature, and temperature settings of individual air conditioners installed in a building, during a predetermined unit time;

processing for extracting the specified actual operation data from the storage unit;

40 processing for predicting the electrical energy consumptions during individual prediction target times in the prediction target period by using a statistical method on the basis of the extracted actual operation data; and

processing for calculating the electrical energy consumption of the building air-conditioning equipment during the prediction target period by using the predicted electrical energy consumptions during the individual prediction target times and the actual operation data stored in the storage unit and relevant to the prediction target period.

FIG. 1

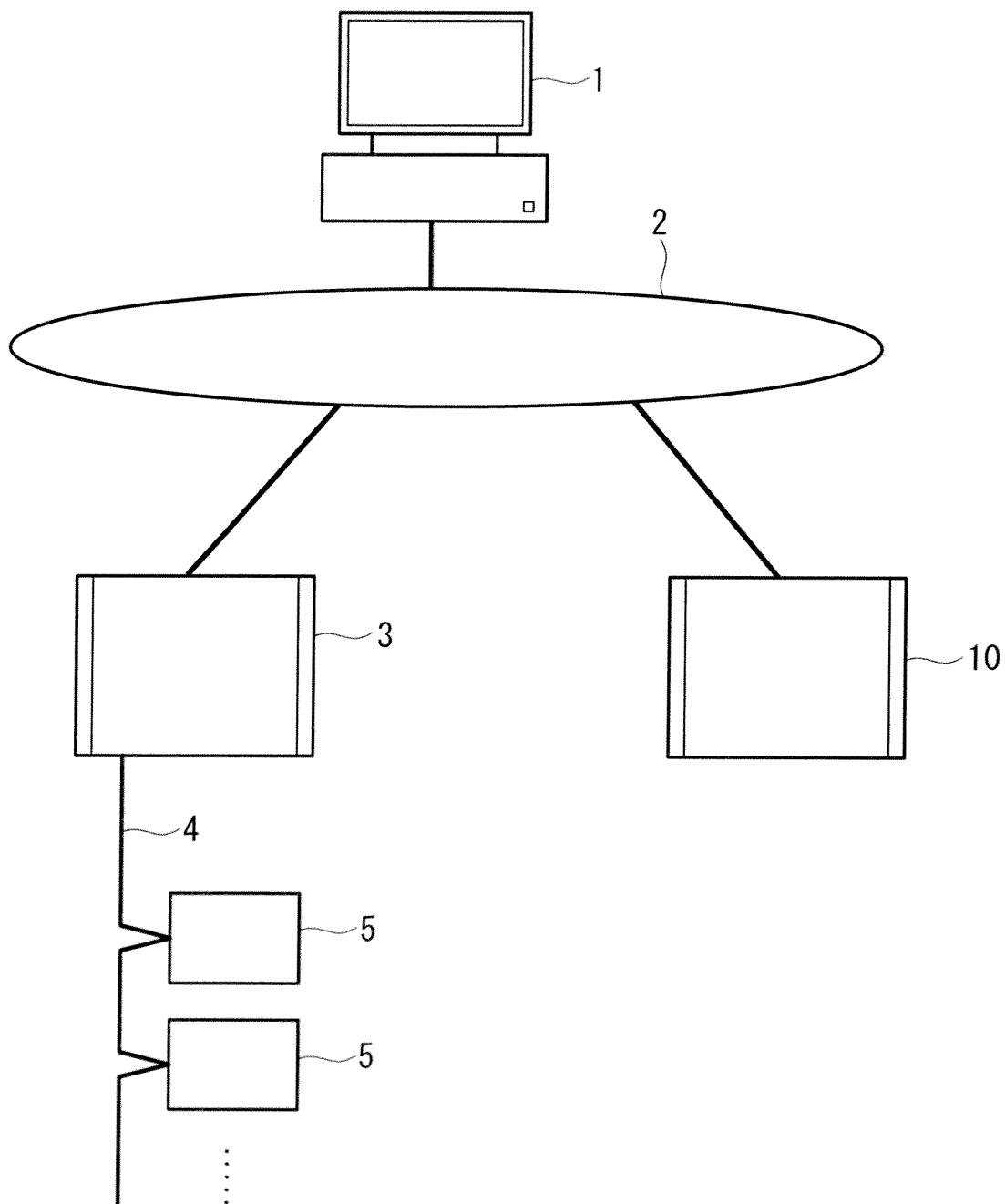


FIG. 2

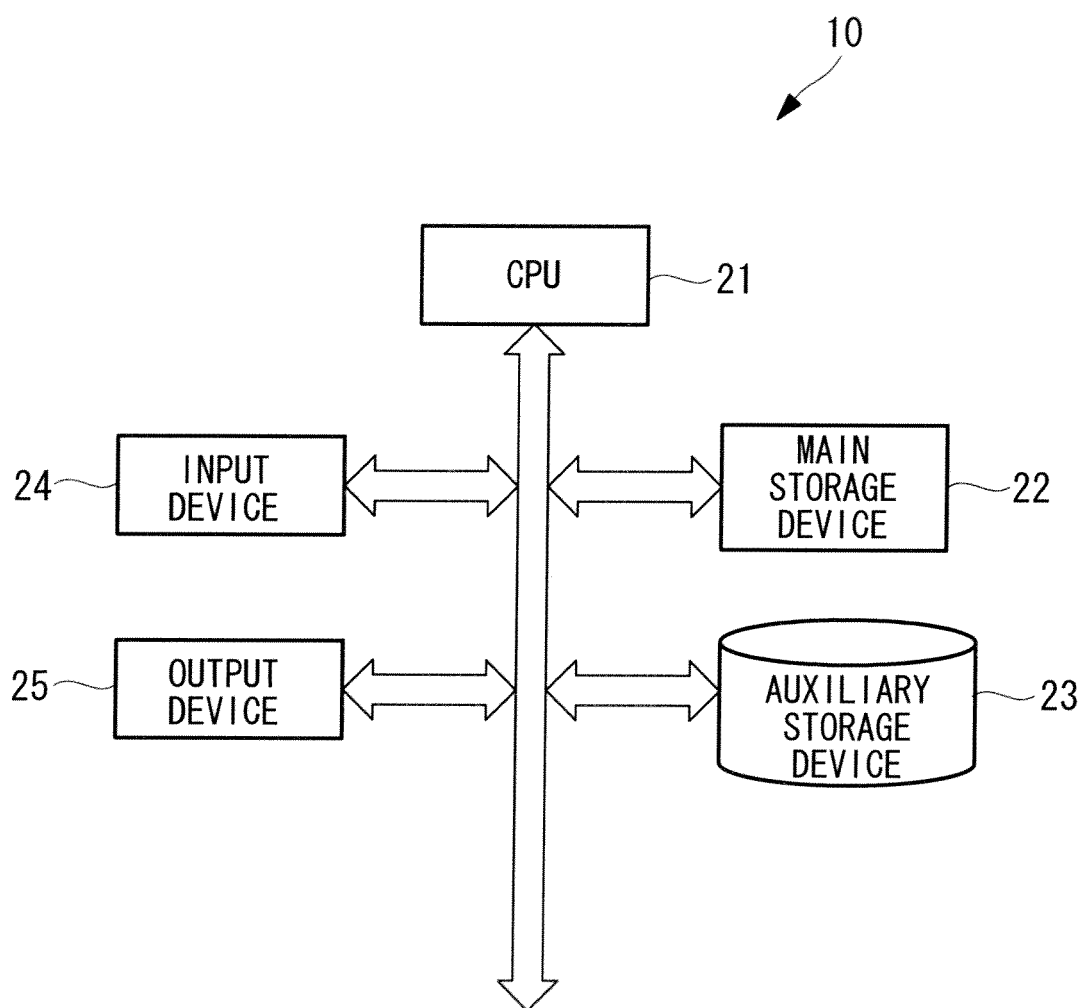


FIG. 3

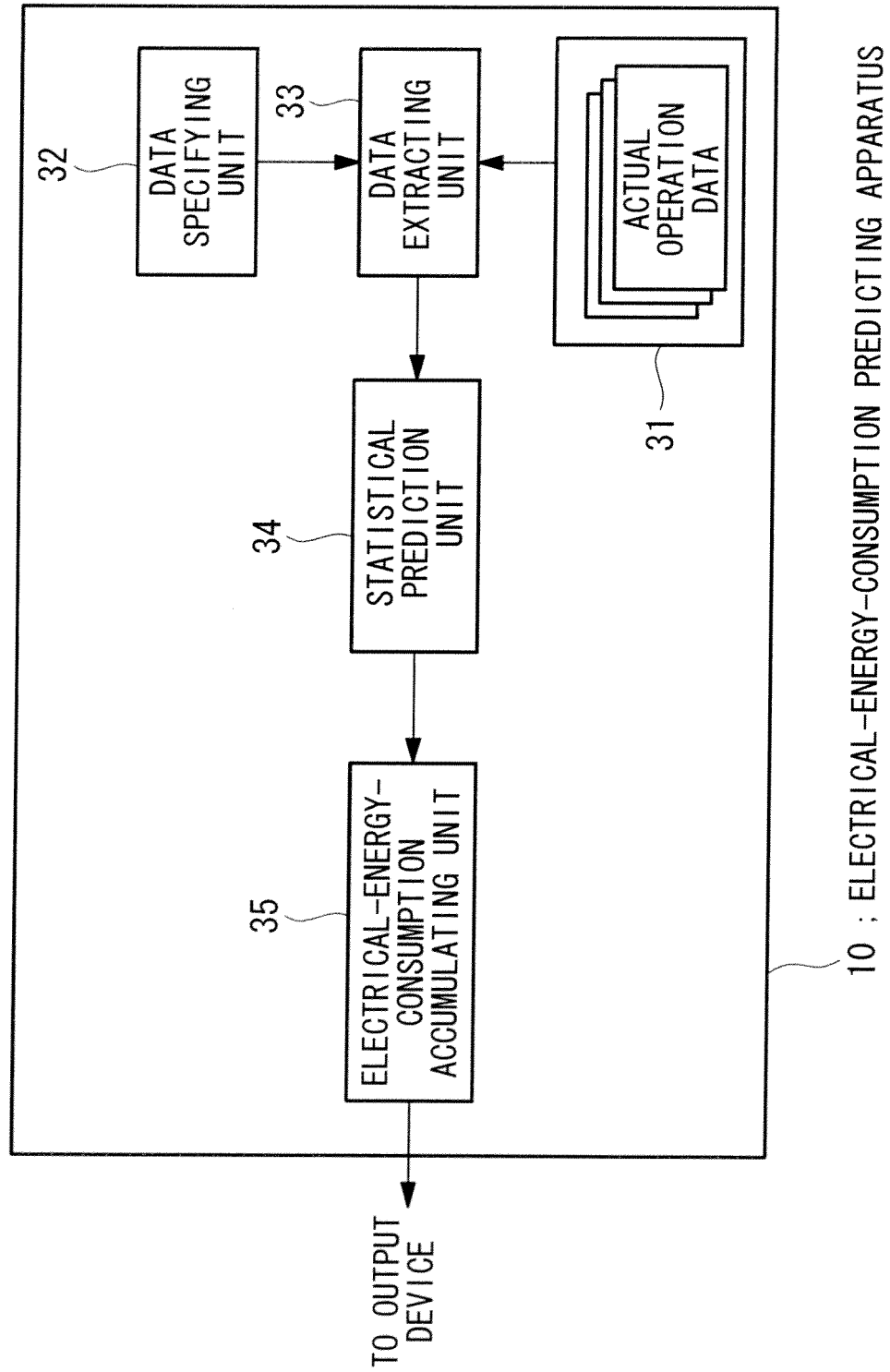


FIG. 4

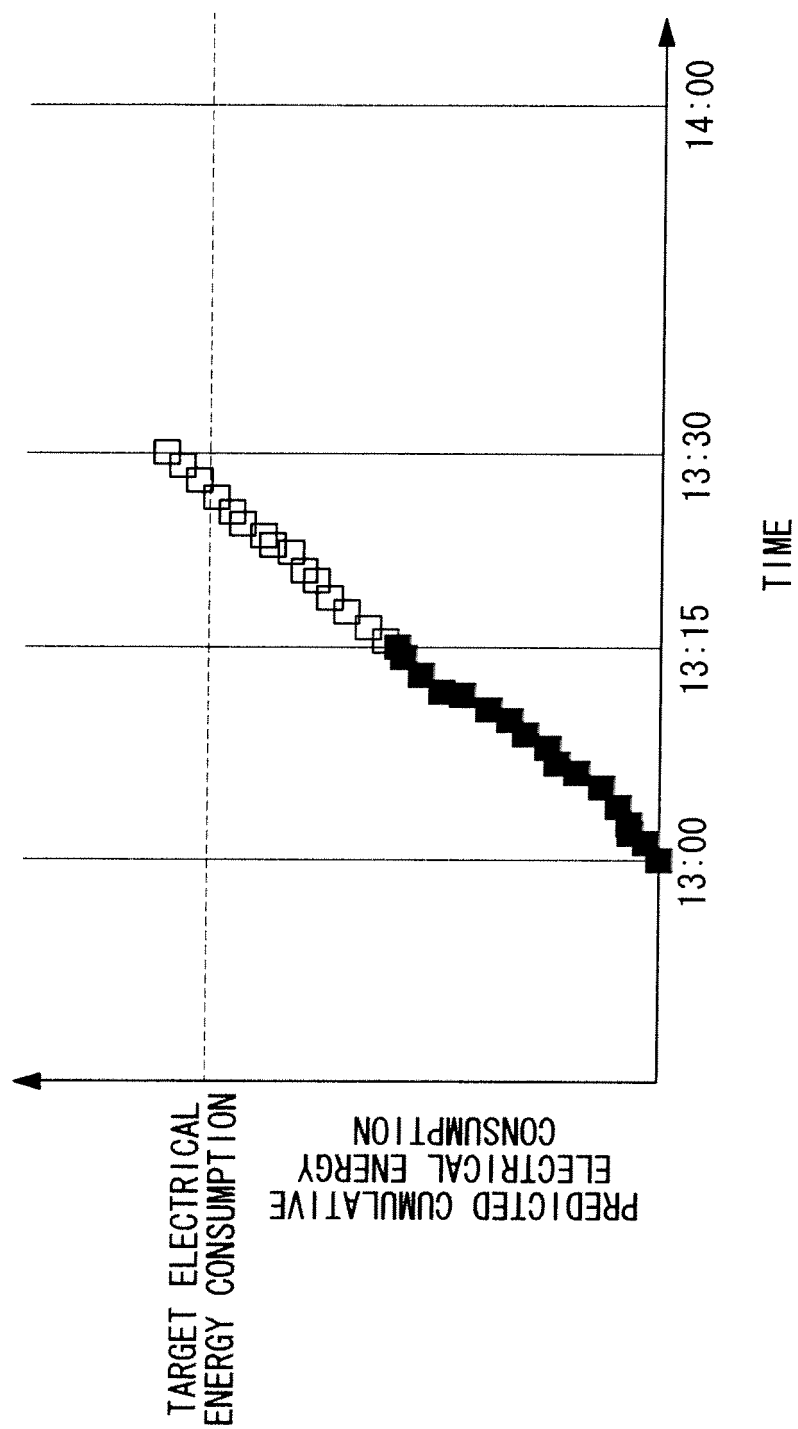
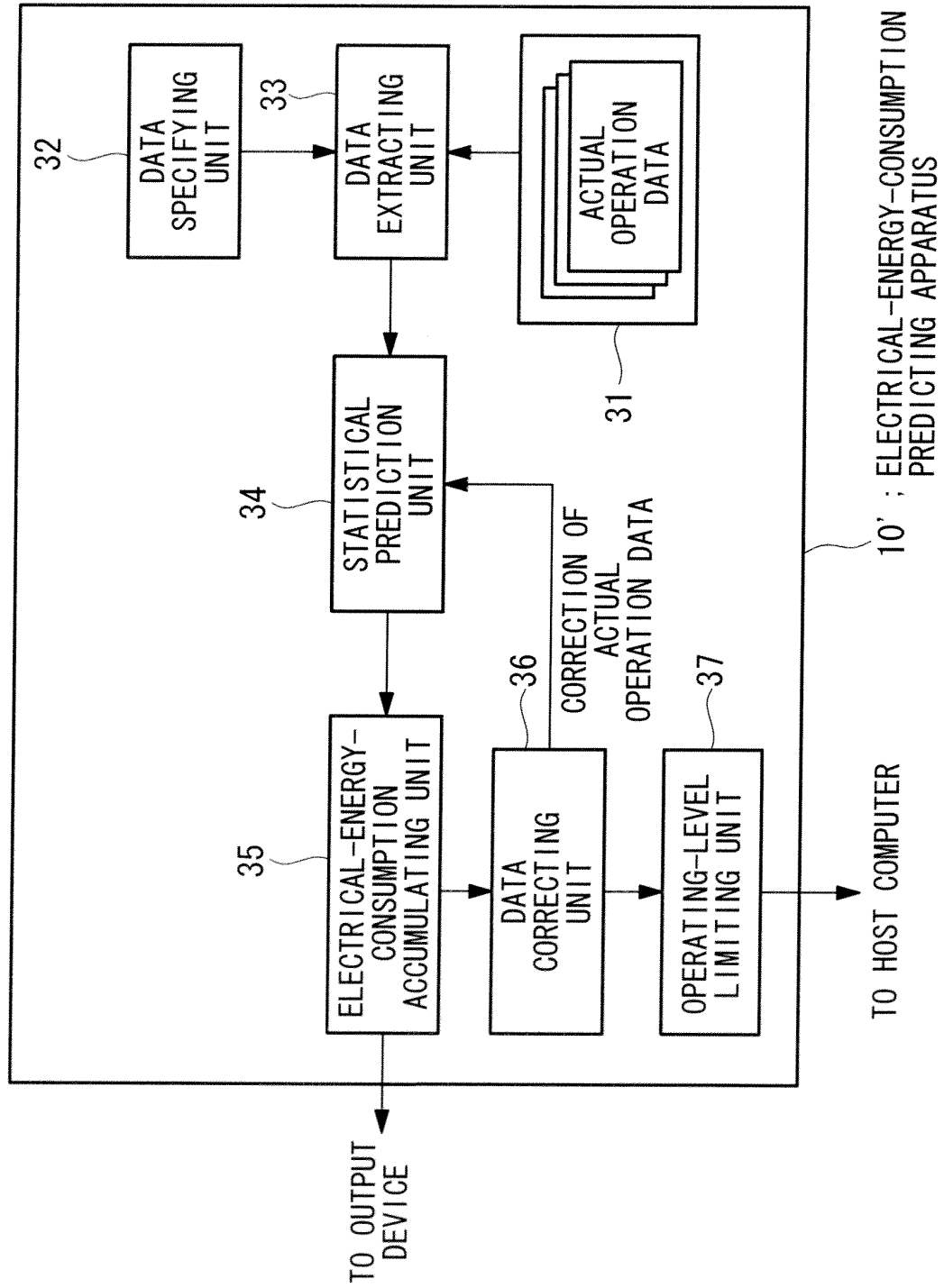


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/053501

A. CLASSIFICATION OF SUBJECT MATTER F24F11/02 (2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) F24F11/02		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009 Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-297854 A (Kabushiki Kaisha Hitachi Haikосу), 21 October, 2004 (21.10.04), Par. Nos. [0002] to [0005]; Fig. 18 (Family: none)	1-14
Y	JP 2007-14179 A (Sanyo Electric Co., Ltd.), 18 January, 2007 (18.01.07), Par. Nos. [0002] to [0009]; Fig. 1 & EP 1729223 A2 & CN 1874105 A & CN 101345420 A	1-14
Y	JP 2004-236422 A (Tokyo Gas Co., Ltd.), 19 August, 2004 (19.08.04), Par. No. [0016] (Family: none)	1-14
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 20 May, 2009 (20.05.09)		Date of mailing of the international search report 02 June, 2009 (02.06.09)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/053501

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 9-215193 A (NTT Facilities, Inc.), 15 August, 1997 (15.08.97), Par. No. [0020] (Family: none)	5-11

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2005308278 A [0002]