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(54) METHOD AND APPARATUS FOR CONTROLLING REFRIGERATION DEVICE, COMPUTER DEVICE, AND COMPUTER READABLE MEDIUM

(57) Provided in the present disclosure is a method for controlling a refrigeration device, comprising: determining a current outdoor temperature; inputting same-period historical sample data of the refrigeration device load and preset impact factors as first input parameters into a first neural network model to obtain the current day predicted load of the refrigeration device; inputting same-period historical sample data of the outdoor temperature and the current day predicted load of the refrigeration device as second input parameters into a second neural network to obtain a current day predicted indoor temperature; inputting the current day predicted indoor temperature and a preset refrigeration efficiency factor as third input parameters into a third neural network to obtain current day optimum control parameters of the refrigeration device; and, on the basis of the optimum control parameters, controlling the operation of the refrigeration device. Also provided in the present disclosure are an apparatus for controlling the refrigeration device, a computer device, and a computer readable storage medium.

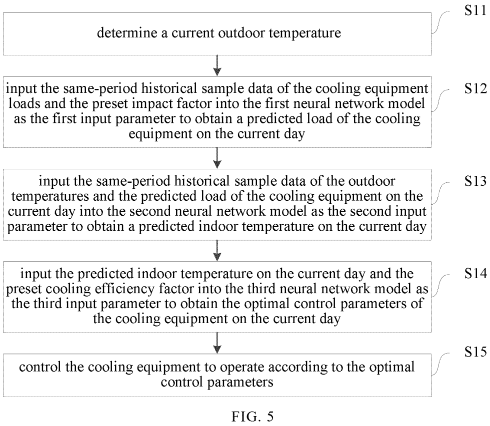

FIG. 5

Processed by Luminess, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present disclosure relates to the technical field of automatic control, and in particular, to a cooling equipment control method and device, a computer device and a computer-readable medium.

BACKGROUND

[0002] In mobile communication networks, about 80% of energy consumption comes from widely distributed base stations, and the denser the base stations, the higher the energy consumption. In general, air conditioners with different capacity are selected for machine rooms in the base stations according to types of the machine rooms (houses of bricks and tiles, cabins, houses of color coated steel plates, etc.) and loads of devices in the machine rooms, so as to cool the devices which overheat and ensure safe operation of the devices. The energy consumption for air conditioning accounts for the largest part in the energy consumption of the mobile base stations, and optimizing an air conditioner control algorithm becomes one of the most important efforts for reducing the energy consumption and electricity expense of the mobile communication base stations.

SUMMARY

[0003] The present disclosure provides a cooling equipment control method, including: determining a current outdoor temperature; inputting same-period historical sample data of cooling equipment loads and a preset impact factor into a first neural network model as a first input parameter to obtain a predicted load of cooling equipment on a current day; inputting same-period historical sample data of outdoor temperatures and the predicted load of the cooling equipment on the current day into a second neural network model as a second input parameter to obtain a predicted indoor temperature on the current day; inputting the predicted indoor temperature on the current day and a preset cooling efficiency factor into a third neural network model as a third input parameter to obtain optimal control parameters of the cooling equipment on the current day; and controlling the cooling equipment to operate according to the optimal control parameters.

[0004] The present disclosure further provides a cooling equipment control device, including: a first processing module, a second processing module, and a control module, where the first processing module is configured to determine a current outdoor temperature, the second processing module is configured to: input same-period historical sample data of cooling equipment loads and a preset impact factor into a first neural network model as a first input parameter to obtain a predicted load of cooling equipment on a current day, input same-period historical sample data of outdoor temperatures and the predicted load of the cooling equipment on the current day into a second neural network model as a second input parameter to obtain a predicted indoor temperature on the current day, and input the predicted indoor temperature on the current day and a preset cooling efficiency factor into a third neural network model as a third input parameter to obtain optimal control parameters of the cooling equipment on the current day; and the control module is configured to control the cooling equipment to operate according to the optimal control parameters.

[0005] The present disclosure further provides a computer device, including: one or more processors; and a storage device having one or more programs stored thereon; and when executed by the one or more processors, the one or more programs cause the one or more processors to carry out the cooling equipment control method according to the present disclosure.

[0006] The present disclosure further provides a computer-readable medium having stored thereon a computer program, which, when executed by a processor, causes the processor to carry out the cooling equipment control method according to the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0007]

FIG. 1 is a schematic diagram of a cooling control system according to the present disclosure;

FIG. 2 to FIG. 4 are schematic diagrams of a process of establishing a first neural network model, a second neural network model, and a third neural network model according to the present disclosure;

FIG. 5 is a schematic diagram of a cooling equipment control process according to the present disclosure;

FIG. 6A to FIG. 6C are schematic diagrams of the first neural network model, the second neural network model, and the third neural network model according to the present disclosure;

FIG. 7 is a schematic diagram of a control process of an air conditioner according to the present disclosure;

FIG. 8 is a schematic diagram of a control process of heat exchange equipment according to the present disclosure;

FIG. 9 is a schematic diagram of a process of redetermining and updating optimal control parameters of cooling equipment on a current day according to the present disclosure; and

FIG. 10 and FIG. 11 are schematic structural diagrams of a cooling equipment control device according to the present disclosure.

DETAIL DESCRIPTION OF EMBODIMENTS

[0008] Exemplary embodiments will be described more fully below with reference to the drawings, but the exemplary embodiments may be embodied in different forms, and should not be interpreted as being limited to the embodiments described herein. The embodiments are provided to make the present disclosure thorough and complete, and are intended to enable those of ordinary skill in the art to fully understand the scope of the present disclosure.

[0009] The term "and/or" used herein includes any and all combinations of one or more associated listed items.

[0010] The terms used herein are merely used to describe specific embodiments, and are not intended to limit the present disclosure. As used herein, "a" and "the" which indicate a singular form are intended to include a plural form, unless expressly stated in the context. It should be further understood that the term(s) "comprise" and/or "be made of' used herein indicate(s) the presence of the described features, integers, operations, elements and/or components, but do not exclude the presence or addition of one or more other features, integers, operations, elements, components and/or combinations thereof.

[0011] The embodiments described herein can be described with reference to plans and/or cross-sectional views with the aid of idealized schematic diagrams of the present disclosure. Accordingly, the exemplary drawings may be modified according to manufacturing techniques and/or tolerances. Therefore, the embodiments are not limited to those illustrated by the drawings, but include modifications to configuration formed based on a manufacturing process. Thus, regions shown in the drawings are illustrative, and shapes of the regions shown in the drawings illustrate specific shapes of regions of elements, but are not intended to make limitations.

[0012] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by those of ordinary skill in the art. It should be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with a meaning in the context of the related technology and the background of the present disclosure, and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0013] When an operator builds and expands a machine room for a base station, the operator considers configuring energy-saving heat exchange equipment to replace an air conditioner or carry out linkage control with the air conditioner, so as to ensure long-term stable operation conditions of various devices in the machine room. A basic principle of the energy-saving heat exchange equipment is to take an outdoor natural environment as a cold source and perform heat exchange using outdoor low-temperature air and high-temperature air in the machine room when an outdoor temperature is lower than an indoor temperature to a certain extent to take away the heat from the machine room, so as to reduce the temperature in the machine room, thereby shortening usage time of the air conditioner and saving electric energy.

[0014] A conventional linkage control algorithm is a traditional temperature-controlled startup-shutdown method, and takes an ambient temperature as a main basis of the linkage control of the heat exchange equipment and the air conditioner. The algorithm is simple but is difficult to improve. A conventional linkage control process is as follows: detecting indoor temperatures and outdoor temperatures in real time, and turning on the heat exchange equipment or the air conditioner for cooling if the indoor temperature exceeds an upper limit of an operation temperature of the devices: when a start condition of the heat exchange equipment is met (if an indoor-outdoor temperature difference reaches a threshold), preferentially turning on the heat exchange equipment, otherwise, turning on the air conditioner. Switching between the air conditioner and the heat exchange equipment should not be carried out frequently, and may be carried out at intervals longer than half an hour.

[0015] Startup/shutdown condition parameters of the heat exchange equipment and startup/shutdown condition parameters of the air conditioner are respectively set, for example, a startup temperature/a shutdown temperature of the heat exchange equipment may be 35°C/25°C and a temperature difference may be 8 °C, that is, the heat exchange equipment is turned on when a room temperature exceeds 35 °C and is turned off when the room temperature is below 25 °C, and the heat exchange equipment is allowed to be turned on when the indoor-outdoor temperature difference exceeds 8°C. However, the startup/shutdown condition parameters are usually difficult to determine in practical engineering applications and are not fixed due to different regions, different seasonal climates and different temperature differences between morning and evening. Therefore, if the startup/shutdown condition parameters are set as fixed parameters, the air conditioner may be turned on frequently, resulting in an increase of energy consumption. With merely an external factor, i.e., the ambient temperature considered, the conventional linkage control algorithm cannot predict startup moments and startup times of the air conditioner, and is low in control accuracy and hard to improve.

[0016] Since various factors such as a climate change in the four seasons, a temperature change, a load change and actual temperatures of the devise and various combinations of those factors can all affect an operation strategy of cooling equipment, there is no rule for a cooling equipment control strategy to follow. Taking a case where a startup temperature of the heat exchange equipment is 35 °C and a startup temperature of the air conditioner is 40 °C as an example, assuming that a room temperature of a certain base station seldom exceeds 35 °C and the heat exchange equipment alone can generally meet a heat load requirement with no need to turn on the air conditioner, when the room temperature occasionally exceeds 40°C during a certain period due to superposition of a traffic peak and a temperature peak, the air conditioner needs to be turned on according to the traditional control algorithm. However, if it may be predicted in advance that the high temperature above 40°C will just last for a short period of time and will not affect the safe operation of the devices (because operation temperature ranges of some base stations/transmission devices allow for up to 40°C for a long period of time and 50 °C for a short period of time), the air conditioner does not need to be turned on in fact, which may save one startup time of the air conditioner while ensuring safety of the devices, thereby saving energy to a certain extent.

[0017] The present disclosure provides a cooling equipment control method capable of control operation of cooling equipment in a machine room. The method is applicable to a cooling control system shown in FIG. 1. As shown in FIG. 1, the cooling control system according to the present disclosure includes a cooling equipment control device, a Field Supervision Unit (FSU), and a cooling equipment. The FSU is a field device disposed in a machine room where the cooling equipment is located, and includes an acquisition unit and an execution unit. The acquisition unit is configured to acquire real-time data such as outdoor temperature, outdoor humidity, indoor temperature and equipment load, and upload the real-time data to the cooling control device. The execution unit is configured to control the cooling equipment to operate according to instructions from the cooling control device. The cooling equipment control device may be a cloud device, and may be the Unified Management Expert (UME) configured with a first neural network (NN) model, a second neural network model, a third neural network model, a historical sample database, and a control strategy (e.g., a cooling control algorithm) of the cooling equipment. The UME may obtain a predicted control scheme of the cooling equipment according to the data reported by the FSU, the first neural network model, the second neural network model and the third neural network model, and issue the predicted control scheme to the FSU. The cooling equipment may include an air conditioner and a heat exchange equipment, which are capable of operating according to the issued control scheme.

[0018] The following first to tenth thresholds and various duration may be set in advance in the cooling equipment control device in an initialization stage.

[0019] A first threshold VHT may be, for example, 45 °C, and the air conditioner is unconditionally turned on when the indoor temperature exceeds VHT. A second threshold VLT may be, for example, 15 °C, the air conditioner is unconditionally turned off when the indoor temperature is lower than VLT, and the second threshold VLT is less than the first threshold VHT. A third threshold HT_{AC} may be, for example, 40°C, and the air conditioner may be turned on when the indoor temperature exceeds HT_{AC}. A fourth threshold HT_{HEE} may be, for example, 35°C, and the heat exchange equipment may be turned on when the indoor temperature exceeds HT_{HEE}. A fifth threshold is configured to determine whether a second high temperature prestart condition for an indirect heat exchange equipment is met. A sixth threshold LT may be, for example, 25 °C, the air conditioner and the heat exchange equipment may be turned off when the indoor temperature is lower than LT, and the sixth threshold LT is less than the fourth threshold HT_{HEE} and the third threshold HT_{AC}. A seventh threshold is configured to determine a shutdown duration of the cooling equipment. An eighth threshold is configured to determine whether an indoor-outdoor temperature difference requirement in the second high temperature prestart condition for a direct heat exchange equipment is met. A ninth threshold is configured to determine whether a humidity requirement in the second high temperature prestart condition for the direct heat exchange equipment is met. A tenth threshold is configured to determine an error between an actual operation parameter of the air conditioner and an optimal control parameter of the air conditioner. Maximum continuous operation time MAXCOT of the air conditioner and minimum continuous shutdown time MINCST of the air conditioner are set, and in general, the maximum continuous operation time MAXCOT of the air conditioner is 12 hours and the minimum continuous shutdown time MINCST of the air conditioner is 0.5 hour.

[0020] The first neural network model, the second neural network model and the third neural network model are built in the initialization stage. A process of building the first, second and third neural network models is described in detail below with reference to FIG. 2.

[0021] As shown in FIG. 2, the process of building the first, second and third neural network models includes the following operations S21 to S23.

[0022] In operation S21, historical sample data is acquired.

[0023] The sample data may include outdoor temperatures, indoor temperatures, and cooling equipment loads.

[0024] In the operation S21, the cooling equipment control device may acquire the historical sample data from the historical sample database which may store a large amount of historical sample data such as daily outdoor temperature T_{Rout}, daily indoor temperature T_{Rin}, and daily cooling equipment load L_R. Sampling periods may be determined according to how fast the parameters change. For example, the sampling period of the outdoor temperature T_{Rout} may be 10 minutes, and both the sampling period of the indoor temperature T_{Rin} and the sampling period of the cooling equipment load L_R may be 5 minutes.

[0025] The sample data may include simulation data and sampled data. The simulation data is the data obtained by simulating operation of the cooling equipment when the indoor temperature is greater than the third threshold HT_{AC}. The sampled data is the data sampled when the indoor temperature is less than the sixth threshold LT and the actual shutdown duration of the cooling equipment is greater than the seventh threshold. That is, in a case where the indoor temperature T_{Rin} is relatively high and the cooling equipment needs to operate, simulation of the real cooling equipment may be carried out using a dummy load, and the data such as T_{Rout}, T_{Rin} and L_R may be recorded. In a case where the indoor temperature T_{Rin} is relatively low and the cooling equipment is off for a long period of time (such as a season or a night when the outdoor temperatures T_{Rout} are relatively low), a large amount of the existing historical sample data may be directly used, so as to accelerate an acquisition speed of the historical sample data.

[0026] In operation S22, the historical sample data is subjected to simulation, and daily optimal control parameters of the cooling equipment are obtained by calculation.

[0027] In the operation S22, a heat distribution map of a room environment, heat generating devices and the cooling equipment is created through simulation training by a computer, the historical sample data is subjected to analog computation, an optimal solution vector for controlling the cooling equipment on a current day (i.e., the daily optimal control parameters of the cooling equipment) is output, and the daily optimal control parameters of the cooling equipment are stored as a sample data label.

[0028] According to the simulation result and experience, the air conditioner should not be turned on frequently. For example, a limitation may be imposed that the air conditioner is turned on at most 12 times every day and the heat exchange equipment is turned on at most 12 times every day. That is, for the air conditioner, if one startup moment/operation duration (T_{moment}/T_{hours}) label set has 2 valid values, it is indicated that the optimal control parameters of the air conditioner on the current day are: the air conditioner is to be turned on twice that day, and the air conditioner is to be turned on at each startup moment T_{moment} and operate during the corresponding operation duration T_{hours} each time.

[0029] In operation S23, the first neural network model, the second neural network model, and the third neural network model are built according to the historical sample data and the daily optimal control parameters of the cooling equipment.

[0030] In the operation S23, the first neural network model, the second neural network model, and the third neural network model are sequentially built.

[0031] As shown in FIG. 3, after the operation of subjecting the historical sample data to the simulation, and obtaining the daily optimal control parameters of the cooling equipment by calculation (i.e., the operation S22), and before the operation of building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment (i.e., the operation S23), the cooling equipment control method according to the present disclosure may further include operations S22' and S23'.

[0032] In operation S22', the historical sample data and the daily optimal control parameters of the cooling equipment are normalized.

[0033] The historical sample data and the daily optimal control parameters of the cooling equipment may be normalized according to the following formula to allow the data to be between 0 and 1:

$$X^* = \frac{X_{real} - X_{min}}{X_{max} - X_{min}}$$

where X_{real} is a true value of an actual sample, X* is the normalized data, X_{max} is a maximum value or an upper limit of a corresponding type of sample data, and X_{min} is a minimum value or a lower limit of a corresponding type of sample data.

[0034] For the outdoor temperature T_{Rout} and the indoor temperature T_{Rin}, X_{max} may be an upper limit of 100°C and X_{min} may be a lower limit of -40°C, so the normalized value X* of each real temperature satisfies $X^*=(X_{real}-X_{min})/(X_{max}-X_{min})=(X_{real}+40)/140$. For the cooling equipment load L_R, X_{max} may be set to a full load of the cooling equipment and X_{min} may be 0, so the normalized value X_{real} of each cooling equipment load L_R satisfies $X^*=X_{real}/X_{max}$.

[0035] For the startup moment $T_{moment\text{-}AC}$ of the air conditioner and the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment (which may be in the form of hh:mm:ss), X_{max} may be set to be an upper limit of 1440 (i.e., 24×60=1440 minutes per day), and X_{min} may be set to be 0, so the normalized values X* of $T_{moment\text{-}AC}$ and $T_{moment\text{-}HEE}$ satisfy X*=(hh*60+mm)/1440. For the operation duration $T_{hours\text{-}AC}$ of the air conditioner and the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment, X_{max} may be set to be an upper limit of 24 (i.e., 24 hours per day), and X_{min} may be set to be 0, so the normalized values X* of $T_{hours\text{-}AC}$ and $T_{hours\text{-}HEE}$ satisfy $X^*=X_{real}/24$.

[0036] In operation S23', training sample data set is established according to the normalized data, where the training sample data set includes a training set, a verification set, and a test set.

[0037] In the operation S23', the training set, the verification set, and the test set may be established at a sample ratio of 6:2:2.

[0038] Correspondingly, the operation of building the first neural network model, the second neural network model and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment (i.e., the operation S23) may include: building the first neural network model, the second neural network model and the third neural network model according to the training sample data set.

[0039] The process of building the first, second and third neural network models is described in detail below with reference to FIG. 4.

[0040] As shown in FIG. 4, the operation of building the first neural network model, the second neural network model and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment (i.e., the operation 23) may include operations S231 to S233.

[0041] In operation S231, the first neural network model is built by taking the same-period historical sample data of the cooling equipment loads and a preset impact factor as a first input parameter and taking the historical sample data of the cooling equipment load on the current day as a first output parameter.

[0042] The impact factor may include one of the following factors or any combination of the following factors: a holiday impact factor $F_{holiday}$, a tide impact factor F_{tide}, and a regional event factor F_{event}. Ranges of values of the holiday impact factor $F_{holiday}$, the tide impact factor F_{tide} and the regional event factor F_{event} are all (0, 1), and may be determined according to artificial experience. For example, for a community, the holiday impact factor $F_{holiday}$ may be 0 on weekdays, 0.1 on the weekends, and 0.25 in the Spring Festival holiday; for an industrial park, the tide impact factor F_{tide} may be 0.5 during working time periods, 0.7 during overtime periods, and 0.3 at late nights; and for a certain region, the regional event factor F_{event} may be 0 under normal conditions, 0.1 in a presence of a commercial marketing activity, 0.2 in a presence of a gathering, and 0.3 in a presence of a concert.

[0043] In operation S232, the second neural network model is built by taking the same-period historical sample data of the outdoor temperatures and the historical sample data of the cooling equipment load on the current day as a second input parameter and taking the historical sample data of the indoor temperature on the current day as a second output parameter.

[0044] In operation S233, the third neural network model is built by taking the historical sample data of the indoor temperature on the current day and a preset cooling efficiency factor as a third input parameter and taking the historical sample data of the optimal control parameters of the cooling equipment on the current day as a third output parameter.

[0045] The optimal control parameters may include the startup moment T_{moment} and the operation duration T_{hours}, that is, the startup moment $T_{moment\text{-}AC}$ of the air conditioner, the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment, the operation duration $T_{hours\text{-}AC}$ of the air conditioner and the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment.

[0046] The cooling efficiency factor may include a heat-exchange cooling efficiency factor F_{eff1} and an air-conditioning cooling efficiency factor F_{eff2}. When the room environment is fixed, both the heat-exchange cooling efficiency factor F_{eff1} and the air-conditioning cooling efficiency factor F_{eff2} are constants; and if the room environment is changed (for example, the cooling equipment is replaced or moved), the heat-exchange cooling efficiency factor F_{eff1} and the air-conditioning cooling efficiency factor F_{eff2} need to be adjusted to new constants.

[0047] Assuming that 24 T_{moment}/T_{hours} data sets of the heat exchange equipment have 2 valid values, for example, $T_{moment1}$ is 0.45, T_{hours1} is 0.05, $T_{moment2}$ is 0.60 and T_{hours2} is 0.10, and 12 T_{moment}/T_{hours} data sets of the air conditioner have no valid values, after the startup moment T_{moment} is converted to the form of hh:mm:ss and the operation duration T_{hours} is set to be standard duration, the meaning of the optimal control parameters of the cooling equipment on the current day is as follows:

(1) the heat exchange equipment is to be turned on and operate twice that day;

(2) the heat exchange equipment is to be turned on for the first time at 10:48 (i.e., 0.45*24=10.8=10:48) and operate for 1.2 hours (i.e., 0.05*24= 1.2), that is, an operation time range is from 10:48 to 12:00 (i.e., 0.45*24+0.05*24=12=12:00);

(3) the heat exchange equipment is to be turned on for the second time at 14:24 (i.e., 0.60*24=14.4=14:24) and operate for 2.4 hours (i.e., 0.10*24=2.4), that is, the operation time range is from 14:24 to 16:48 (i.e., 0.60*24+0.10*24=16.8=16:48); and

(4) the air conditioner is not turned on at that day.

[0048] After trained and optimized, the first neural network model, the second neural network model and the third neural network model may be deployed according to an actual operating environment. The three neural network models may be all deployed on the UME to make full use of powerful computing resources in the cloud, thereby realizing real-time or online training. If necessary, the three neural network models may also be deployed at an edge side such as the FSU by adding a compute stick or by other means.

[0049] FIG. 5 is a schematic diagram of a cooling equipment control process according to the present disclosure.

[0050] As shown in FIG. 5, the cooling equipment control method provided by the present disclosure may be used to control the operation of the cooling equipment, and includes operations S11 to S15.

[0051] In operation S11, a current outdoor temperature is determined.

[0052] The current outdoor temperature T_{Rout} may be obtained through weighted calculation of a predicted temperature and a detected outdoor temperature, that is, an outdoor temperature within a preset time period before a current moment is determined first, and then the current outdoor temperature T_{Rout} is determined according to the outdoor temperature within the preset time period before the current moment, a predicted temperature on the current day, a preset first weight and a preset second weight. In general, the preset time period may be 1 hour, and the predicted temperature on the current day may be the temperature at that day predicted by the weather forecast. For example, the outdoor temperature T_{Rout}=the temperature predicted by the weather forecast*0.8+the measured outdoor temperature within the last one hour*0.2.

[0053] It should be noted that the FSU may collect the data such as the indoor and outdoor temperatures, the indoor and outdoor humidity, and the cooling equipment loads, and upload the data to the LTME.

[0054] In operation S12, the same-period historical sample data of the cooling equipment loads and the preset impact factor are input into the first neural network model as the first input parameter to obtain a predicted load of the cooling equipment on the current day.

[0055] The term "same-period" refers to the same period in the history, for example, the same moment of the current day in the last year and the same moment of the current day in the year before last can both be the same periods of the current day.

[0056] In the operation S12, as shown in FIG. 6A, the same-period historical sample data L_N of the cooling equipment loads, the holiday impact factor $F_{holiday}$, the tide impact factor F_{tide}, and the regional event factor F_{event} are input into the first neural network model to obtain the predicted load L_R of the cooling equipment on the current day as an output value of the first neural network model.

[0057] In operation S13, the same-period historical sample data of the outdoor temperatures and the predicted load of the cooling equipment on the current day are input into the second neural network model as the second input parameter to obtain a predicted indoor temperature on the current day.

[0058] In the operation S13, as shown in FIG. 6B, the same-period historical sample data T_{Rout} of the outdoor temperatures and the predicted load L_R of the cooling equipment on the current day (i.e., the output value of the first neural network model) are input into the second neural network model to obtain the predicted indoor temperature T_{Rin} on the current day as an output value of the second neural network model.

[0059] In operation S14, the predicted indoor temperature on the current day and the preset cooling efficiency factor are input into the third neural network model as the third input parameter to obtain optimal control parameters of the cooling equipment on the current day.

[0060] In the operation S14, as shown in FIG. 6C, the predicted indoor temperature T_{Rin} on the current day (i.e., the output value of the second neural network), the heat-exchange cooling efficiency factor F_{eff1}, and the air-conditioning cooling efficiency factor F_{eff2} are input into the third neural network model to obtain the optimal control parameters of the air conditioner on the current day (i.e., the startup moment $T_{moment\text{-}AC}$ of the air-conditioner and the operation duration $T_{hours\text{-}AC}$ of the air-conditioner) and the optimal control parameters of the heat exchange equipment on the current day (i.e., the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment and the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment).

[0061] It should be noted that the startup moment T_{moment} may be converted to the form of hh:mm:ss and the operation duration T_{hours} may be set to be the standard duration (e.g., X hours) in practical applications.

[0062] In the operations S12 to S14, the UME sequentially runs the first neural network model, the second neural network model and the third neural network model to output the optimal control parameters of the cooling equipment on the current day.

[0063] The optimal control parameters of the air conditioner may include the startup moment $T_{moment\text{-}AC}$ of the air conditioner and the operation duration $T_{hours\text{-}AC}$ of the air-conditioner, and the optimal control parameters of the heat exchange equipment may include the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment and the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment.

[0064] The optimal control parameters for each day may include at most 12 sets of the startup moment $T_{moment\text{-}AC}$ of the air-conditioner and the operation duration $T_{hours\text{-}AC}$ of the air-conditioner, and at most 24 sets of the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment and the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment.

[0065] In operation S15, the cooling equipment is controlled to operate according to the optimal control parameters.

[0066] In the operation S15, the air conditioner is controlled to operate according to the optimal control parameters of the air conditioner, and the heat exchange equipment is controlled to operate according to the optimal control parameters of the heat exchange equipment.

[0067] According to the cooling equipment control method provided by the present disclosure, the prediction of the control scheme of the air conditioner and the heat exchange equipment and the linkage control of the air conditioner and the heat exchange equipment are realized by using the neural network models based on the parameters such as the current outdoor temperature, the same-period historical sample data of the cooling equipment loads, the impact factors and the cooling efficiency factors, so that the predicted control scheme has relatively high accuracy, the defect of the traditional algorithm, i.e., the traditional algorithm is difficult to improve, is overcome, active control of the air conditioner and the heat exchange equipment is realized, operation efficiency is optimized, and the energy consumption is reduced; in addition, by combining the historical data and the current measured data and considering the impact factors of special events and the cooling efficiency factors of the cooling equipment, the predicted control scheme is more accurate, can adapt to a change of the room environment, and has a widened application range.

[0068] FIG. 7 is a schematic diagram of a control process of the air conditioner according to the present disclosure.

[0069] As shown in FIG. 7, the control process of the air conditioner provided by the present disclosure includes operations S31 to S39.

[0070] In operation S31, if a current indoor temperature is greater than the first threshold VHT, operation S36 is performed; otherwise, operation S32 is performed.

[0071] In the operation S31, if the current indoor temperature is greater than VHT, which indicates that the current indoor temperature is too high, whether the air conditioner is operating overtime may be further determined (i.e., the operation S36 is performed); if the current indoor temperature is less than or equal to VHT, whether the current indoor temperature is too low may be further determined (i.e., the operation S32 is performed).

[0072] In operation S32, if the current indoor temperature is less than the second threshold VLT, operation S39 is performed; otherwise, operation S33 is performed.

[0073] In the operation S32, if the current indoor temperature is less than the second threshold VLT, which indicates that the current indoor temperature is too low, the air conditioner may be turned off due to a low temperature anomaly (i.e., the operation S39 is performed); and if the current indoor temperature is greater than or equal to the second threshold VLT, which indicates that the current indoor temperature does not cause a shutdown due to a high temperature anomaly or a shutdown due to the low temperature anomaly, whether a first high temperature prestart condition is met may be further determined (i.e., the operation S33 is performed).

[0074] In operation S33, if the first high temperature prestart condition is met, operation S34 is performed; otherwise, the operation S31 is performed.

[0075] In the operation S33, in a case where the current indoor temperature is less than or equal to the first threshold VHT and greater than or equal to the second threshold VLT, if the first high temperature prestart condition is met, the air conditioner is controlled to operate according to the optimal control parameters of the air conditioner on the current day (i.e., the operation S34 is performed); and if the first high temperature prestart condition is not met, the operation S31 is performed.

[0076] The first high temperature prestart condition may include that the startup moment $T_{moment\text{-}AC}$ of the air conditioner is reached, the current indoor temperature is greater than the third threshold HT_{AC}, and the actual shutdown duration of the air conditioner is greater than the minimum continuous shutdown time MINCST of the air conditioner.

[0077] In operation S34, maximum operation duration $T_{on\text{-}max}$ of the air conditioner is set to be the smaller one of the operation duration $T_{hours\text{-}AC}$ of the air conditioner and the maximum continuous operation time MAXCOT of the air conditioner.

[0078] In the operation S34, the smaller one of the operation duration $T_{hours\text{-}AC}$ of the air conditioner and the maximum continuous operation time MAXCOT of the air conditioner may be taken as a control parameter for actually controlling the operation of the air conditioner, so as to ensure reliability and safety of the operation of the air conditioner.

[0079] In operation S35, the air conditioner is turned on, and operation S38 is performed.

[0080] In the operation S35, after the air conditioner is turned on under the control, recording of actual operation duration $T_{on\text{-}AC}$ of the air conditioner begins, the actual shutdown duration $T_{off\text{-}AC}$ of the air conditioner is cleared, and the operation S38 is performed.

[0081] In operation S36, if the actual shutdown duration $T_{off\text{-}AC}$ of the air conditioner is greater than the minimum continuous shutdown time MINCST of the air conditioner, operation S37 is performed; otherwise, the operation S31 is performed.

[0082] In the operation S36, in the case where the current indoor temperature is greater than the first threshold VHT, if the current actual shutdown duration $T_{off\text{-}AC}$ of the air conditioner is greater than the minimum continuous shutdown time MINCST of the air conditioner, which indicates that a high-temperature anomaly start condition is met, a high-temperature anomaly start operation of the air conditioner is performed (i.e., the operation 37 is performed); and if the current actual shutdown duration $T_{off\text{-}AC}$ of the air conditioner is less than or equal to the minimum continuous shutdown time MINCST of the air conditioner, the operation S31 is performed.

[0083] In operation S37, the maximum operation duration $T_{on\text{-}max}$ of the air conditioner is set to be the maximum continuous operation time MAXCOT of the air conditioner, and the operation S35 is performed.

[0084] In the operation S37, in the case of the high-temperature anomaly start of the air conditioner, the operation duration of the air conditioner is directly controlled according to the preset maximum continuous operation time MAXCOT of the air conditioner.

[0085] In operation S38, if the actual operation duration $T_{on\text{-}AC}$ of the air conditioner is greater than or equal to the maximum operation duration $T_{on\text{-}max}$ of the air conditioner, operation S39 is performed; otherwise, the air conditioner is kept in a current state.

[0086] After the air conditioner is turned on, recording of the actual operation duration $T_{on\text{-}AC}$ of the air conditioner begins; if the actual operation duration $T_{on\text{-}AC}$ of the air conditioner is greater than or equal to the maximum operation duration $T_{on\text{-}max}$ of the air conditioner, the air conditioner is turned off; otherwise, the air conditioner is kept in the current state.

[0087] In operation S39, the air conditioner is turned off, and the operation S31 is performed.

[0088] In the operation S39, after the air conditioner is turned off under the control, recording of the actual shutdown duration $T_{off\text{-}AC}$ of the air conditioner begins, the actual operation duration $T_{on\text{-}AC}$ of the air conditioner is cleared, and then the operation S31 is performed to detect the indoor temperature again.

[0089] The control process of the air conditioner may further include: turning off the air conditioner if the current indoor temperature is less than the sixth threshold LT.

[0090] It can be seen from the above operations S31 to S39 that, by using the predicted scheme output by the third neural network model together with the pre-built startup/shutdown strategy algorithm of the air conditioner and the heat exchange equipment, safe operation of the air conditioner and the heat exchange equipment can be ensured when the prediction by the neural network model is abnormal. When the actual room temperature exceeds the first threshold VHT, the air conditioner can be turned on due to the high temperature anomaly; and when the actual room temperature is lower than the second threshold VLT, the air conditioner can be turned off due to the low temperature anomaly; when the startup moment $T_{moment\text{-}AC}$ of the air conditioner is reached, the actual room temperature exceeds the third threshold HT_{AC} and an operation interval exceeds the minimum continuous shutdown time MINCST, the air conditioner can operate according to the predicted scheme output by the third neural network model, that is, the air conditioner is turned on at the startup moment $T_{moment\text{-}AC}$ of the air conditioner and operates for the operation duration $T_{hours\text{-}AC}$ of the air conditioner.

[0091] FIG. 8 is a schematic diagram of a control process of the heat exchange equipment according to the present disclosure.

[0092] As shown in FIG. 8, the control process of the heat exchange equipment provided by the present disclosure includes operations S41 to S44.

[0093] In operation S41, if the second high temperature prestart condition is met, operation S42 is performed; otherwise, the heat exchange equipment is kept in a current state.

[0094] It should be noted that the heat exchange equipment may include a direct heat exchange equipment and an indirect heat exchange equipment, the direct heat exchange equipment may include a fresh air system, and the indirect heat exchange equipment may include Heat Pipe Equipment (HPE).

[0095] When the heat exchange equipment is the indirect heat exchange equipment, the second high temperature prestart condition may include that the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment is reached, the current indoor temperature is greater than the fourth threshold HT_{HEE}, and a difference between the current indoor temperature and the current outdoor temperature is greater than the fifth threshold.

[0096] When the heat exchange equipment is the direct heat exchange equipment, the second high temperature prestart condition includes one of the following conditions:

(1) the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment is reached, the current indoor temperature is greater than the fourth threshold HT_{HEE}, and the difference between the current indoor temperature and the current outdoor temperature is greater than the eighth threshold. The eighth threshold may be greater than the fifth threshold, that is, an indoor-outdoor temperature difference requirement in the second high temperature prestart condition of the direct heat exchange equipment is higher than that in the second high temperature prestart condition of the indirect heat exchange equipment, for example, the fifth threshold may be 6°C, and the eighth threshold may be 10°C.

(2) the startup moment $T_{moment\text{-}HEE}$ of the heat exchange equipment is reached, the current indoor temperature is greater than the fourth threshold HT_{HEE}, the difference between the current indoor temperature and the current outdoor temperature is greater than the eighth threshold, and a current indoor humidity is less than or equal to the ninth threshold. That is, the second high temperature prestart condition of the direct heat exchange equipment may include a temperature condition and a humidity condition, for example, the ninth threshold may be 90%.

[0097] In operation S42, the heat exchange equipment is turned on.

[0098] In the operation S42, after the heat exchange equipment is turned on under the control, recording of actual operation duration $T_{on\text{-}HEE}$ of the heat exchange equipment begins, and the actual shutdown duration $T_{off\text{-}HEE}$ of the heat exchange equipment is cleared.

[0099] In the operation S43, if the actual operation duration $T_{on\text{-}HEE}$ of the heat exchange equipment is greater than or equal to the operation duration $T_{hours\text{-}HEE}$ of the heat exchange equipment, operation S44 is performed; otherwise, the heat exchange equipment is kept in the current state.

[0100] In operation S44, the heat exchange equipment is turned off.

[0101] In the operation S44, after the heat exchange equipment is turned off under the control, recording of the actual shutdown duration $T_{off\text{-}HEE}$ of the heat exchange equipment begins, and the actual startup duration $T_{on\text{-}HEE}$ of the heat exchange equipment is cleared.

[0102] The control process of the heat exchange equipment may further include: turning off the heat exchange equipment if the current indoor temperature is less than the sixth threshold LT.

[0103] It should be noted that the air conditioner and the indirect heat exchange equipment can operate simultaneously, but the operation of the air conditioner and the operation of the direct heat exchange equipment are mutually exclusive, that is, the air conditioner and the direct heat exchange equipment cannot operate simultaneously. In addition, when a delay occurs or a fire alarm is given, the direct heat exchange equipment needs to be turned off immediately and an air valve needs to be closed immediately, so as to ensure the safety.

[0104] When the heat exchange equipment is the direct heat exchange equipment, the startup moment of the air conditioner is different from the startup moment of the heat exchange equipment; correspondingly, the cooling equipment control method according to the present disclosure may further include: if the air conditioner is turned on, turning off the heat exchange equipment; and if the heat exchange equipment is turned on, turning off the air conditioner.

[0105] It should be noted that the control algorithm of the air conditioner and the heat exchange equipment may run on the LTME; and if necessary, the control algorithm of the air conditioner and the heat exchange equipment may also be copied to the FSU to be executed locally, in which case the UME needs to issue the cooling equipment control scheme predicted by the third neural network model to the FSU in advance.

[0106] It should be noted that the control of the air conditioner and the control of the heat exchange equipment may be carried out concurrently, and the operations S11 to S14 shown in FIG. 5 are performed once before zero every day, so as to output the optimal control parameters of the cooling equipment at that day.

[0107] FIG. 9 is a schematic diagram of a process of re-determining and updating the optimal control parameters of the cooling equipment on the current day according to the present disclosure.

[0108] As shown in FIG. 9, after the operation of controlling the cooling equipment to operate according to the optimal control parameters (i.e., the operation S15 shown in FIG. 5), the cooling equipment control method according to the present disclosure may further include operations S51 to S53.

[0109] In operation S51, if an error between actual operation parameters of the air conditioner on the current day and the optimal control parameters of the air conditioner on the current day exceeds the tenth threshold, operation S52 is performed; otherwise, the process is ended.

[0110] In operation S52, the optimal control parameters of the air conditioner on the current day are re-determined.

[0111] Specific implementation of the operation S52 is the same as that of the operations S12 to S14, and thus is not repeated here.

[0112] In operation S53, the training sample data set is updated according to the re-determined optimal control parameters of the air conditioner on the current day.

[0113] For example, if an error between an actual startup moment of the air conditioner on current the day and the startup moment of the air conditioner in the optimal control parameters of the air conditioner on the current day exceeds 10 minutes, the optimal control parameters of the air conditioner on the current day need to be predicted again, and the training sample data set is updated according to the re-predicted optimal control parameters of the air conditioner on the current day, thereby improving timely response capability of the cooling control strategy and timeliness and accuracy of the control prediction.

[0114] The neural network models may be deployed and run on the cloud, and may also be continuously trained in real time or online when external parameters are continuously changed, so that prediction accuracy of the neural network models can be continuously improved, and the neural network models can be trained and adjusted to adapt to abnormal conditions such as a change of the room environment.

[0115] The air conditioner and the heat exchange equipment may be switched in a presence of failures, and correspondingly, the cooling equipment control method according to the present disclosure may further include: if one type of the cooling equipment that is operating currently fails and the other type of the cooling equipment is normal, turning off the failed cooling equipment, and turning on the normal cooling equipment; and if both of the two types of the cooling equipment that are operating currently fail, turning on the cooling equipment whose failure is eliminated during elimination of failures. That is, if the cooling equipment that is turned on currently fails, the failed cooling equipment is turned off, and the normal cooling equipment is turned on, and when the failure is eliminated, the previously failed cooling equipment is turned on again, and the other cooling equipment is turned off. By taking the air conditioner and the heat exchange equipment as backups of each other to be turned on and operated in the presence of the failures, the danger of abnormal high temperature of the machine room can be avoided.

[0116] During the process of controlling the cooling equipment to operate according to the optimal control parameters (i.e., the operation S15 shown in FIG. 5), the cooling equipment control method according to the present disclosure may further include: if the current indoor temperature is less than the sixth threshold LT and the actual shutdown duration of the cooling equipment is greater than the seventh threshold, training the second neural network model according to currently acquired sample data, which includes the outdoor temperatures, the indoor temperatures and the cooling equipment loads. That is, the real-time or online training of the model can be supported when environmental conditions are good (for example, the FSU and the UME are connected on a fast Ethernet, and the computing power resources in the cloud are sufficient). When the temperature in the machine room is relatively low and the cooling equipment does not operate for a long period of time (such as in a cool season with low temperatures or at nights with low temperatures), the second neural network model can be trained online in real time according to the data collected in real time such as the outdoor temperatures, the cooling equipment loads and the indoor temperatures.

[0117] After controlling the cooling equipment to operate according to the optimal control parameters (i.e., the operation S15 shown in FIG. 5), the cooling equipment control method according to the present disclosure may further include: adding the sample data acquired on the current day and the actual operation parameters of the cooling equipment on the current day to the training sample data set, so as to train the first neural network model and the third neural network model according to the training sample data set. By adding the sample data on the current day and the actual cooling control result on the current day to a big data set, the training set and the test set may be enriched, so that the prediction accuracy of the models can be improved when the first neural network model and the third neural network model are trained online.

[0118] In a case where the FSU fails to communicate with the LTME due to an interruption of a communication network, in order to realize the control of the cooling equipment, the FSU may automatically run a built-in temperature startup-shutdown control algorithm, or may receive and store a cooling control plan which is issued by the UME in advance, and locally run a cooling linkage control algorithm copied from the UME.

[0119] Correspondingly, after the first neural network model, the second neural network model and the third neural network model are built in the initialization stage, the cooling equipment control method according to the present disclosure may further include: deploying the first neural network model, the second neural network model and the third neural network model on the FSU to determine the optimal control parameters of the cooling equipment on the current day when the FSU fails to communicate with the UME, and controlling the cooling equipment to operate according to the optimal control parameters.

[0120] One application scenario of the present disclosure is: a base station room in which the heat productivity of communication devices in the room is less than 10KW, and the base station room is generally a data base station room, or a transmission base station room, or an exchange base station room of an operator. Merely one air conditioner is originally installed as the cooling equipment in the base station room; and in order to reduce the energy consumption of the air conditioner, an indirect heat exchange equipment, i.e. the intelligent HPE, is added after an external environment, the heat productivity and an installation condition of the base station room are considered, so as to provide a solution for the room through the linkage control of the air conditioner and the HPE. The HPE adopts the heat pipe technology which does not need mechanical cooling and can basically keep the indoor-outdoor temperature difference to be about 6 °C, so that the HPE is applicable for more than 90% of the time all the year round. Meanwhile, the energy consumption of the components of the HPE is much less than that of the traditional compressor-type air conditioner, and the energy consumption of the HPE is merely about 1/5 of the energy consumption of the original air conditioner system, so that the power consumption of the air conditioner can be greatly saved.

[0121] In general, an application environment of a machine room will be fully considered no matter for building a new machine room or expanding an existing machine room, so as to select proper heat exchange equipment. Adopting the indirect heat exchange equipment such as the HPE or a heat exchanger can realize isolation of an indoor environment from an outdoor environment and has a wide application range, but needs a relatively high initial cost. Under conditions of good air quality (no salt spray or corrosive gas pollution exists), low temperature and humidity and strong regular maintenance capability of a user, a fresh air system can be selected as a direct heat exchange equipment. Thus, another application scenario of the present disclosure is: a base station room adopting linkage control of the fresh air system and the air conditioner for cooling.

[0122] According to the cooling equipment control solution provided by the present disclosure, based on a big data technology and the neural network technology, by fully considering the data such as the current indoor/outdoor temperatures and humidity and system loads and calculating by the neural network models according to the load prediction, the weather forecast and the same-period historical sample data, the cooling equipment loads and the indoor temperatures can be predicted in advance, and the optimal plan for the linkage control of the cooling equipment on the current day can be output and then be used together with the traditional control strategy, so that the predictable active control of the air conditioner and the heat exchange equipment in the machine room can be realized, thereby optimizing the control, saving the energy, and reducing the power consumption.

[0123] Since the predictable active linkage control of the heat exchange equipment and the air conditioner is realized, the operation time and the startup times of the air conditioner are significantly reduced; meanwhile, the operation temperatures of the devices in the machine room can be increased to controllable safety ranges of 30°C to 40 °C, so that the energy consumption of the cooling equipment is further reduced. By preliminary estimate, compared with a single cooling mode adopting the air conditioner alone, the predictable active linkage control of the air conditioner and the heat exchange equipment can save nearly 10,000kwh for a communication base station every year and reduce average electricity consumption by 40%, that is, if calculated by taking 10% of 5 million base stations as an example, an electricity expense of 5 billion yuan and 1.35 million tons of carbon emissions can be saved every year, thus producing remarkable economic and social benefits.

[0124] Based on the same technical concept, the present disclosure further provides a cooling equipment control device.

[0125] FIG. 10 and FIG. 11 are schematic structural diagrams of a cooling equipment control device according to the present disclosure.

[0126] As shown in FIG. 10, the cooling equipment control device provided by the present disclosure includes a first processing module 101, a second processing module 102, and a control module 103.

[0127] The first processing module 101 is configured to determine a current outdoor temperature.

[0128] The second processing module 102 is configured to: input same-period historical sample data of cooling equipment loads and a preset impact factor into a first neural network model as a first input parameter to obtain a predicted load of cooling equipment on a current day; input same-period historical sample data of outdoor temperatures and the predicted load of the cooling equipment on the current day into a second neural network model as a second input parameter to obtain a predicted indoor temperature on the current day; and input the predicted indoor temperature on the current day and a preset cooling efficiency factor into a third neural network model as a third input parameter to obtain optimal control parameters of the cooling equipment on the current day.

[0129] The control module 103 is configured to control the cooling equipment to operate according to the optimal control parameters.

[0130] As shown in FIG. 11, the cooling equipment control device according to the present disclosure may further include a model building module 104.

[0131] The model building module 104 is configured to build the first neural network model, the second neural network model, and the third neural network model in an initialization stage. The model building module 104 may be configured to: acquire historical sample data which includes outdoor temperatures, indoor temperatures, and cooling equipment loads; subject the historical sample data to simulation, and obtain daily optimal control parameters of the cooling equipment by calculation; and build the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment.

[0132] The model building module 104 may be further configured to: after subjecting the historical sample data to the simulation and obtaining the daily optimal control parameters of the cooling equipment by calculation, and before building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment, normalize the historical sample data and the daily optimal control parameters of the cooling equipment; and establish training sample data set according to the normalized data, where the training sample data set includes a training set, a verification set, and a test set.

[0133] The model building module 104 may be configured to build the first neural network model, the second neural network model, and the third neural network model according to the training sample data set.

[0134] The model building module 104 may be configured to: build the first neural network model by taking the same-period historical sample data of the cooling equipment loads and the preset impact factor as the first input parameter and taking historical sample data of the cooling equipment load on the current day as a first output parameter; build the second neural network model by taking the same-period historical sample data of the outdoor temperatures and the historical sample data of the cooling equipment load on the current day as the second input parameter and taking historical sample data of an indoor temperature on the current day as a second output parameter; and build the third neural network model by taking the historical sample data of the indoor temperature on the current day and the preset cooling efficiency factor as the third input parameter and taking historical sample data of the optimal control parameters of the cooling equipment on the current day as a third output parameter.

[0135] The sample data may include simulation data and sampled data. The simulation data is the data obtained by simulating operation of the cooling equipment when an indoor temperature is greater than a preset third threshold. The sampled data is the data sampled when an indoor temperature is less than a preset sixth threshold and actual shutdown duration of the cooling equipment is greater than a preset seventh threshold.

[0136] The first processing module 101 may be configured to determine an outdoor temperature within a preset time period before a current moment; and determine the current outdoor temperature according to the outdoor temperature within the preset time period before the current moment, a predicted temperature on the current day, a preset first weight and a preset second weight.

[0137] The optimal control parameters may include startup moment and operation duration. The impact factor may include one of the following factors or any combination of the following factors: a holiday impact factor, a tide impact factor, and a regional event factor.

[0138] The control module 103 may be configured to: if a current indoor temperature is less than or equal to a preset first threshold and greater than or equal to a preset second threshold and a first high temperature prestart condition is met, set maximum operation duration of an air conditioner to be the smaller one of operation duration of the air conditioner and a preset maximum continuous operation time of the air conditioner, and turn on the air conditioner, with the second threshold being less than the first threshold; and if actual operation duration of the air conditioner is greater than or equal to the maximum operation duration of the air conditioner, turn off the air conditioner.

[0139] The first high temperature prestart condition may include that a startup moment of the air conditioner is reached, the current indoor temperature is greater than the preset third threshold, and actual shutdown duration of the air conditioner is greater than a preset minimum continuous shutdown time of the air conditioner.

[0140] The control module 103 may be further configured to: during a process of controlling the cooling equipment to operate according to the optimal control parameters, if the current indoor temperature is greater than the first threshold and the actual shutdown duration of the air conditioner is greater than the minimum continuous shutdown time of the air conditioner, set the maximum operation duration of the air conditioner to be the maximum continuous operation time of the air conditioner, and turn on the air conditioner; and/or, if the current indoor temperature is less than the second threshold, turn off the air conditioner.

[0141] The control module 103 may be further configured to: if a second high temperature prestart condition is met, turn on heat exchange equipment; and if actual operation duration of the heat exchange equipment is greater than or equal to operation duration of the heat exchange equipment, turn off the heat exchange equipment.

[0142] When the heat exchange equipment is an indirect heat exchange equipment, the second high temperature prestart condition may include that a startup moment of the heat exchange equipment is reached, the current indoor temperature is greater than a preset fourth threshold, and a difference between the current indoor temperature and the current outdoor temperature is greater than a preset fifth threshold.

[0143] When the heat exchange equipment is a direct heat exchange equipment, the second high temperature prestart condition may include one of the following conditions: the startup moment of the heat exchange equipment is reached, the current indoor temperature is greater than the preset fourth threshold, the difference between the current indoor temperature and the current outdoor temperature is greater than a preset eighth threshold, and the eighth threshold is greater than the fifth threshold; and the startup moment of the heat exchange equipment is reached, the current indoor temperature is greater than the preset fourth threshold, the difference between the current indoor temperature and the current outdoor temperature is greater than the preset eighth threshold, and a current indoor humidity is less than or equal to a preset ninth threshold.

[0144] When the heat exchange equipment is the direct heat exchange equipment, the startup moment of the air conditioner is different from that of the heat exchange equipment; and the control module 103 may be further configured to: if the air conditioner is turned on, turn off the heat exchange equipment; and if the heat exchange equipment is turned on, turn off the air conditioner.

[0145] The control module 103 may be further configured to: after controlling the cooling equipment to operate according to the optimal control parameters, if an error between actual operation parameters of the air conditioner on the current day and the optimal control parameters of the air conditioner on the current day exceeds a preset tenth threshold, instruct the second processing module 102 to re-determine the optimal control parameters of the air conditioner on the current day; and update the training sample data set according to the re-determined optimal control parameters of the air conditioner on the current day.

[0146] The control module 103 may be further configured to: if one type of the cooling equipment that is operating currently fails and the other type of the cooling equipment is normal, turn off the failed cooling equipment, and turn on the normal cooling equipment; and if both of the two types of the cooling equipment that are operating currently fail, turn on the cooling equipment whose failure is eliminated during elimination of failures

[0147] The second processing module 102 may be further configured to: if the current indoor temperature is less than the preset sixth threshold and the actual shutdown duration of the cooling equipment is greater than the preset seventh threshold, train the second neural network model according to currently acquired sample data which includes outdoor temperatures, indoor temperatures and cooling equipment loads.

[0148] The present disclosure further provides a computer device, including one or more processors, and a storage device having stored thereon one or more programs, which, when executed by the one or more processors, cause the one or more processors to carry out the cooling equipment control method provided by the present disclosure.

[0149] The present disclosure further provides a computer-readable medium having stored thereon a computer program, which, when executed by a processor, causes the processor to carry out the cooling equipment control method provided by the present disclosure.

[0150] It should be understood by those of ordinary skill in the art that the functional modules/units in all or some of the operations and devices disclosed in the above method may be implemented as software, firmware, hardware, or suitable combinations thereof. If implemented as hardware, the division between the functional modules/units stated above is not necessarily corresponding to the division of physical components; and for example, one physical component may have a plurality of functions, or one function or operation may be performed through cooperation of several physical components. Some or all of the physical components may be implemented as software executed by a processor, such as a central processing unit, a digital signal processor or a microprocessor, or may be implemented as hardware, or may be implemented as an integrated circuit, such as an application specific integrated circuit. Such software may be distributed on a computer-readable medium, which may include a computer storage medium (or a non-transitory medium) and a communication medium (or a transitory medium). As well known by those of ordinary skill in the art, the term "computer storage medium" includes volatile/nonvolatile and removable/non-removable media used in any method or technology for storing information (such as computer-readable instructions, data structures, program modules and other data). The computer storage medium includes, but is not limited to, a Random Access Memory, a Read-Only Memory, an Electrically Erasable Programmable Read-Only Memory (EEPROM), a flash memory or other storage technology, a Compact Disc Read Only Memory (CD-ROM), a Digital Versatile Disc (DVD) or other optical discs, a magnetic cassette, a magnetic tape, a magnetic disk or other magnetic storage devices, or any other medium which can be configured to store desired information and can be accessed by a computer. In addition, it is well known by those of ordinary skill in the art that the communication media generally include computer-readable instructions, data structures, program modules, or other data in modulated data signals such as carrier wave or other transmission mechanism, and may include any information delivery medium.

[0151] The present disclosure discloses exemplary embodiments using specific terms, but the terms are merely used and should be merely interpreted as having general illustrative meanings, rather than for the purpose of limitation. Unless expressly stated, it is apparent to those of ordinary skill in the art that features, characteristics and/or elements described in connection with a particular embodiment can be used alone or in combination with features, characteristics and/or elements described in connection with other embodiments. Therefore, it should be understood by those of ordinary skill in the art that various changes in the forms and the details can be made without departing from the scope of the present disclosure of the appended claims.

Claims

1. A cooling equipment control method, comprising:

determining a current outdoor temperature;
inputting same-period historical sample data of cooling equipment loads and a preset impact factor into a first neural network model as a first input parameter to obtain a predicted load of cooling equipment on a current day;
inputting same-period historical sample data of outdoor temperatures and the predicted load of the cooling equipment on the current day into a second neural network model as a second input parameter to obtain a predicted indoor temperature on the current day;
inputting the predicted indoor temperature on the current day and a preset cooling efficiency factor into a third neural network model as a third input parameter to obtain optimal control parameters of the cooling equipment on the current day; and
controlling the cooling equipment to operate according to the optimal control parameters.

2. The method of claim 1, wherein before determining the current outdoor temperature, the method further comprises:

acquiring historical sample data which comprises the outdoor temperatures, indoor temperatures, and the cooling equipment loads;
subjecting the historical sample data to simulation, and obtaining daily optimal control parameters of the cooling equipment by calculation; and
building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment.

3. The method of claim 2, wherein after subjecting the historical sample data to the simulation and obtaining the daily optimal control parameters of the cooling equipment by calculation, and before building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment, the method further comprises:

normalizing the historical sample data and the daily optimal control parameters of the cooling equipment; and
establishing training sample data set according to the normalized data, wherein the training sample data set comprises a training set, a verification set, and a test set; and
building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment comprises:
building the first neural network model, the second neural network model, and the third neural network model according to the training sample data set.

4. The method of claim 2, wherein building the first neural network model, the second neural network model, and the third neural network model according to the historical sample data and the daily optimal control parameters of the cooling equipment comprises:

building the first neural network model by taking the same-period historical sample data of the cooling equipment loads and the preset impact factor as the first input parameter and taking historical sample data of the cooling equipment load on the current day as a first output parameter;
building the second neural network model by taking the same-period historical sample data of the outdoor temperatures and the historical sample data of the cooling equipment load on the current day as the second input parameter and taking historical sample data of the indoor temperature on the current day as a second output parameter; and
building the third neural network model by taking the historical sample data of the indoor temperature on the current day and the preset cooling efficiency factor as the third input parameter and taking historical sample data of the optimal control parameters of the cooling equipment on the current day as a third output parameter.

5. The method of claim 2, wherein the sample data comprises simulation data and sampled data,

the simulation data is data obtained by simulating operation of the cooling equipment when the indoor temperature is greater than a preset third threshold; and
the sampled data is data sampled when the indoor temperature is less than a preset sixth threshold and actual shutdown duration of the cooling equipment is greater than a preset seventh threshold.

6. The method of claim 1, wherein determining the current outdoor temperature comprises:

determining an outdoor temperature within a preset time period before a current moment; and
determining the current outdoor temperature according to the outdoor temperature within the preset time period before the current moment, a predicted temperature on the current day, a preset first weight and a preset second weight.

7. The method of any one of claims 1 to 6, wherein the cooling equipment comprises an air conditioner and heat exchange equipment, the optimal control parameters comprise a startup moment of the air conditioner, an operation duration of the air conditioner, a startup moment of the heat exchange equipment, and an operation duration of the heat exchange equipment, and the impact factor comprises one of the following factors or any combination of the following factors: a holiday impact factor, a tide impact factor, and a regional event factor.

8. The method of claim 7, wherein controlling the cooling equipment to operate according to the optimal control parameters comprises:

in response to a case where a current indoor temperature is less than or equal to a preset first threshold and greater than or equal to a preset second threshold and a first high temperature prestart condition is met, setting maximum operation duration of the air conditioner to be a smaller one of the operation duration of the air conditioner and a preset maximum continuous operation time of the air conditioner, and turning on the air conditioner, wherein the second threshold is less than the first threshold; and
in response to a case where actual operation duration of the air conditioner is greater than or equal to the maximum operation duration of the air conditioner, turning off the air conditioner.

9. The method of claim 8, wherein the first high temperature prestart condition comprises that:

the startup moment of the air conditioner is reached, the current indoor temperature is greater than a preset third threshold, and actual shutdown duration of the air conditioner is greater than a preset minimum continuous shutdown time of the air conditioner.

10. The method of claim 8, wherein during a process of controlling the cooling equipment to operate according to the optimal control parameters, the method further comprises:

in response to a case where the current indoor temperature is greater than the first threshold and actual shutdown duration of the air conditioner is greater than a minimum continuous shutdown time of the air conditioner, setting the maximum operation duration of the air conditioner to be the maximum continuous operation time of the air conditioner, and turning on the air conditioner; and/or
in response to a case where the current indoor temperature is less than the second threshold, turning off the air conditioner.

11. The method of claim 7, wherein controlling the cooling equipment to operate according to the optimal control parameters comprises:

in response to a case where a second high temperature prestart condition is met, turning on the heat exchange equipment; and
in response to a case where actual operation duration of the heat exchange equipment is greater than or equal to the operation duration of the heat exchange equipment, turning off the heat exchange equipment.

12. The method of claim 11, wherein when the heat exchange equipment is an indirect heat exchange equipment, the second high temperature prestart condition comprises that:

the startup moment of the heat exchange equipment is reached, a current indoor temperature is greater than a preset fourth threshold, and a difference between the current indoor temperature and the current outdoor temperature is greater than a preset fifth threshold; or
when the heat exchange equipment is a direct heat exchange equipment, the second high temperature prestart condition comprises one of the following conditions:

the startup moment of the heat exchange equipment is reached, the current indoor temperature is greater than the preset fourth threshold, and the difference between the current indoor temperature and the current outdoor temperature is greater than a preset eighth threshold, wherein the eighth threshold is greater than the fifth threshold; and

the startup moment of the heat exchange equipment is reached, the current indoor temperature is greater than the preset fourth threshold, the difference between the current indoor temperature and the current outdoor temperature is greater than the preset eighth threshold, and a current indoor humidity is less than or equal to a preset ninth threshold.

13. The method of claim 7, wherein the heat exchange equipment is a direct heat exchange equipment, the startup moment of the air conditioner is different from the startup moment of the heat exchange equipment, and the method further comprises:

turning off the heat exchange equipment in response to a case where the air conditioner is turned on; and

turning off the air conditioner in response to a case where the heat exchange equipment is turned on.

14. The method of claim 3, wherein the cooling equipment comprises an air conditioner, and after controlling the cooling equipment to operate according to the optimal control parameters, the method further comprises:

in response to a case where an error between actual operation parameters of the air conditioner on the current day and the optimal control parameters of the air conditioner on the current day exceeds a preset tenth threshold, re-determining the optimal control parameters of the air conditioner on the current day; and

updating the training sample data set according to the re-determined optimal control parameters of the air conditioner on the current day.

15. The method of claim 1, further comprising:

in response to a case where one type of the cooling equipment that is operating currently fails and the other type of the cooling equipment is normal, turning off the failed cooling equipment, and turning on the normal cooling equipment; and

in response to a case where both of two types of the cooling equipment that are operating currently fail, turning on the cooling equipment whose failure is eliminated during elimination of failures.

16. The method of claim 1, wherein during a process of controlling the cooling equipment to operate according to the optimal control parameters, the method further comprises:

in response to a case where a current indoor temperature is less than a preset sixth threshold and actual shutdown duration of the cooling equipment is greater than a preset seventh threshold, training the second neural network model according to currently acquired sample data which comprises the outdoor temperatures, indoor temperatures, and the cooling equipment loads.

17. A cooling equipment control device, comprising: a first processing module, a second processing module, and a control module,

wherein the first processing module is configured to determine a current outdoor temperature,

the second processing module is configured to:

input same-period historical sample data of cooling equipment loads and a preset impact factor into a first neural network model as a first input parameter to obtain a predicted load of cooling equipment on a current day;

input same-period historical sample data of outdoor temperatures and the predicted load of the cooling equipment on the current day into a second neural network model as a second input parameter to obtain a predicted indoor temperature on the current day; and

input the predicted indoor temperature on the current day and a preset cooling efficiency factor into a third neural network model as a third input parameter to obtain optimal control parameters of the cooling equipment on the current day; and

the control module is configured to control the cooling equipment to operate according to the optimal control parameters.

18. A computer device, comprising:

one or more processors; and

a storage device having one or more programs stored thereon;

wherein when the one or more programs are executed by the one or more processors, the one or more processors carry out the cooling equipment control method of any one of claims 1 to 16.

19. A computer-readable medium having a computer program stored thereon, wherein when the computer program is executed by a processor, the processor carries out the cooling equipment control method of any one of claims 1 to 16.

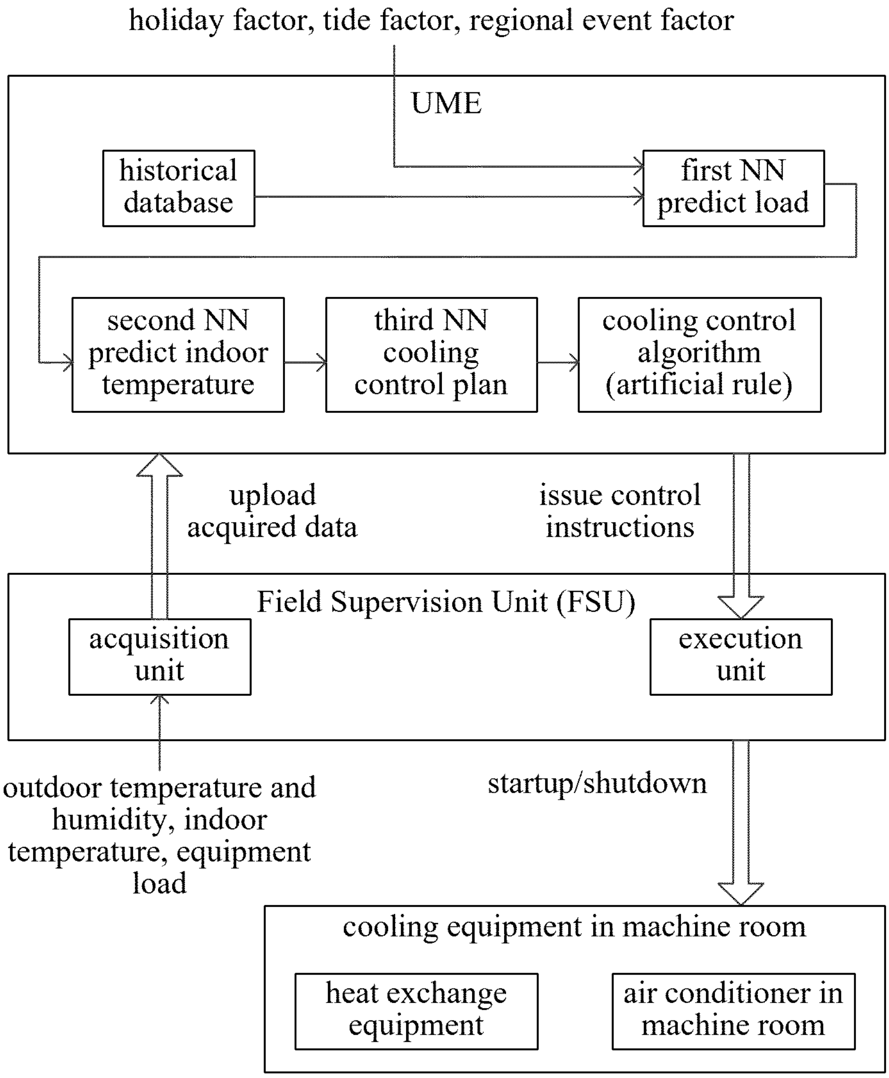
holiday factor, tide factor, regional event factor
UME
historical database
first NN predict load
second NN predict indoor temperature
third NN cooling control plan
cooling control algorithm (artificial rule)
upload acquired data
issue control instructions
Field Supervision Unit (FSU)
acquisition unit
execution unit
outdoor temperature and humidity, indoor temperature, equipment load
startup/shutdown
cooling equipment in machine room
heat exchange equipment
air conditioner in machine room

FIG. 1

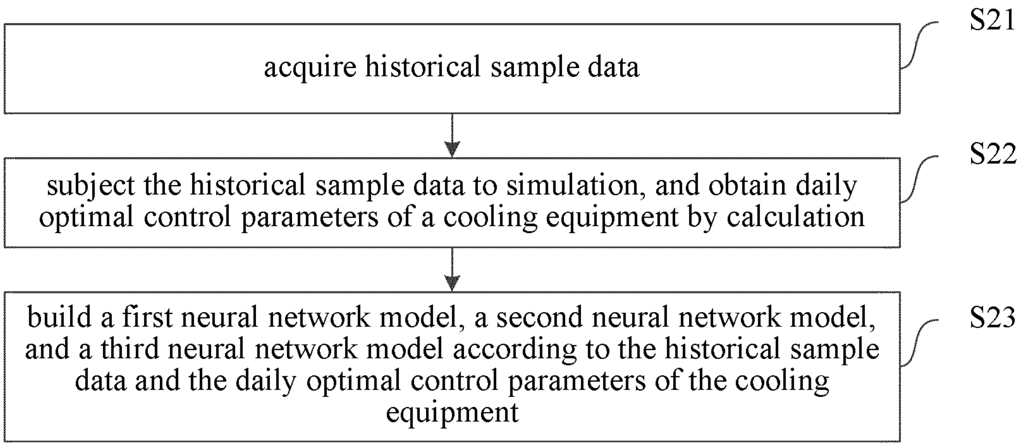

FIG. 2

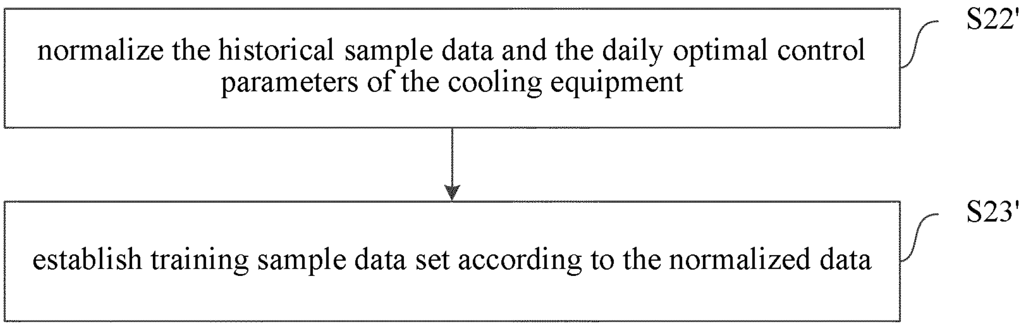

FIG. 3

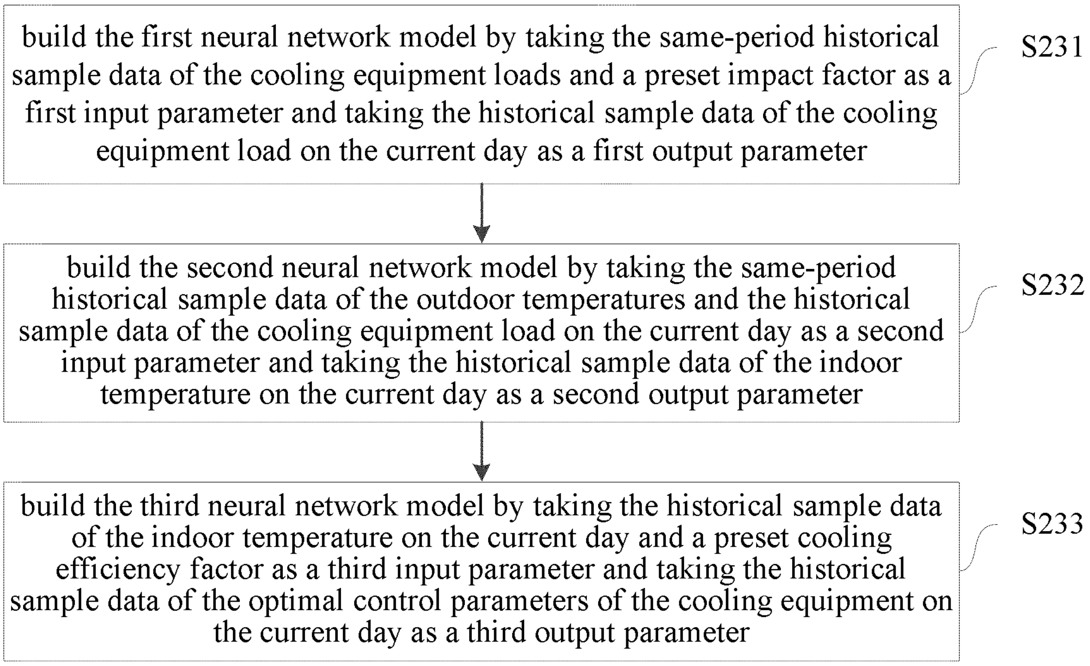

FIG. 4

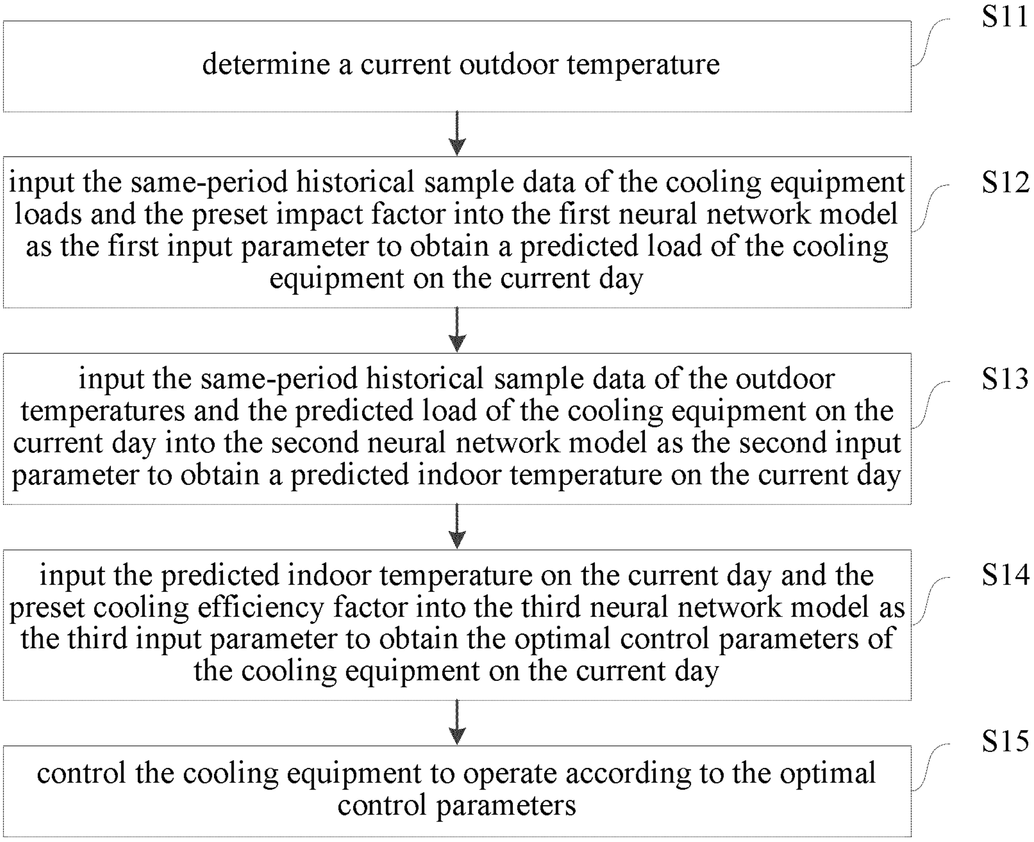

FIG. 5

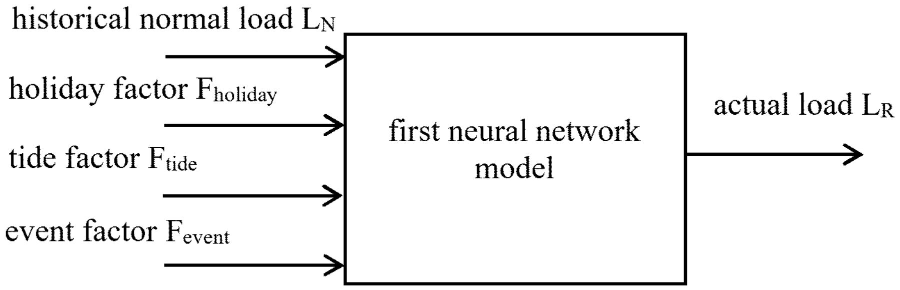

FIG. 6A

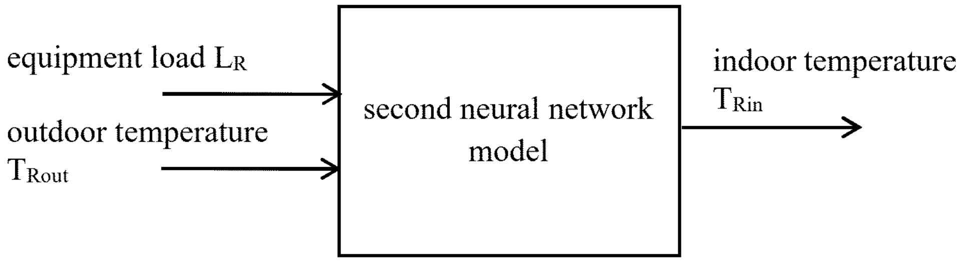

FIG. 6B

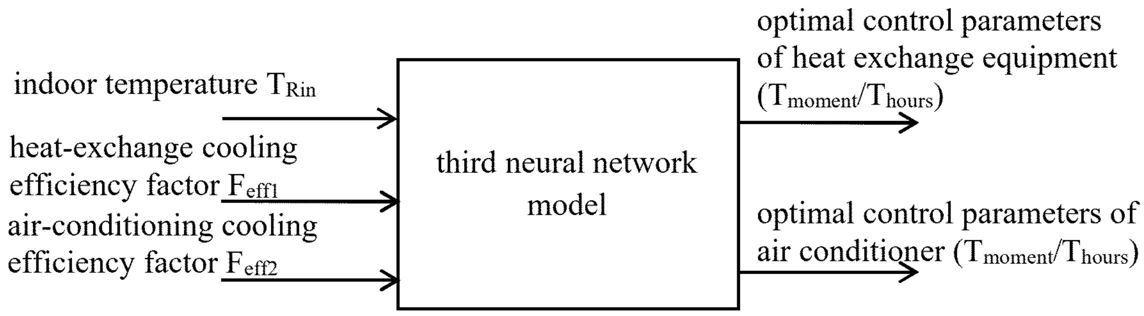
indoor temperature T_{Rin}
heat-exchange cooling efficiency factor F_{eff1}
air-conditioning cooling efficiency factor F_{eff2}
third neural network model
optimal control parameters of heat exchange equipment (T_{moment}/T_{hours})
optimal control parameters of air conditioner (T_{moment}/T_{hours})

FIG. 6C

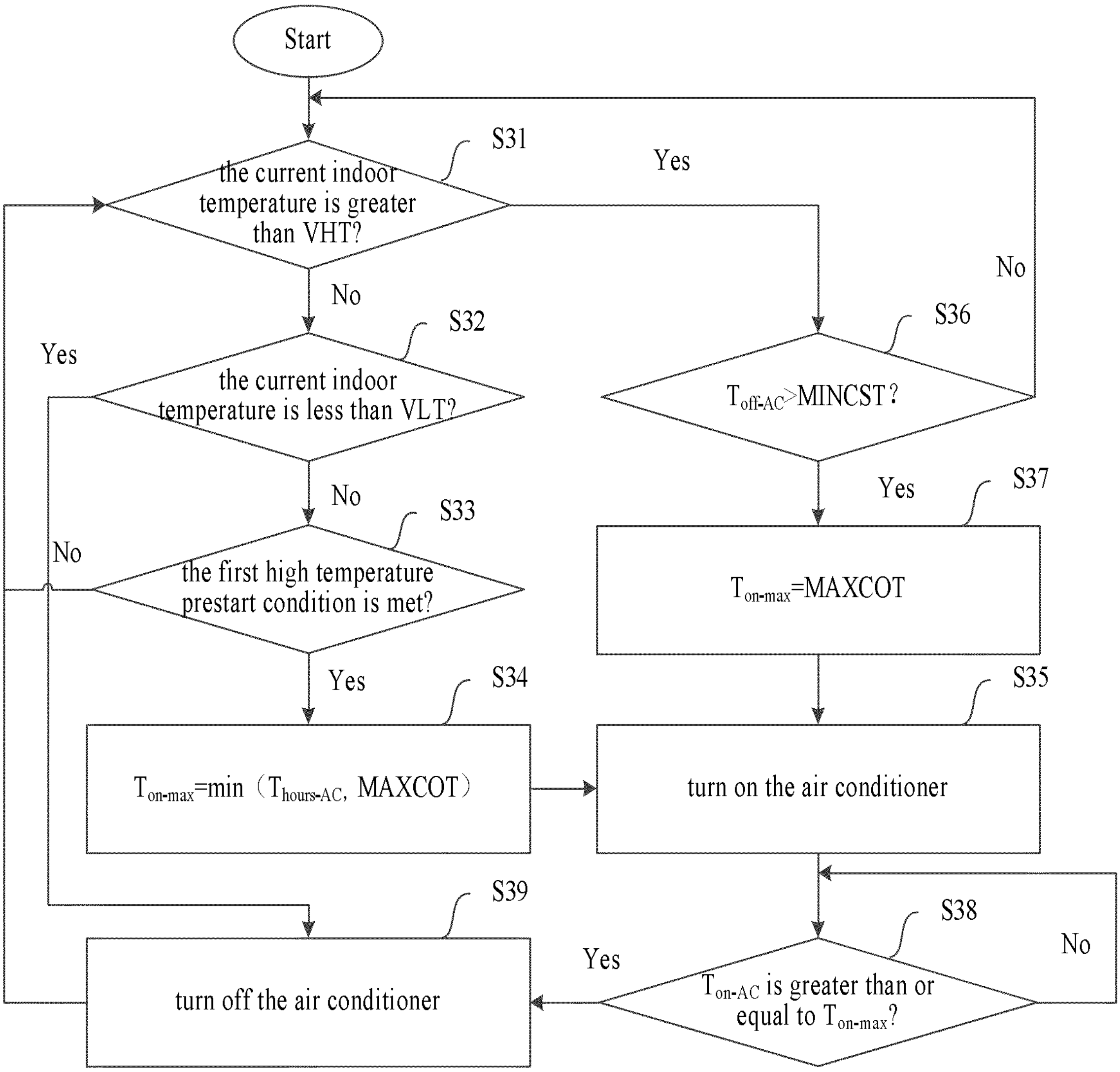
Start
S31
the current indoor temperature is greater than VHT?
Yes
No
S32
the current indoor temperature is less than VLT?
Yes
No
S33
the first high temperature prestart condition is met?
No
Yes
S34
T_{on-max}=min（$T_{hours-AC}$, MAXCOT）
S36
T_{off-AC}>MINCST?
No
Yes
S37
T_{on-max}=MAXCOT
S35
turn on the air conditioner
S38
T_{on-AC} is greater than or equal to T_{on-max}?
No
Yes
S39
turn off the air conditioner

FIG. 7

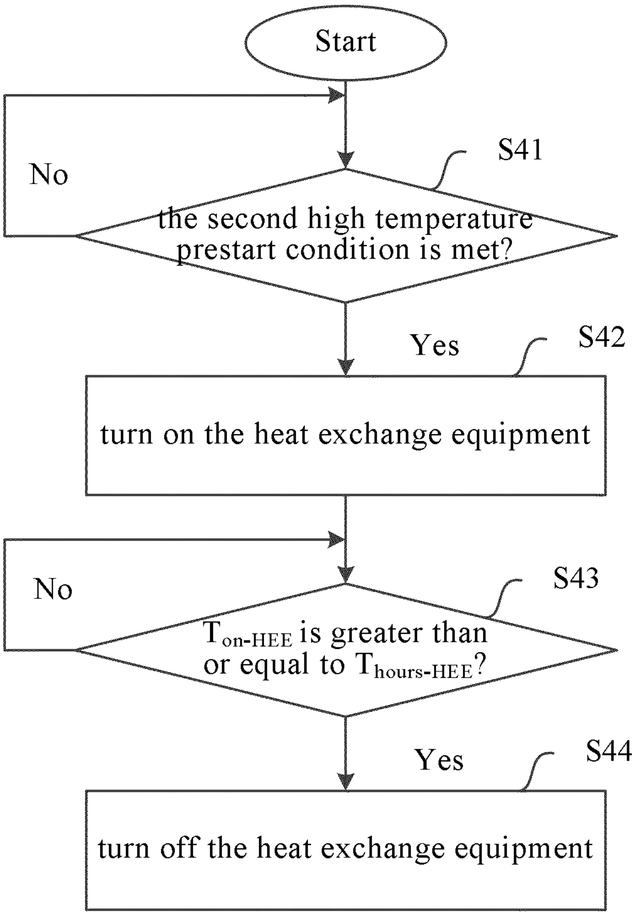
Start
S41
No
the second high temperature prestart condition is met?
Yes
S42
turn on the heat exchange equipment
S43
No
$T_{on\text{-}HEE}$ is greater than or equal to $T_{hours\text{-}HEE}$?
Yes
S44
turn off the heat exchange equipment

FIG. 8

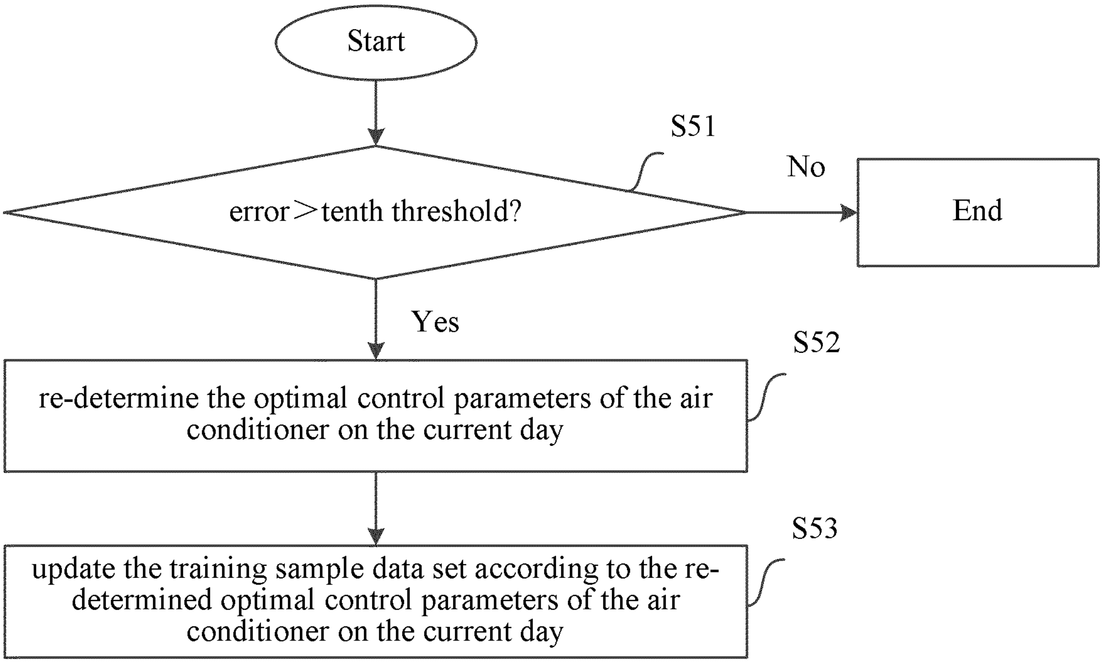
Start
S51
error>tenth threshold?
No
End
Yes
S52
re-determine the optimal control parameters of the air conditioner on the current day
S53
update the training sample data set according to the re-determined optimal control parameters of the air conditioner on the current day

FIG. 9

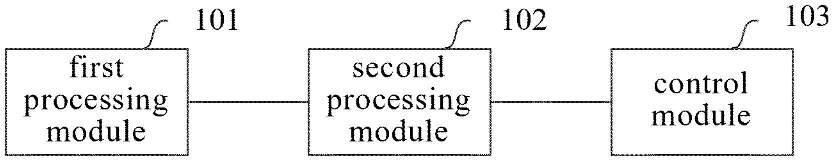
101
first processing module
102
second processing module
103
control module

FIG. 10

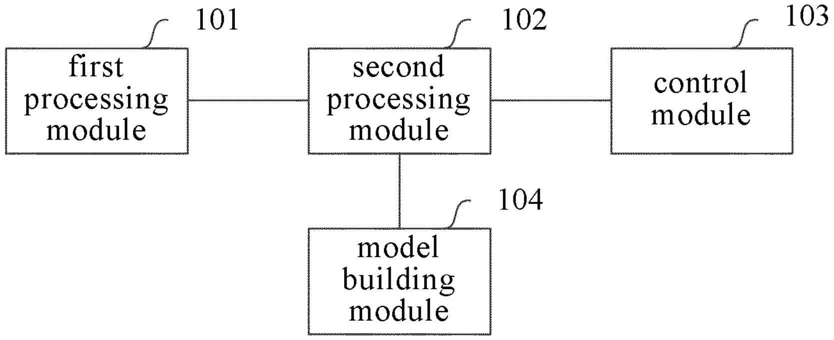
101
first processing module
102
second processing module
103
control module
104
model building module

FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/099313

A. CLASSIFICATION OF SUBJECT MATTER

F24F 11/64(2018.01)i； F24F 11/63(2018.01)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)

F24F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNKI, DWPI, VEN: 制冷, 负荷, 预测, 历史同期, 神经网络模型, 影响因子, 室外温度, 室内温度, 最优控制参数, refrigeration, load, forecast, historical synchronization, neural network model, influence factor, outdoor temperature, indoor temperature, optimal control parameters

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 109945420 A (NR ELECTRIC CO., LTD. et al.) 28 June 2019 (2019-06-28) description, paragraphs [0033]-[0156], and figures 1-8	1-19
A	CN 105928292 A (SHANDONG SANJIU REFRIGERATION EQUIPMENT CO., LTD.) 07 September 2016 (2016-09-07) entire document	1-19
A	CN 109130767 A (BEIJING JIAOTONG UNIVERSITY) 04 January 2019 (2019-01-04) entire document	1-19
A	CN 109871987 A (THE THIRD CONSTRUCTION CO., LTD. OF CHINA CONSTRUCTION EIGHTH ENGINEERING DIVISION) 11 June 2019 (2019-06-11) entire document	1-19
A	JP H08210689 A (HITACHI PLANT ENG & CONSTR CO) 20 August 1996 (1996-08-20) entire document	1-19
A	KR 2020052437 A (SKTE SK TELECOM CO LTD) 15 May 2020 (2020-05-15) entire document	1-19
A	WO 2009064111 A2 (IAC IN NAT UNIV CHUNGNAM et al.) 22 May 2009 (2009-05-22) entire document	1-19

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search **01 September 2021**	Date of mailing of the international search report **08 September 2021**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088** **China**	Authorized officer
Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/099313

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	109945420	A	28 June 2019	CN	109945420	B	17 November 2020
CN	105928292	A	07 September 2016	CN	105928292	B	22 May 2018
CN	109130767	A	04 January 2019	CN	109130767	B	11 August 2020
CN	109871987	A	11 June 2019		None		
JP	H08210689	A	20 August 1996		None		
KR	2020052437	A	15 May 2020		None		
WO	2009064111	A2	22 May 2009	US	2010256958	A1	07 October 2010
				KR	100830095	B1	20 May 2008
				WO	2009064111	A3	13 August 2009
				US	8457933	B2	04 June 2013

Form PCT/ISA/210 (patent family annex) (January 2015)