

ANOMALY DETECTION DEVICE AND ANOMALY DETECTION METHOD

[TECHNICAL FIELD]

[0001]

The present invention relates to a technique of an anomaly detection device and an anomaly detection method, each of which detects an indication of anomaly in a facility.

[BACKGROUND ART]

[0002]

An early detection of an indication of an operation anomaly in a facility is of importance in order to improve reliability of the facility set up in a plant or an office building and reduce downtime and running cost. An operating state of a facility is managed using monitoring data acquired by sensor, such as a temperature, a pressure, and a vibration, with an appropriate threshold set on the basis of a design value or an empirical value. For example, Patent Document 1 discloses a state monitoring system which: monitors a state of a mechanical element constituting a device; and includes a sensor that detects the state of the mechanical element and a processor that diagnoses an abnormality of the mechanical element. The processor: calculates a plurality of feature amounts from a detection signal of the sensor; extracts at least one feature amount of which temporal features are dependent from each other, as an effective feature amount, from the plurality of calculated feature amounts; and diagnoses an abnormality of the mechanical element on the basis of the extracted effective feature amount.

[RELATED ART DOCUMENT]

[PATENT DOCUMENT]

[0003]

[Patent Document 1] Japanese Laid-Open Patent Application, Publication No. 2020-153836

[SUMMARY OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0004]

The state monitoring system disclosed in Patent Document 1: sets a threshold based on an amount of statistics such as an average value or a standard deviation of a feature amount; and, when the feature amount exceeds the threshold, diagnoses an abnormality. Behaviors of a facility vary, however, depending on processing load or environment (for example, weather conditions). When the facility is managed using a threshold based on an amount of past statistics, as in Patent Document 1, it may be difficult in some cases to detect an indication of an operation anomaly in the facility at an early stage. In another technique of determining an anomaly, an estimation mode of an operating state is created for each of instruments constituting the facility, based on which an anomaly is diagnosed. The technique has, however, a problem that creation of the estimation model requires man-hours.

[0005]

In light of the aforementioned background, the present invention has been made in an attempt to provide an anomaly detection device and an anomaly detection method, each of which can efficiently extract an anomaly indication in a facility.

[MEANS FOR SOLVING THE PROBLEM]

[0006]

According to a first aspect, an anomaly detection device of the present invention includes: an anomaly indication index calculation part configured to calculate a statistical amount of a state amount of a facility, the state amount being a time series data; and calculate an anomaly indication index which shows a degree of anomaly of the state amount; and a correlation analysis part configured to calculate a correlation coefficient between the anomaly indication index and a variable factor candidate which becomes a variable factor of the anomaly indication index.

[0006a]

According to a second aspect, an anomaly detection method of an anomaly detection device of the present invention, comprises the steps, performed by the anomaly detection device, of: calculating a statistical amount of a state amount of a facility, the state amount being a time series data; and calculating an anomaly indication index which shows a degree of anomaly of the state amount; and calculating a correlation coefficient between the anomaly indication index and a variable factor candidate which becomes a variable factor of the anomaly indication index.

[ADVANTAGEOUS EFFECTS OF THE INVENTION]

[0007]

The present invention can provide an anomaly detection device and an anomaly detection method, each of which can efficiently extract an anomaly indication in a facility. Problems, structures, and aspects other than the described above will be apparent from the following description of the embodiments.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0008]

[FIG. 1] A diagram illustrating an entire structure of a heat source system which is a target to be monitored by an anomaly detection device according to an embodiment of the present invention.

[FIG. 2] A functional block diagram illustrating the anomaly detection device according to the embodiment.

[FIG. 3] A diagram illustrating a data structure of a state amount database according to the embodiment.

[FIG. 4] A diagram illustrating a data structure of a excluded period database according to the embodiment.

[FIG. 5] A diagram illustrating a data structure of a state amount attribute database according to the embodiment.

[FIG. 6] A diagram illustrating a data structure of an anomaly indication index database according to the embodiment.

[FIG. 7] A diagram illustrating a data structure of an anomaly indication summary database according to the embodiment.

[FIG. 8] A graph showing a cold load of a refrigerating machine according to the embodiment.

[FIG. 9] A graph showing: moving averages of cool water supply temperatures of the refrigerating machine; moving averages of cooling water return temperatures thereof; and moving averages of outside air temperatures thereof, according to the

embodiment.

[FIG. 10] A graph showing a power consumption of the refrigerating machine according to the embodiment.

[FIG. 11] A graph showing: power consumptions of a cool water pump; power consumptions of a cooling water pump; and power consumptions of a cooling tower, according to the embodiment.

[FIG. 12] A graph showing an anomaly indication index in a system of the refrigerating machine, according to the embodiment.

[FIG. 13] A graph showing an anomaly indication index in the system of the refrigerating machine, when the refrigerating machine is operating, according to the embodiment.

[FIG. 14] A graph showing an anomaly indication index in the system of the refrigerating machine, when the refrigerating machine is not operating, according to the embodiment.

[FIG. 15] A diagram illustrating a screen structure of an analysis result display screen according to the embodiment.

[FIG. 16] A flowchart illustrating an anomaly indication analysis processing according to the embodiment.

[FIG. 17] A diagram illustrating an entire structure of a heat source system according to a variation of the embodiment.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0009]

<<Anomaly detection device: Outline>>

An anomaly detection device is described hereinafter according to an embodiment for carrying out the present invention (which may be simply referred to as an embodiment). Based on a feature calculated from a state amount of a facility measured by a sensor installed in the facility, the anomaly detection device calculates an anomaly indication index that indicates a deviation from an average value, so as to

visualize an anomaly. The feature herein includes, for example, a moving average of a state amount and a moving standard deviation thereof. The anomaly detection device calculates and visualizes a correlation coefficient between the anomaly indication index and a variable factor. The variable factor (a variable factor candidate) herein includes, for example, a time, an outside air temperature, and a cold load.

[0010]

By referring to such an anomaly indication index, a controller (an operator) of a facility can detect an indication of an anomaly in the facility. By referring to a degree of correlation between the anomaly and a variable factor such as a change over time or season, or a change of load, the controller can see how the anomaly is relevant to the change and obtain a clue to figure out what causes the anomaly. The controller can thus recognize a possible cause of why the anomaly has occurred, taking into account the change over time or season, or change of load.

[0011]

<<Entire configuration of heat source system>>

FIG. 1 is a diagram illustrating an entire structure of a heat source system 200 which is a target to be monitored by an anomaly detection device 100 (see FIG. 2 to be described hereinafter) according to this embodiment. The heat source system 200 includes: a cooling tower 211 and a refrigerating machine 221 in the first system; a cooling tower 212 and a refrigerating machine 222 in the second system; and a cooling tower 213 and a refrigerating machine 223 in the third system. The heat source system 200: supplies cool water to the cold load 233 (an outdoor air handling unit, a fan coil unit, or the like) via piping and the cool water supply header 232; and cools cool water returned via the piping and the cool water return header 231. The three system are not necessarily operated all together. When, for example, a load is small because only a small number of outdoor air handling units or fan coil units are operating, only one of the systems is operated.

[0012]

The heat source system 200 has various sensors for measuring such as, for example, a temperature and a flow rate of cool water, and power consumptions of the cooling towers 211 212, 213 and the refrigerating machines 221, 222, 223, so as to monitor operating conditions. In FIG. 1, a circled T represents a temperature sensor; a circled F, a flow rate sensor; and, a circled W, a power sensor. A circled triangle or a circled upside-down triangle represents a pump and each pump has a power sensor. The sensor transmits a measurement result at a prescribed timing, for example, at regular intervals, to the anomaly detection device 100.

[0013]

<<Anomaly detection device: Entire configuration>>

FIG. 2 is a functional block diagram illustrating the anomaly detection device 100 according to the embodiment. The anomaly detection device 100: is a computer; and includes a controller 110, a storage part 120, and an input and output part 190. The input and output part 190 is connected to a user interface device such as a display, a keyboard, and a mouse. The input and output part 190: is equipped with a communication device; and can transmit and receive data to and from other device including a sensor installed in the heat source system 200. The input and output part 190 may be connected to a media drive, by which data can be exchanged using a recording medium.

[0014]

<<Anomaly detection device: Storage part>>

The storage part 120 is configured to include a storage device such as a ROM (Read Only Memory), a RAM (Random Access Memory), and a SSD (Solid State Drive). The storage part 120 stores therein a state amount database 130, an excluded period database 140, a state amount attribute database 150, an anomaly indication index database 160, an anomaly indication index upper limit database 121, an anomaly indication summary database 170, and a program 128. The program 128 contains description of an anomaly indication analysis processing to be described

hereinafter with reference to FIG. 16.

[0015]

FIG. 3 is a diagram illustrating a data structure of the state amount database 130 according to the embodiment. The state amount database 130 stores therein: a measurement value measured by a sensor, as a state amount (a monitoring data) of the heat source system 200; and a date and time of the measurement (a date and a time when the measurement value is acquired). Some examples of the measurement value include a power consumption, a cool water return temperature, a cool water supply temperature, a cooling water return temperature, a cooling water supply temperature, a flow rate of cool water, a flow rate of cooling water, a cold load, and a COP (a coefficient of performance, an energy consumption efficiency), of each of the main refrigerating machines 221, 222, 223. Other examples of the measurement value include a power and a frequency of each of a cool water pump, a cooling water pump, and the cooling towers 211, 212, 213, each as an auxiliary machine. The measurement value is a time series data having, for example, a one-hour cycle. The state amount database 130 also stores therein an outside air temperature as a variable factor, though the temperature is not a measurement value of the heat source system 200.

[0016]

FIG. 4 is a diagram illustrating a data structure of the excluded period database 140 according to the embodiment. The excluded period database 140 stores therein, with respect to a period which is excluded from calculation of an anomaly indication index (an excluded period), a reason for exclusion, a start date and time, and an end date and time, together with identification information of the excluded period (described as "ID" in FIG. 4). The reason for exclusion includes, for example, a transitional behavior of a facility which is different from that during normal operation, such as a boot sequence, an abort sequence, a maintenance thereof.

[0017]

FIG. 5 is a diagram illustrating a data structure of the state amount attribute database 150 according to the embodiment. The state amount attribute database 150 stores therein, as information on a state amount (a monitoring data) of the heat source system 200, a name, a category of a facility, a system No., a category of machinery, a type of machinery, a type of a physical amount, and a correlation calculation, in association with each other.

The name includes, for example, “refrigerating machine 1: power consumption” and “refrigerating machine 1: cool water supply temperature”.

The category of a facility includes, for example, “heat source system” and “air conditioning system”.

[0018]

The category of machinery includes, for example, “main machine” and “auxiliary machine”.

The type of machinery includes, for example, “refrigerating machine”, “cool water pump”, and “cooling water pump”.

The type of a physical amount includes, for example, “power”, “heat quantity”, “temperature”, and “flow rate”.

The correlation calculation is either “Y” or “N” which specifies whether a correlation coefficient between an anomaly indication index and a time, an outside air temperature, or a cold load, each as a variable factor, is to be calculated or not, respectively.

[0019]

FIG. 6 is a diagram illustrating a data structure of the anomaly indication index database 160 according to the embodiment. The anomaly indication index database 160 stores therein an anomaly indication index as a result calculated from data stored in the state amount database 130 (see FIG. 3). The anomaly indication index database 160 has a data structure same as that of the state amount database 130.

The anomaly indication index upper limit database 121 stores therein an upper

limit used as a reference value for determining whether or not an anomaly indication index is abnormal, in association with respective items of the anomaly indication index.

[0020]

FIG. 7 is a diagram illustrating a data structure of the anomaly indication summary database 170 according to the embodiment. The anomaly indication summary database 170 stores therein information on an anomaly indication index which has been stored in the anomaly indication index database 160 and exceeds an upper limit stored in the anomaly indication index upper limit database 121. More specifically, the anomaly indication summary database 170 stores therein a name, a category of facility, a system No., a category of machinery, a type of the machinery, a type of a physical quantity, the number of records of anomaly indication indexes, the number of records exceeding the upper limit, a maximum value of the anomaly indication index, an average value thereof, and a correlation coefficient between an anomaly indication index and a variable factor (a time, a cold load, or an outside air temperature).

[0021]

<<Anomaly detection device: Controller>>

Referring back to FIG. 2, explanation of the structure of the controller 110 of the anomaly detection device 100 is continued. The controller 110 is configured by a CPU (Central Processing Unit) and includes a state amount acquisition part 111, a specified period exclusion part 112, an operation state determination part 113, a feature calculation part 114, an anomaly indication index calculation part 115, a correlation analysis part 116, and an analysis result display part 117.

The state amount acquisition part 111: acquires a measurement result (a monitoring data or a state amount) of a temperature, a flow rate, or a power consumption from a sensor installed in the heat source system 200 (see FIG. 1); and stores the acquired measurement result in the state amount database 130. The state amount acquisition part 111 acquires the measurement result at a prescribed timing,

for example, on a one-hour cycle.

[0022]

In analyzing a state amount in the state amount database 130, the specified period exclusion part 112 excludes a state amount in a period stored in the excluded period database 140.

The operation state determination part 113 divides a state amount in a period not excluded by the specified period exclusion part 112, into an operating period and a non-operating period. More specifically, the operation state determination part 113: references the state amount attribute database 150 (see FIG. 5); and determines an operating state based on a power consumption of each of the refrigerating machines 221, 222, 223, which are the main machines of the respective systems. For example, when a power consumption of the refrigerating machine of interest has a value equal to or larger than a prescribed value, the operation state determination part 113 determines that the refrigerating machine is in operating state. When the power consumption of the refrigerating machine of interest has a value smaller than the prescribed value, the operation state determination part 113 determines that the refrigerating machine is in non-operating state. The prescribed value is set for each of the refrigerating machines 221, 222, 223. The operation state determination part 113 determines an operating state of an auxiliary machine (a cool water pump, a cooling water pump, or a cooling tower) which corresponds to a main machine for each of the systems and works with an operating state of the main machine. A facility exhibits different behaviors according to different operating states. Analysis of a state amount for each of the operating states thus makes it possible to detect an anomaly indication with high accuracy.

[0023]

The feature calculation part 114 calculates a feature based on a state amount (a monitoring data). The feature herein includes: a state amount itself as a time series data; a moving average of state amounts during a prescribed period (for

example, for one day); and a moving standard deviation thereof. The moving standard deviation herein: means a standard deviation of moving averages of state amounts during a second prescribed period; and shows dispersion of the moving averages during the second prescribed period.

[0024]

The anomaly indication index calculation part 115: calculates an anomaly indication index; and stores the calculated result in the anomaly indication index database 160 (see FIG. 6). More specifically, the anomaly indication index calculation part 115 calculates an average value μ of features calculated by the feature calculation part 114 and a standard deviation σ thereof, for each of data items (items of a state amount), to thereby obtain $((\text{feature}-\mu)/\sigma)^2$ as an anomaly indication index. The average value μ herein is an average over a learning period as well as all of the systems (in the heat source system 200, three systems in total). Note that the anomaly indication index calculation part 115 may calculate an anomaly indication index for each of data items or operating states.

[0025]

The learning period herein is a period during which the average value μ is calculated. The average value μ is a reference value used in calculating an anomaly indication index. The learning period herein is, for example, a period during which a state amount is accumulated in the state amount database 130, and a period of one year, two years, and the like. The analysis target period: is a period after the learning period during which an anomaly indication index is calculated and the heat source system 200 is monitored. A default analysis target period is a period after the learning period. An excluded period is not included in the learning period or the analysis target period contains .

[0026]

The anomaly indication index calculation part 115 extracts an item of an anomaly indication index (an item of state amounts, a data item) that contains an

anomaly indication index having a value equal to or larger than an upper limit stored in the anomaly indication index upper limit database 121; and stores the extracted item in the anomaly indication summary database 170 (see FIG. 7). More specifically, the anomaly indication index calculation part 115 stores a name, a system No., or the like, of the item of a state amount from which the anomaly indication index of interest is calculated, in a column of “state amount attribute” of the anomaly indication summary database 170. The anomaly indication index calculation part 115 also stores the number of records (the number of data) in an analysis target period, the number of records having a value exceeding the upper limit, the maximum value of the anomaly indication index, and an average value thereof, in a column of “anomaly indication index”. The state amount and the anomaly indication index are described next with reference to FIG. 8 to FIG. 14.

[0027]

FIG. 8 is a graph 310 illustrating a cold load of the refrigerating machine 221 according to the embodiment (see “heat load” of “refrigerating machine 1” illustrated in FIG. 3). The graph 310 presents data for three days, showing that the refrigerating machine 221 is stopped at night (from 21:00 to 7:00 on the following day), during which a cold load thereof is almost zero. Note that the graphs 310, 320, 330, 340, illustrated in FIG. 8 to FIG. 11, respectively, concerning a cold load, a temperature, or a power are each a graph with respect to a moving average. Description may be hereinafter made without explicitly referring to the moving average. For example, “outside air temperature” herein means a moving average of outside air temperatures.

[0028]

FIG. 9 is a graph 320 showing: moving averages of cool water supply temperatures of the refrigerating machine 221 (plotted with ●); moving averages of cooling water return temperatures (plotted with ○); and moving averages of outside air temperatures (plotted with ▲), according to the embodiment. Though not a state amount of the facility, the outside air temperature is shown for purpose of reference. It

is demonstrated that during night time, the cool water supply temperature and the cooling water return temperature approach the outside air temperature (change along with that of the outside air temperature). The cool water supply temperature during daytime is almost constant as set in advance. Meanwhile, the cooling water return temperatures during early afternoon (from about 12:00 to about 15:00) are high, which is considered to be affected by the outside air temperature.

[0029]

FIG. 10 is a graph 330 showing power consumptions of the refrigerating machine 221 according to the embodiment. Similarly to the graph 310 (see FIG. 8), the refrigerating machine 221 is stopped at night (from 21:00 to 7:00 on the following day), during which the power consumptions are almost zero.

[0030]

FIG. 11 is a graph 340 showing: power consumptions (plotted with ●) of a cool water pump; power consumptions (plotted with ○) of a cooling water pump; and power consumptions (plotted with ▲) of a cooling tower 211, according to the embodiment. The power consumptions at night are low with a partial exception (that is, the power consumption of cool water pump from 21:00 to 24:00 on day 3 (plotted with ●)). It is thus demonstrated that the cool water pump, the cooling water pump, and the cooling tower are not operated at night time.

[0031]

FIG. 12 is a graph 350 showing an anomaly indication index in the system of the refrigerating machine 221 according to the embodiment. The anomaly indication index in the system of the refrigerating machine 221 herein is the maximum value of an anomaly indication index having, as a feature, a moving average for each of: cooling water supply temperatures of the refrigerating machine 221; cooling water return temperatures of the refrigerating machine 221; power consumptions of the refrigerating machine 221; power consumptions of a cool water pump of the refrigerating machine 221; power consumptions of a cooling water pump of the

refrigerating machine 221; and power consumptions of a cooling tower of the refrigerating machine 221. When the system of the refrigerating machine 221 has another state amount, the anomaly indication index in the system of the refrigerating machine 221 may include the maximum value of an anomaly indication index having, as a feature, a moving average of another state amount.

[0032]

An anomaly indication index in an area 351 encircled by a dotted line has a high value. The value is not, however, abnormal, because the value is taken immediately after a maintenance checkup. In order to exclude such a high-but-not-abnormal anomaly indication index, the specified period exclusion part 112 excludes a state amount during a period stored in and specified by the excluded period database 140 (see FIG. 4), from a target to be analyzed.

[0033]

FIG. 13 is a graph 360 showing an anomaly indication index in the system of the refrigerating machine 221, when the refrigerating machine 221 is operating, according to the embodiment. Anomaly indication indexes in an area 361 encircled by a dotted line have high values. It is demonstrated that the cool water supply temperatures (● in the graph 320 (see FIG. 9)) of the refrigerating machine 221 have increased during the same period of time. There is thus a possibility that charge air temperatures in an air conditioning system increased.

[0034]

FIG. 14 is a graph 370 showing an anomaly indication index in the system of the refrigerating machine 221, when the refrigerating machine 221 is not operating, according to the embodiment. Anomaly indication indexes in an area 371 encircled by a dotted line have high values. It is demonstrated that the power consumptions of the cool water pump (● in the graph 340 (see FIG. 11)) have increased during the same period of time. It is demonstrated that the cool water pump have been operated, though, normally, not operating at night. There is thus a possibility of a loss of power.

Calculation of an anomaly indication index as described above makes it possible to recognize a possible anomaly in the heat source system 200, which may be difficult to detect using a feature alone (the graphs 310, 320, 330, and 340 illustrated in FIG. 8 to FIG. 11, respectively).

[0035]

Referring back to FIG. 2, explanation of the controller 110 is continued. The correlation analysis part 116 calculates a correlation coefficient between an anomaly indication index and a variable factor (such as a time, an outside air temperature, and a cold load) of a state amount (a data item) having “Y” of “correlation calculation” in the state amount attribute database 150 (see FIG. 5).

Calculation of a correlation coefficient (for example, a Pearson's product-moment correlation coefficient) between an anomaly indication index and a time makes it possible to obtain how an item of the state amount tends to change (on the increase/no change/on the decrease). Calculation of a correlation coefficient between an anomaly indication index and an outside air temperature makes it possible to obtain a relationship between an item of the state amount and a seasonality or a temperature. Calculation of a correlation coefficient between an anomaly indication index and a cold load makes it possible to obtain an interrelation between an amount of a state amount and the load. Thus, a controller of the system looks at a degree of correlation between the anomaly indication index and a variable factor, to thereby recognize how the state amount is correlated with a change in a time, a season, and a load and obtain a clue to figure out what causes an anomaly of interest.

[0036]

The analysis result display part 117 displays an analysis result display screen 400 (see FIG. 15 to be described hereinafter) in a display connected to the input and output part 190. FIG. 15 is a diagram illustrating a screen structure of the analysis result display screen 400 according to the embodiment.

A maximum anomaly indication index display area 410 displays, in a graphic

form, maximum values of anomaly indication indexes during an analysis result display period included in an analysis target period. A default analysis result display period is, for example, three months. A hatched period in the area shows a period during which each of the maximum values of the anomaly indication indexes exceeds a prescribed threshold.

[0037]

An analysis result display area 420 displays an analysis result display period. The analysis result display period can be appropriately edited. When the analysis result display period is edited and “Enter” button is then pressed down, respective updated graphs are displayed in the maximum maximum anomaly indication index display area 410 and an anomaly indication index display area 450 to be described later.

[0038]

A period length change specify area 430 has buttons to change a length of the analysis result display period. For example, when “-1 day” button is pressed down, the analysis result display period is reduced by one day. A start date change specify area 440 has buttons to change a start date of the analysis result display period. For example, when “previously day” button is pressed down, the start date of the analysis result display period is set to one day before the original date.

[0039]

The anomaly indication index display area 450 displays graphs of: an anomaly indication index of each of data items during the analysis result display period; and an original data thereof (a state amount as it is or a moving average of the state amount). FIG. 15 displays an anomaly indication index of each of “refrigerating machine 1: power consumption” and “refrigerating machine 1: cold load”, as well as respective original data thereof.

A hatched period in the graph of “refrigerating machine 1: power consumption” is the same as the hatched period in the graph of the maximum anomaly indication

indexes. This means that each of anomaly indication indexes of “refrigerating machine 1: power consumption” during the hatched period exceeds a prescribed threshold of the maximum value of the anomaly indication index.

[0040]

In response to a press down of “Anomaly indication summary” button 481, the anomaly indication summary database 170 (see FIG. 7) is displayed. In response to a press down of “Excluded period setting” button 482, , contents of the excluded period database 140 (see FIG. 4) are displayed. When the contents are edited, the excluded period database 140 is updated.

[0041]

<<Anomaly indication analysis processing>>

FIG. 16 is a flowchart illustrating an anomaly indication analysis processing according to the embodiment.

In step S11, the feature calculation part 114 calculates a feature of each of state amounts during a preset learning period. The anomaly indication index calculation part 115 calculates an average value μ and a standard deviation σ of the calculated feature.

In step S12, the anomaly indication index calculation part 115 sets an analysis target period to a prescribed period. The prescribed period is a period after the learning period.

[0042]

In step S13, the feature calculation part 114 calculates a feature during the analysis target period.

In step S14, the anomaly indication index calculation part 115: calculates an anomaly indication index, based on the feature calculated in step S13; and stores the calculated result in the anomaly indication index database 160. The anomaly indication index calculation part 115 stores a state amount attribute, the number of records, or any other item, of the anomaly indication index exceeding an upper limit

stored in the anomaly indication index upper limit database 121, in the anomaly indication summary database 170.

[0043]

In step S15, the correlation analysis part 116 calculates a correlation coefficient between the anomaly indication index and a variable factor of interest during the analysis target period. The correlation analysis part 116 stores the calculated correlation coefficient in the anomaly indication summary database 170.

In step S16, the analysis result display part 117 displays the analysis result display screen 400 (see FIG. 15).

In step S17, the analysis result display part 117 advances the processing in response to a press down of any of the buttons on the analysis result display screen 400. In response to a press down of a button for changing the analysis result display period, placed in the period length change specify area 430 or in a start date change specify area 440 (step S17→Change), the analysis result display part 117 advances the processing to step S18.

[0044]

In response to a press down of “Enter” placed in the analysis result display area 420 (step S17→Enter), the analysis result display part 117 advances the processing to step S19.

In response to a press down of “Excluded period setting” button 482 (step S17→Excluded period setting), the analysis result display part 117 advances the processing to step S20.

In response to a press down of “Anomaly indication summary” button 481 (step S17→Anomaly indication summary), the analysis result display part 117 advances the processing to step S21.

In response to a press down of “End” button 483 (step S17→End), the analysis result display part 117 terminates the anomaly indication analysis processing.

[0045]

In step S18, the analysis result display part 117: displays a graph during the analysis result display period in response to the button pressed down in step S17; and returns the processing to step S17. More specifically, the analysis result display part 117 displays: a graph showing a maximum value of an anomaly indication index during the analysis result display period, in the maximum anomaly indication index display area 410; and a graph showing an anomaly indication index of each data item and an original data thereof during the analysis result display period, in the anomaly indication index display area 450. For example, in response to a press down of “+1 day” button placed in the period length change specify area 430, the analysis result display part 117 displays an analysis result display period extended by one day.

[0046]

In step S19, the analysis result display part 117 displays a graph showing a maximum value of an anomaly indication index, an anomaly indication index of each data item, and an original data thereof, during the analysis result display period after the editing; and returns the processing to step S17.

In step S20, the analysis result display part 117: displays contents of the excluded period database 140; allows an input of a change in the excluded period; and reflects the change in the excluded period database 140. The analysis result display part 117 then returns the processing to step S11.

In step S21, the analysis result display part 117 displays contents of the anomaly indication summary database 170; and returns the processing to step S17.

[0047]

In FIG. 16, after the anomaly indication index is calculated, the analysis result display part 117 displays a graph having a specified display period. When, for example, a new state amount is obtained, an anomaly indication index of the state amount may be calculated and reflected in the graph.

In FIG. 16, each time the anomaly indication analysis processing is performed, an average value, a standard deviation, and an anomaly indication index of a feature

are calculated. Instead, the analysis result display part 117 may: store therein those calculated results; and display an appropriate graph, using the stored calculated results, unless a learning period or an excluded period is changed.

[0048]

<<Characteristics of anomaly detection device>>

The anomaly detection device 100: calculates an anomaly indication index that indicates a deviation from an average value, based on a feature of a state amount of the heat source system 200 measured by a sensor installed in the heat source system 200; and displays the analysis result display screen 400. The anomaly detection device calculates and visualizes a correlation coefficient between the anomaly indication index and a variable factor. The variable factor herein includes, for example, a time, an outside air temperature, and a cold load.

[0049]

By referring to such an anomaly indication index, a controller (an operator) of a facility can detect an anomaly indication in the facility. By referring to a degree of correlation (a correlation coefficient) between the anomaly indication index and the variable factor such as a change over time or season, or change of load, the controller can see how the anomaly indication index is relevant to the change and obtain a clue to figure out what causes an anomaly of interest. The controller can thus recognize a possible cause of why the anomaly has occurred, taking into account the change over time or season, or change of load.

[0050]

<<Variation: Anomaly indication index>>

In the above-described embodiment, the anomaly indication index is calculated for each of items of a state amount (see the anomaly indication index database 160 illustrated in FIG. 6). Herein, the maximum value of an anomaly indication index of a data item of, for example, the refrigerating machine 221 as an facility (or an instrument constituting the facility) may be taken as an anomaly indication index of

the refrigerating machine 221 (see the graphs 350, 360, and 370 illustrated in FIG. 12 to FIG. 14, respectively).

[0051]

In the above-described embodiment, the anomaly indication index is calculated based on an average value μ and a standard deviation σ of a feature of a state amount during a learning period. The anomaly indication index may be, however, calculated using another technique. For example, features of a state amount are subjected to a cluster analysis, based on which an anomaly indication index may be calculated. For example, the anomaly indication index calculation part 115 may: create clusters from data during a learning period; calculates a distance of a cluster closest to the data during an analysis target period; and determines the calculated distance as an anomaly indication index. Alternatively, the anomaly indication index calculation part 115 may: perform clustering using the k-means in which a plurality of data items are standardized and an Euclidean distance is calculated; and determines an anomaly by means of the k-nearest neighbor algorithm.

[0052]

<<Variation: Operating mode>>

An average value μ and a standard deviation σ may be calculated during a learning period, and an operating mode may be provided in calculating an anomaly indication index. The operating mode herein is a combination of operating/non-operating of the refrigerating machines 221, 222, 223. Some examples of the operating mode include: an operating mode in which the refrigerating machine 221 is operating and the refrigerating machines 222, 223 are non-operating; and another operating mode in which all of the refrigerating machines 221, 222, 223 are operating. The anomaly indication index calculation part 115 calculates an average value μ or a standard deviation σ for each of the operating modes. In calculating an anomaly indication index, the anomaly indication index calculation part 115 may use an average value μ or a standard deviation σ in accordance with the operating mode.

In the heat source system 200 according to the above-described embodiment, the refrigerating machines 221, 222, 223 are connected through cooling water piping to the cooling towers 211, 212, 213, respectively, on a one-to-one basis. Alternatively, all of the refrigerating machines may be connected through cooling water piping to all of the cooling towers.

[0053]

FIG. 17 is a diagram illustrating an entire structure of a heat source system 200A according to a variation of the embodiment. Refrigerating machines 221, 222, 223, are connected through cooling water piping to cooling towers 211, 212, 213, respectively, via a cooling water return header 241 and a cooling water supply header 242. In the heat source system 200A as described above, the cooling water piping (a cooling water system) is shared by a plurality of the refrigerating machines and a plurality of the cooling towers. This means that an operating status of an entire heat source facility cannot be known just by an operating state of only one of the refrigerating machines. Thus, respective operating states (operating modes) of all the refrigerating machines 221, 222, 223 are taken into account, based on which an anomaly indication index can be calculated with an increased accuracy.

[0054]

<<Other variations>>

The present invention has been described above with reference to some embodiments. Those embodiments are given by way of illustration and are not intended as an undue limitation on the technical scope of the present invention. In the above-described embodiments, for example, the anomaly detection device 100 stores various databases in the storage part 120. The anomaly detection device 100 may, however, access a database in another device such as a storage in a cloud.

The present invention can be realized by other various embodiments. Various changes such as deletion and substitution are possible within a scope not departing from the gist of the present invention. Those embodiments and their variations are

included in the scope and the gist of the present invention described in this specification, claims, and their equivalents.

DESCRIPTION OF REFERENCE NUMERALS

[0055]

- 100 anomaly detection device
- 111 state amount acquisition part
- 112 specified period exclusion part
- 113 operation state determination part
- 115 anomaly indication index calculation part
- 116 correlation analysis part
- 117 analysis result display part
- 130 state amount database
- 140 excluded period database
- 150 state amount attribute database
- 160 anomaly indication index database
- 121 anomaly indication index upper limit database
- 170 anomaly indication summary database
- 200, 200 A heat source system

Claims

[Claim 1]

An anomaly detection device, comprising:

an anomaly indication index calculation part configured to calculate a statistical amount of a state amount of a facility, the state amount being a time series data; and calculate an anomaly indication index which shows a degree of anomaly of the state amount; and

a correlation analysis part configured to calculate a correlation coefficient between the anomaly indication index and a variable factor candidate which becomes a variable factor of the anomaly indication index.

[Claim 2]

The anomaly detection device according to claim 1,

wherein the anomaly indication index calculation part is configured to calculate the anomaly indication index, based on a ratio between a deviation of an average value of features of the state amount and a standard deviation of the features, and

wherein the feature is selected from the group consisting of the state amount as it is, a moving average of the state amount, and a moving standard deviation of the state amount.

[Claim 3]

The anomaly detection device according to claim 1,

wherein the anomaly indication index calculation part is configured to: divide the features of the state amount into clusters; and calculate the anomaly indication index based on the clusters, and

wherein the feature is selected from the group consisting of the state amount as it is, a moving average of the state amounts, and a moving standard deviation of the state amounts.

[Claim 4]

The anomaly detection device according to claim 1,

wherein the anomaly indication index calculation part is configured to calculate the maximum value of anomaly indication indexes of a state amount with respect to a machine constituting the facility and determine the calculated maximum value as an anomaly indication index of the machine.

[Claim 5]

The anomaly detection device according to claim 1,
wherein the facility is a heat source system, and
wherein the variable factor candidate is selected from the group consisting of a time, an outside air temperature, and a cold load.

[Claim 6]

The anomaly detection device according to claim 1,
wherein the facility is a heat source system having a plurality of systems, and
wherein the anomaly indication index calculation part is configured to calculate an anomaly indication index for each of combinations of respective operating states of a plurality of the systems.

[Claim 7]

The anomaly detection device according to claim 1,
wherein the facility is a heat source system, and
wherein the state amount includes at least one selected from the group consisting of: a power consumption, a cool water return temperature, a cool water supply temperature, a cooling water return temperature, a cooling water supply temperature, a flow rate of cool water, a flow rate of cooling water, a cold load, and an energy consumption efficiency, of a refrigerating machine as a main machine of the heat source system; a power and a frequency of a cool water pump as an auxiliary machine; a power and a frequency of a cooling water pump as another auxiliary machine; and a power and a frequency of a cooling tower as a still another auxiliary machine.

[Claim 8]

The anomaly detection device according to claim 1,
further comprising an analysis result display part configured to display an anomaly indication index which has the maximum value at each time, from among the anomaly indication indexes.

[Claim 9]

An anomaly detection method of an anomaly detection device, comprising the steps, performed by the anomaly detection device, of:

calculating a statistical amount of a state amount of a facility, the state amount being a time series data; and calculating an anomaly indication index which shows a degree of anomaly of the state amount; and

calculating a correlation coefficient between the anomaly indication index and a variable factor candidate which becomes a variable factor of the anomaly indication index.