

DESCRIPTION

Title of Invention

OPERATION DIAGNOSTIC METHOD OF CIRCULATING FLUIDIZED BED

5 BOILER, AND OPERATION DIAGNOSTIC DEVICE

Technical Field

[0001]

The present invention relates to an operation diagnostic method and an operation
10 diagnostic device of a circulating fluidized bed boiler.

Background Art

[0002]

In the related art, a steam pressure control device of a circulating fluidized bed
boiler described in PTL 1 is known. In this control device, the steam pressure of the
15 circulating fluidized bed boiler is detected, and a deviation value of the steam pressure
with respect to a prescribed target pressure is calculated. Then, a fuel supply amount to
a furnace is controlled based on the deviation value, thereby maintaining the steam
pressure to the target pressure.

Citation List

20 Patent Literature

[0003]

[PTL 1] Japanese Unexamined Patent Application Publication No. 4-6304

Summary of Invention

Technical Problem

25 [0004]

The circulating fluidized bed boiler has a plurality of index items which are an index of an operation state. Then, input values to setting items relating to the index items are adjusted such that the plurality of index items are maintained to predetermined target values.

5 [0005]

However, the index items of the circulating fluidized bed boiler and the setting items relating to the index items are related complicatedly. For this reason, for example, when a plurality of control devices, each of which maintains one index item to a predetermined target value, are combined, it is difficult to simultaneously control the
10 plurality of index items. In the related art, in order to operate the boiler in a state in which the plurality of index items are satisfied simultaneously, an experienced operator operates the boiler by selecting setting items based on sensor data or the like which represents the values of the index items acquired from the boiler and determines input values input to the setting items.

15 [0006]

Accordingly, an object of the invention is to provide an operation diagnostic method and an operation diagnostic device of a circulating fluidized bed boiler which provide settings necessary for simultaneously satisfying the target values of a plurality of index items without requiring the judgment of the experienced operator.

20 Solution to Problem

[0007]

According to an aspect of the invention, there is provided an operation diagnostic method of a circulating fluidized bed boiler which operates with a predetermined input value input to each of a plurality of setting items. The operation
25 diagnostic method includes an estimation step of estimating the degree of influence of the

plurality of setting items relating to the respective index items on the index items, and the target values of the setting items for satisfying the target values of the index items based on the target values of a plurality of index items representing the operation state of the circulating fluidized bed boiler, an ordering step of ordering the plurality of setting items based on the degree of influence of the setting items on the index items, and an output step of outputting information for controlling the index items to the target values using the target values of the setting items with a high order given in the ordering step and the input values of the setting items with a high order. In the estimation step, the target values of the plurality of index items are input to a Bayesian network, in which each of the setting items is a master node and each of the index items is a slave node, to calculate probability values, which are the degree of influence of the plurality of setting items on the index items, and the target values of the setting items. In the ordering step, the plurality of setting items are ordered using the probability values.

[0008]

According to another aspect of the invention, there is provided an operation diagnostic device of a circulating fluidized bed boiler which operates with a predetermined input value input to each of a plurality of setting items. The operation diagnostic device includes estimation means for estimating the degree of influence of the plurality of setting items relating to the respective index items on the index items, and the target values of the setting items for satisfying the target values of the index items based on the target values of a plurality of index items representing the operation state of the circulating fluidized bed boiler, ordering means for ordering the plurality of setting items based on the degree of influence of the setting items on the index items, and output means for outputting information for controlling the index items to the target values using the target values of the setting items with a high order and the input values of the

setting items with a high order. The estimation means inputs the target values of the plurality of index items to a Bayesian network, in which each of the setting items is a master node and each of the index items is a slave node, to calculate probability values, which are the degree of influence of the plurality of setting items on the index items, and
5 the target values of the setting items. The ordering means orders the plurality of setting items using the probability values.

[0009]

In the operation diagnostic method and the operation diagnostic device, the degree of influence of the setting items on the index items is calculated using the
10 Bayesian network. According to the method and the device, it is possible to extract setting items with a large degree of influence to simultaneously satisfy the target values given to a plurality of index items. Furthermore, the tendency of a value which should be taken by each of the extracted setting items is obtained. Accordingly, the operation diagnostic method and the operation diagnostic device can provide settings necessary for
15 simultaneously satisfying the target values of a plurality of index items without requiring the judgment of the experienced operator.

[0010]

The Bayesian network has a first probability table which includes the possible input values of the setting items and probabilities corresponding to the input values, and
20 a second probability table which includes possible sensor data of the index items and probabilities corresponding to the sensor data. In this case, it is possible to calculate a probability corresponding to the possible input value of a setting item relating to an index item when the index item has a predetermined value.

[0011]

25 The operation diagnostic method according to the aspect of the invention may

further include a data input step of inputting the input values input to the setting items and sensor data which is the measurement values of index values acquired by sensors provided in the circulating fluidized bed boiler, and an update step of updating the first probability table and the second probability table based on the input values and the sensor data. In this case, since a probability table included in each node constituting the Bayesian network is updated, the precision of probability data in the probability table is increased. Accordingly, it is possible to further increase precision of extraction of setting items with a large degree of influence.

Advantageous Effects of Invention

10 [0012]

According to the operation diagnostic method and the operation diagnostic device of the invention, it is possible to provide settings for simultaneously satisfying the target values of a plurality of index items without requiring the judgment of the experienced operator.

15 Brief Description of Drawings

[0013]

FIG. 1 is a diagram showing the configuration of an operation diagnostic device of an embodiment.

FIG. 2 is a diagram showing the configuration of a circulating fluidized bed boiler.

FIG. 3 is a diagram showing hardware constituting a part of the operation diagnostic device.

FIG. 4 is a diagram showing an example of a Bayesian network model.

FIG. 5 is a diagram showing a step of diagnosing the operation state of the circulating fluidized bed boiler.

FIG. 6 is a diagram showing an example of a Bayesian network model.

FIG. 7 is a diagram showing an example of a report.

Description of Embodiments

[0014]

5 Hereinafter, an embodiment of an operation diagnostic device and an operation diagnostic method according to the invention will be described in detail referring to the accompanying drawings. In the description of the drawings, the same elements are represented by the same reference numerals, and overlapping description will be omitted.

[0015]

10 As shown in FIG. 1, an operation diagnostic device 1 of this embodiment diagnoses the operation state of a circulating fluidized bed boiler 2 (hereinafter, simply referred to as "boiler"). First, the boiler 2 will be described. As shown in FIG. 2, the boiler 2 is an external circulating (Circulating Fluidized Bed) boiler. The boiler 2 includes a fluidized bed furnace 3 having a longitudinal tubular shape. A fuel input port 15 3a through which fuel is input is provided in the intermediate portion of the furnace 3, and a gas exit 3b through which combustion gas is exhausted is provided in the upper portion of the furnace 3. Fuel supplied from a fuel input device 5 to the furnace 3 is input into the furnace 3 through the fuel input port 3a.

[0016]

20 A cyclone 7 which functions as a solid-gas separation device is connected to the gas exit 3b of the furnace 3. An exhaust port 7a of the cyclone 7 is connected to a poststage gas processing system through a gas line. A return line 9, called a downcomer, extends downward from the bottom exit of the cyclone 7, and the lower end of the return line 9 is connected to the lateral surface of the intermediate portion of the furnace 3.

25 [0017]

In the furnace 3, a solid substance including fuel input from the fuel input port 3a is fluidized by air for combustion and fluidization introduced from a gas supply line 3c in a lower portion, and fuel is combusted at about 800 to 900°C while being fluidized. Combustion gas generated in the furnace 3 is introduced into the cyclone 7 while being accompanied by solid particles. The cyclone 7 separates solid particles and gas by a centrifugal separation effect, returns the separated solid particles to the furnace 3 through the return line 9, and sends combustion gas with the solid particles removed from the exhaust port 7a to the poststage gas processing system through the gas line.

[0018]

In the furnace 3, a solid substance, called "in-furnace bed material", is generated and accumulated on the bottom thereof, and it is necessary to suppress defective operation due to sintering and melting-solidification of the bed material or an incombustible impurity when an impurity (low melting point substance or the like) is concentrated by the in-furnace bed material. For this reason, in the furnace 3, the in-furnace bed material is exhausted from an exhaust port 3d on the bottom thereof to the outside regularly. The exhausted bed material is input to the furnace 3 again after an inappropriate substance, such as metal, is removed on a circulating line (not shown).

[0019]

The above-described gas processing system includes a gas heat exchange device 13 which is connected to the exhaust port 7a of the cyclone 7 through the gas line, and a bag filter (dust collector) 15 which is connected to an exhaust port 13a of the gas heat exchange device 13 through the gas line. The gas heat exchange device 13 is provided with a boiler tube 13b which fluidizes water to cross the flow channel of exhaust gas. High-temperature exhaust gas sent from the cyclone 7 comes into contact with the boiler tube 13b, whereby heat of exhaust gas is recovered to water in the tube and generated

high-temperature steam is sent to a turbine for power generation through the boiler tube 13b. The bag filter 15 removes particulates, such as fly ash, accompanied by combustible gas. Clean gas exhausted from an exhaust port 15a of the bag filter 15 is exhausted from a chimney 19 to the outside through the gas line and a pump 17.

5 [0020]

Referring to FIG. 1, the boiler 2 is provided with a sensor group 14 which acquires sensor data constituting operation data and outputs sensor data to the operation diagnostic device 1. The sensor group 14 includes, for example, a temperature sensor 14a which measures the temperature of a predetermined region of the boiler 2, a flow rate
10 sensor 14b which measures the flow rate of exhaust gas or water, a concentration sensor 14c which measures the concentration of a predetermined substance in exhaust gas, and the like. A part of sensor data is index items. The index items are items which are an index of an operation state in sensor data, and include, for example, a pressure deviation, a heat absorption amount, boiler efficiency, an exhaust concentration of an environmental
15 load substance, such as CO or NOX, and the like.

[0021]

The boiler 2 operates with a predetermined input value input to each of a plurality of setting items constituting a setting item group 16. The setting items are items to which an operator or a control device (not shown) can input predetermined input
20 values to the boiler 2 to operate the boiler 2. The setting items include, for example, a blow flow rate 16a, a sand supply amount 16b, a coal supply amount 16c which is the supply amount of coal supplied to the furnace 3, and the like. The setting item group 16 also includes a blower operation frequency, an air flow rate, a release frequency of an atmosphere release valve, a water injection amount, a valve opening, and the like.

25 [0022]

Subsequently, the operation diagnostic device 1 will be described. The operation diagnostic device 1 diagnoses the operation state of the boiler 2 based on sensor data of the boiler 2 and the target values of the index items. The target values which are given to the index items are based on a plurality of operation indexes, such as an operation index for causing the boiler 2 to operate with high efficiency and an operation index for reducing a discharge amount of an environmental load substance. The operation diagnostic device 1 diagnoses the operation state of the boiler 2 based on sensor data input from the sensor group 14 arranged in the boiler 2, the target values of the index items input to the operation diagnostic device 1, and a Bayesian network model recorded in advance in the operation diagnostic device 1. As a result of diagnosis, the operation diagnostic device 1 shows setting items which should be adjusted to satisfy a target and shows the tendency of values which should be input to the setting items to be adjusted.

[0023]

The operation diagnostic device 1 includes a data processing device 20, an input device 21 which is provided to input predetermined data to the data processing device 20, and an output device 22 which is provided to display data output from the data processing device 20.

[0024]

The operation diagnostic device 1 is realized using, for example, a computer 100 shown in FIG. 3. As shown in FIGS. 1 and 3, the computer 100 is an example of hardware constituting the data processing device 20 of this embodiment. The computer 100 includes various data processing devices, such as a server device or a personal computer which includes a CPU and performs processing or control by software. The computer 100 is constituted as a computer system including a CPU 41, a RAM 42 and a

ROM 43 which are a main storage device, an input device 21, such as a keyboard and a mouse as an input device, an output device 22, such as a display and a printer, a communication module 47 which is a data transmission and reception device, such as a network card, an auxiliary storage device 48, such as a hard disk, and the like. The functional constituent elements shown in FIG. 1 are realized by reading predetermined computer software on hardware, such as the CPU 41 or the RAM 42 shown in FIG. 3, operating the input device 21, the output device 22, and the communication module 47 under the control of the CPU 41, and performing reading and writing of data in the RAM 42 or the auxiliary storage device 48.

[0025]

The data processing device 20 includes, as functional constituent elements, a data input unit 23 which receives sensor data input from the sensor group 14 arranged in the boiler 2, a model recording unit 24 which records a Bayesian network model, a model update unit 25 which updates the Bayesian network model based on sensor data, an inference data calculation unit 26 which calculates the degree of influence of the setting items on the index items, an inference data processing unit 27 which calculates setting items to be adjusted and the tendency of the values based on sensor data and the output of the inference data calculation unit 26, and a report creation unit 28 which creates a report to be an operation index based on the output of the inference data processing unit 27.

[0026]

Sensor data acquired by the sensor group 14 of the boiler 2 and the input values input to the setting item group 16 are input to the data input unit 23. The data input unit 23 outputs input sensor data to the inference data processing unit 27, and if necessary, outputs sensor data to the model update unit 25. The data input unit 23 outputs the input values to the setting item group 16 to the inference data calculation unit 26.

[0027]

The Bayesian network model is recorded in the model recording unit 24. The model recording unit 24 is constituted to be referred from the inference data calculation unit 26 described below, and outputs the Bayesian network model to the inference data calculation unit 26 according to a request from the inference data calculation unit 26.

[0028]

Here, a Bayesian network model 50 will be described. FIG. 4 shows an example of a Bayesian network having the setting items and the index items of the boiler 2. The Bayesian network expresses the relationship between a cause 51 and an effect 52 by a simple drawing and expresses the transition of a probabilistic phenomenon graphically. It is possible to find the probability of a variable, which is not observed when the value of a certain variable is found, from the Bayesian network.

[0029]

In this embodiment, the setting items are defined as the cause 51 and the index items are defined as the effect 52. In regard to the cause 51 including a plurality of setting items, items to which set values can be input by the operator or the control device are, for example, a blower operation frequency 51a, an air flow rate 51b, an opening of an atmosphere release valve 51c, a water injection amount 51d, a valve opening 51e, a coal supply amount 51f, a sand supply amount 51g, and a blow flow rate 51h, and the like. The setting items defined as the cause are shown as a master node in the Bayesian network. In regard to the effect 52 including a plurality of index items, items to be an index of an operation state in sensor data are, for examples, a pressure deviation 52a, a heat absorption amount 52b, an exhaust gas CO concentration, boiler efficiency 52d, and the like. The index items defined as the effect are shown as a slave node in the Bayesian network. Then, it is shown that the relationship between the setting items and

the index items has a relationship by an arrow extending from the master node to the slave node. For example, an arrow extends from the blower operation frequency 51a and the air flow rate 51b to the pressure deviation 52a. Accordingly, it is shown that the blower operation frequency 51a and the air flow rate 51b relate to the pressure deviation 52a. Each node has a probability table (Conditional Probability Table: CPT) (see FIG. 6).

[0030]

Referring to FIG. 1, the model update unit 25 updates data included in the Bayesian network model based on sensor data input from the data input unit 23. Updated data of the model is output to the model recording unit 24 and recorded.

[0031]

The inference data calculation unit 26 is estimation means for calculating the degree of influence of the setting items on the index items based on the Bayesian network model and the target values of the index items input from the input device 21. Specifically, the inference data calculation unit 26 outputs the degree of influence of the setting items on the index items as probability values. An output process of the probability values will be described below. Then, the inference data calculation unit 26 outputs the output result to the inference data processing unit 27.

[0032]

The inference data processing unit 27 is ordering means for ordering a plurality of setting items based on the degree of influence of the setting items relating to the index items on the index items. Specifically, the setting items are ordered based on the probability values calculated by the inference data calculation unit 26. The inference data processing unit 27 compares the state of each of the ordered setting items with the state of the input value actually input to each of the setting items of the boiler 2. With

the comparison, determination about whether or not the states of the input values to the setting items match the states of the setting items obtained based on the Bayesian network model is performed. The inference data processing unit 27 calculates statistics, such as the average value, maximum value, and minimum value of sensor data. The inference data processing unit 27 outputs the determination result and the statistics to the report creation unit 28.

[0033]

The report creation unit 28 is output means for creating data of a report which displays information for controlling the index items to the target values using the target values of the setting items with a high order and the input values of the setting items with a high order. The report creation unit 28 outputs created data to the output device 22. For example, when the output device 22 is a display, the report is displayed on a screen. When the output device 22 is a printer, the report is printed on a paper medium.

[0034]

As described above, according to the operation diagnostic device 1 of this embodiment, the inference data calculation unit 26 calculates the degree of influence of each of a plurality of setting items on each of a plurality of index items. According to the operation diagnostic device 1, it is possible to extract setting items with a large degree of influence based on the probability values to simultaneously satisfy the target values given to a plurality of index items. Furthermore, the tendency of a value which should be taken by each of the extracted setting items is obtained. Accordingly, the operation diagnostic device 1 of the boiler 2 can diagnose the operation state of the boiler 2 and can provide information necessary for simultaneously satisfying the target values of a plurality of index items without requiring the judgment of the experienced operator.

[0035]

Next, an operation diagnostic method using the operation diagnostic device 1 will be described. FIG. 5 is a diagram showing the main steps of the operation diagnostic method. The operation diagnostic method includes a data input step S1 of inputting sensor data and the like, a model reading step S2 of reading a Bayesian network model, a target value input step S3 of inputting the target values of the index items, an inference data calculation step S4 of calculating inference data, an inference data processing step S5 of processing inference data, and an output step S6 of outputting a report.

[0036]

10 <Data Input Step S1>

In the data input step S1, sensor data from the sensor group 14 set in the boiler 2 and the input values input to the setting items of the boiler 2 are input to the operation diagnostic device 1. The data input step S1 is primarily executed by the data input unit 23. Data collected in the data input step S1 is data for a long period of time, such as a day, a week, or a month. Data may be input from the sensor group 14 arranged in the boiler 2 and the setting items directly to the data input unit 23, or sensor data and the input values of the setting items may be recorded in a recording medium (not shown) or may be read from the recording medium.

[0037]

20 <Model Reading Step S2>

In the model reading step S2, the Bayesian network model recorded in the model recording unit 24 is read to the inference data calculation unit 26. The model reading step S2 is primarily executed by the model recording unit 24. The model reading step S2 includes an update determination step S2a of performing determination about whether or not to update a probability table included in the Bayesian network model, an update

step S2b of updating the probability table, and a reading step S2c of reading the model.

[0038]

First, in the update determination step S2a, determination about whether or not to update the model is performed. When it is determined to update the model (Step S2a: YES), the process progresses to the update step S2b, and the model is updated by the model update unit 25. When it is determined not to update the model (Step S2a: NO), the process progresses to the reading step S2c.

[0039]

<Update Step S2b>

10 The update step S2b of updating the model is primarily executed by the model update unit 25. First, the model update unit 25 reads a plurality of pieces of sensor data input to the data input unit 23 and data of the probability tables in the model recorded in the model recording unit 24. Here, sensor data for use in updating the model should be data when the boiler 2 is operated in an ideal state. Next, the values of sensor data are
15 discretized using a predetermined threshold value to classify into several states. Subsequently, the probability that each classified state is present is calculated. That is, data of a new probability table is calculated using sensor data input to the data input unit 23. Then, probability data of the calculated probability table is fetched to probability data of the probability table recorded in the model recording unit 24 to update probability
20 data. In this way, in the model based on the Bayesian statistic, a previous model is easily fetched and a new model is obtained. After the update step S2b is executed, the process progresses to the reading step S2c.

[0040]

<Reading Step S2c>

25 In the reading step S2c, data of the Bayesian network model recorded in the

model recording unit 24 is read to the inference data calculation unit 26. The reading step S2c is primarily performed by the model recording unit 24 and the inference data calculation unit 26.

[0041]

5 <Target Value Input Step S3>

In the target value input step S3, the target values of the index items for use in the calculation of the inference data calculation step S4 are read. The target values of the index items are based on an operation index for operating the boiler 2 with high efficiency or for reducing a discharge amount of an environmental load substance.

10 These target values are input using the input device 21 in a discretized state such that, for example, boiler efficiency is "high" and the exhaust gas CO concentration is "low".

[0042]

<Inference Data Calculation Step S4>

The inference data calculation step S4 is an estimation step of estimating the degree of influence of a plurality of setting items on the index items and the target values of the setting items for satisfying the target values of the index items based on the target values of the index items input in the target value input step S3 and the Bayesian network model. That is, the target values of the index items are input to the Bayesian network model, and the probability values of the setting items corresponding to the index items are calculated. The inference data calculation step S4 is primarily executed by the inference data calculation unit 26.

[0043]

A method of calculating the probability values of the setting items using the Bayesian network model will be described in detail. The Bayesian network is based on the Bayes' theorem according to an idea for a conditional probability. First, the Bayes'

theorem will be described. The probability that an event A and an event B are generated simultaneously is referred to as a simultaneous probability. Meanwhile, the probability that the event B is generated under a condition that the event A has been generated is referred to as the conditional probability that B is generated based on A, and represented
5 by Expression (1).

[Equation 1]

$$P(B|A) = \frac{P(A \cap B)}{P(A)} \dots (1)$$

The probability that the event A is generated under a condition that the event B has been generated is referred to as the conditional probability that A is generated based
10 on B, and is represented by Expression (2).

[Equation 2]

$$P(A|B) = \frac{P(A \cap B)}{P(B)} \dots (2)$$

The Bayes' theorem is represented by Expression (3) using Expression (1) and Expression (2).

15 [Equation 3]

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \dots (3)$$

From the Bayes' theorem represented by Expression (3), the probability (P(A|B)) that A is generated when B has been generated can be calculated from the probability (P(B|A)) that B is generated when A has been generated. In general, A is handled as a
20 cause, and B is handled as an effect. That is, the probability that the cause A is generated when the effect B has been generated is calculated from the probability that the effect B is generated when the cause A has been generated.

[0044]

FIG. 6 shows an example of the Bayesian network having the setting items and the index items of the boiler 2. In this embodiment, the setting items are defined as the cause A, and the index items are defined as the effect B. FIG. 6 shows the relationship between the state of a water supply flow rate and an exhaust gas concentration and the relationship between a water supply temperature and an exhaust gas concentration in the Bayesian network. A Bayesian network model 60 has a master node 61 which represents the water supply flow rate as a cause A1, a master node 62 which represents a water supply temperature as a cause A2, and a slave node 63 which represents an exhaust gas concentration as an effect B. The master node 61 as the cause A1 is connected to the slave node 63 by an arrow 64 toward the slave node 63 as the effect B. The master node 62 as the cause A2 is connected to the slave node 63 by an arrow 65 toward the slave node 63 as the effect B.

[0045]

The master nodes 61 and 62 and the slave node 63 respectively have probability tables 61a, 62a, and 63a. The probability table 61a which is a first probability table in the master node 61 divides the water supply flow rate into two states using a predetermined threshold value, and shows the probability that each state is present. That is, a probability variable is defined as 1 in a state in which the water supply flow rate is "high" and 0 in a state in which the water supply flow rate is "low". Then, a probability corresponding to when the probability variable of the water supply flow rate is "high = 1" is a2, and a probability corresponding to when the water supply flow rate is "low = 0" is a1.

[0046]

The probability table 62a which is a first probability table in the master node 62 divides a water supply temperature into two states using a predetermined threshold value,

and shows the probability that each state is present. That is, a probability variable is defined as 1 in a state in which the water supply temperature is "high" and 0 in a state in which the water supply temperature is "low". Then, a probability corresponding to when the probability variable of the water supply temperature is "high = 1" is a4, and a
5 probability corresponding to when the water supply temperature is "low = 0" is a3.

[0047]

The probability table 63a which is a second probability table in the slave node 63 shows conditional probabilities relating to the master node 61 as the cause A1 and the master node 62 as the cause A2 of the slave node 63 as the effect B. Here, an exhaust
10 gas concentration is illustrated as an index item included in center data. The probability table 63a in the slave node 63 divides the exhaust gas concentration as one piece of sensor data into two states using a predetermined threshold value, and shows a probability corresponding to the state of each piece of sensor data. That is, a probability variable is defined as 1 in a state in which the exhaust gas concentration is "high" and 0
15 in a state in which the exhaust gas concentration is "low". For example, when the water supply flow rate A1 is "low" and the water supply temperature A2 is "low", the probability that the probability variable of the exhaust gas concentration is "low = 0" is b11, and the probability that the probability variable of the exhaust gas concentration is "high = 1" is b21.

20 [0048]

From the Bayesian network model 60, when the probability variable B of the exhaust gas concentration is 1, that is, when "the exhaust gas concentration is high", a calculation example of finding a probability value when the water supply flow rate is high (A1 = 1) and a probability value when the water supply temperature is high (A2 = 1)
25 will be described.

[0049]

First, when the exhaust gas concentration is high ($B = 1$), a probability value $X1$ when the water supply flow rate is high ($A1 = 1$) is calculated. The probability value $X1$ is represented as in Expression (4) when using Expression (3). In Expression (4),
 5 the event of $A1 = 1$ is simply represented as $A1$, and the event of $B = 1$ is simply represented as B .

[Equation 4]

$$X1 = P(A1 | B) = \frac{P(B | A1)P(A1)}{P(B)} \dots (4)$$

The numerator $P(B)$ is represented by Expression (5).

10 [Equation 5]

$$\begin{aligned} P(B) &= P(B \cap A1 \cap A2) + P(B \cap \overline{A1} \cap A2) + P(B \cap A1 \cap \overline{A2}) + P(B \cap \overline{A1} \cap \overline{A2}) \\ &= P(B | A1 \cap A2)P(A1 \cap A2) + P(B | \overline{A1} \cap A2)P(\overline{A1} \cap A2) \\ &\quad + P(B | A1 \cap \overline{A2})P(A1 \cap \overline{A2}) + P(B | \overline{A1} \cap \overline{A2})P(\overline{A1} \cap \overline{A2}) \dots (5) \\ &= P(B | A1 \cap A2)P(A1)P(A2) + P(B | \overline{A1} \cap A2)P(\overline{A1})P(A2) \\ &\quad + P(B | A1 \cap \overline{A2})P(A1)P(\overline{A2}) + P(B | \overline{A1} \cap \overline{A2})P(\overline{A1})P(\overline{A2}) \\ &= B24 \times a2 \times a4 + B22 \times a1 \times a4 + B23 \times a2 \times a3 + B21 \times a1 \times a3 \end{aligned}$$

The denominator $P(B|A1)$ is represented by Expression (6).

[Equation 6]

$$\begin{aligned} P(B | A1) &= P(B | A1 \cap \overline{A2})P(\overline{A2}) + P(B | A1 \cap A2)P(A2) \dots (6) \\ &= b23 \times a3 + b24 \times a4 \end{aligned}$$

15 From Expressions (4), (5), and (6), when the exhaust gas concentration is high, the probability value $X1$ with a high water supply flow rate is obtained.

[0050]

Next, when the exhaust gas concentration is high ($B = 1$), a probability value $X2$ when the water supply temperature is high ($A2 = 1$) is calculated. The probability value
 20 $X2$ is represented as in Expression (7) when using Expression (3). In Expression (7), the event of $A2 = 1$ is simply represented as $A2$, and the event of $B = 1$ is simply

represented as B.

[Equation 7]

$$X2 = P(A2 | B) = \frac{P(B | A2)P(A2)}{P(B)} \dots (7)$$

Here, the numerator P(B) is calculated by Expression (5). The denominator
5 P(B|A2) is represented by Expression (8).

[Equation 8]

$$\begin{aligned} P(B | A2) &= P(B | \overline{A1} \cap A2)P(\overline{A1}) + P(B | A1 \cap A2)P(A1) \dots (8) \\ &= b22 \times a1 + b24 \times a2 \end{aligned}$$

From Expressions (5), (7), and (8), when the exhaust gas concentration is high,
the probability value X2 with a high water supply temperature is obtained.

10 [0051]

With the above-described calculation, the probability value X1 when the exhaust
gas concentration is high (B=1) and the water supply flow rate is high (A1 = 1) and the
probability value X2 when the exhaust gas concentration is high (B = 1) and the water
supply temperature is high (A2 = 1) are calculated. From the probability value X1 and
15 the probability value X2, the degree of influence of the setting items, such as the water
supply flow rate and the water supply temperature, on the index items, such as the
exhaust gas concentration, and the target values of the setting items for satisfying the
target values of the index items can be estimated. For example, when the probability
value X1 is greater than the probability value X2, it is assumed that the water supply flow
20 rate has a larger degree of influence on the exhaust gas concentration as the index item
than the water supply temperature.

[0052]

As described above, when the Bayesian network model is applied to the
operation diagnosis of the boiler 2, the cause A is defined as a setting item, and the effect

B is defined as sensor data. Then, if the probability $P(B|A)$ of an index item included in sensor data obtained when the setting item reaches a predetermined state is calculated from previous data, the probability $P(A|B)$ of the setting items when the state of the index item is a predetermined target value can be inferred.

5 [0053]

The value (in the above-described example, 0 or 1) of the probability variable is handled as a discrete value due to the restriction to the processing ability of the computer. Accordingly, when handling sensor data having continuous values, it is necessary to perform processing for discretization, such as high, middle, and low, using a
10 predetermined threshold value.

[0054]

<Inference Data Processing Step S5>

As shown in FIG. 5, the inference data processing step S5 performs data processing necessary for creating a report on data calculated in the inference data
15 calculation unit 26. The inference data processing step S5 has an ordering step S5a and a comparison step S5b. In the ordering step S5a, a plurality of setting items are ordered based on the degree (probability value) of influence of the setting items on the index items. The ordering step S5a is primarily executed by the inference data processing unit
20 27. For example, as the target values of the ideal operation state of the boiler 2, boiler efficiency is set to high, and the discharge concentration of the environmental load substance is set to low. From these target values and the Bayesian network model, the setting items corresponding to the index items and the possible states of the setting items are obtained by the probability values. A setting item having the maximum probability value is given a first order, and ordering is performed with the magnitude of the
25 probability values as the magnitude of the degree of influence. If the setting items are

ordered in a descending order of the probability values for the index items, and improvement is made sequentially from the setting items with a high probability, the operation state of the boiler 2 approaches an ideal state. In the comparison step S5b, the states of the input values input to the setting items of the boiler 2 are compared with the states of the setting items which satisfy the target values of the index items calculated in the inference data calculation step S4. With the comparison, determination is performed about whether or not the states of the input values input to the setting items of the boiler 2 match the states of the setting items which satisfy the target values of the index items calculated in the inference data calculation step S4. In the inference data processing step S5, the statistics for an evaluation target period are calculated for each piece of sensor data. The statistics include an average value, a maximum value, a minimum value, and the like.

[0055]

<Output Step S6>

The output step S6 outputs information for controlling the index items to the target values using the target values of the setting items with a high order given in the inference data processing step S5 and the input values of the setting items with a high order. The output step S6 is primarily executed by the report creation unit 28. Data created in the output step S6 is output to the display or printer as the output device 22. An example of a report is shown in FIG. 7. As shown in FIG. 7, a report 70 has a table 71 which displays the index items of the operation state of the boiler 2, and a table 72 which displays information necessary for improving the operation state.

[0056]

In the table 71 of the report 70, information representing the operation state of the boiler 2 is displayed. The table 71 has a column 71a which displays the index items,

a column 71b which displays the statistics of data of the index items acquired by the sensor group 14, and a column 71c which displays the discretized result of data of the index items. The statistics include, for example, an average value, a maximum value, and a minimum value. In the discretized result, for example, as in a row representing boiler efficiency, the states of discretization of "low", "middle", and "high", the threshold values for use in discretization that "low" is less than 90.2, "middle" is equal to or greater than 90.2 and less than 93.4, and "high" is equal to or greater than 93.4, and the probability distribution of the states that "low" is 13.5%, "middle" is 74.5%, and "high" is 12% are represented.

[0057]

In the table 72 of the report 70, information of settings necessary for approaching the operation state of the boiler 2 to an ideal state which is information for controlling the index items to the target values is displayed. The table 72 has a column 72a which displays the setting items with a high order given in the ordering step S5a, a column 72b which displays the preferred states of the setting items, a column 72c which displays the states of the setting items as the input values of the setting items with a high order, and a column 72d which represents the diagnosis result of the setting items for improving the operation state. For example, referring to a row representing a blow flow rate, it is understood that the blow flow rate is desirably large, in the present state, the ratio of large among (large, middle, and small) is 0%, and the input values are desirably adjusted to increase the blow flow rate.

[0058]

As described above, according to the operation diagnostic method of this embodiment, the degree of influence of each of a plurality of setting items on each of a plurality of index items is calculated using the Bayesian network. According to the

method, it is possible to extract setting items with a large degree of influence to simultaneously satisfy the target values given to a plurality of index items. Furthermore, the tendency of a value which should be taken by each of the extracted setting items is obtained. Accordingly, the operation diagnostic method of the boiler 2 can provide
5 settings necessary for simultaneously satisfying the target values of a plurality of index items without requiring the judgment of the experienced operator.

[0059]

The operation diagnostic method of this embodiment may further include a data input step S1 of acquiring the input values input to the setting items and sensor data as
10 the measurement values of the index items acquired by the sensors provided in the boiler 2, and an update step S2b of updating the first probability tables 61a and 62a in the master nodes 61 and 62 and the second probability table 63a in the slave node 63 based on the input values and sensor data. In this case, since the probability tables 61a, 62a, and 63a included in the nodes 61, 62, and 63 constituting the Bayesian network are
15 updated, precision of probability data of the probability tables 61a, 62a, and 63a is increased. Accordingly, it is possible to further increase precision of extraction of setting items with a large degree of influence.

[0060]

The above-described embodiment shows an example of the operation diagnostic
20 device 1 and the operation diagnostic method. The operation diagnostic device 1 and the operation diagnostic method according to the invention are not limited to the above-described embodiment, and the operation diagnostic device 1 and the operation diagnostic method of the above-described embodiment may be modified or may be applied to other applications within the scope without changing the concept described in
25 the appended claims.

[0061]

As the index items, sensor data different from the above-described items may be used. In regard to the setting items, items different from the above-described items may be used as setting items.

5 Industrial Applicability

[0062]

According to the operation diagnostic method and the operation diagnostic device of a circulating fluidized bed boiler, it is possible to provide settings for simultaneously satisfying the target values of a plurality of index items without requiring
10 the judgment of the experienced operator.

Reference Signs List

[0063]

1: operation diagnostic device, 2: circulating fluidized bed boiler, 14:
15 sensor group, 16: setting item group, 20: data processing device, 21: input device,
22: output device, 23: data input unit, 24: model recording unit, 25: model update
unit, 26: inference data calculation unit, 27: inference data processing unit, 28:
report creation unit, 50, 60: model, 61, 62: master node, 61a, 62a, 63a: probability
table, 63: slave node, 70: report, S1: data input step, S2: model reading step, S3:
20 target value input step, S4: inference data calculation step, S5: inference data
processing step, S5a: ordering step, S6: output step.

CLAIMS

1. An operation diagnostic method of a circulating fluidized bed boiler which operates with a predetermined input value input to each of a plurality of setting items, the
5 operation diagnostic method comprising:

an estimation step of estimating the degree of influence of the plurality of setting items relating to the respective index items on the index items, and the target values of the setting items for satisfying the target values of the index items based on the target values of a plurality of index items representing the operation state of the circulating
10 fluidized bed boiler;

an ordering step of ordering the plurality of setting items based on the degree of influence of the setting items on the index items; and

an output step of outputting information for controlling the index items to the target values using the target values of the setting items with a high order given in the
15 ordering step and the input values of the setting items with a high order,

wherein, in the estimation step, the target values of the plurality of index items are input to a Bayesian network, in which each of the setting items is a master node and each of the index items is a slave node, to calculate probability values, which are the degree of influence of the plurality of setting items on the index items, and the target
20 values of the setting items, and

in the ordering step, the plurality of setting items are ordered using the probability values.

2. The operation diagnostic method according to claim 1,

25 wherein the Bayesian network has a first probability table which includes the

possible input values of the setting items and probabilities corresponding to the input values, and a second probability table which includes possible sensor data of the index items and probabilities corresponding to the sensor data.

5 3. The operation diagnostic method according to claim 2, further comprising:
a data input step of inputting the input values input to the setting items and sensor data which is the measurement values of index values acquired by sensors provided in the circulating fluidized bed boiler; and
an update step of updating the first probability table and the second probability
10 table based on the input values and the sensor data.

4. An operation diagnostic device of a circulating fluidized bed boiler which operates with a predetermined input value input to each of a plurality of setting items, the operation diagnostic device comprising:

15 estimation means for estimating the degree of influence of the plurality of setting items relating to the respective index items on the index items, and the target values of the setting items for satisfying the target values of the index items based on the target values of a plurality of index items representing the operation state of the circulating fluidized bed boiler;

20 ordering means for ordering the plurality of setting items based on the degree of influence of the setting items on the index items; and

output means for outputting information for controlling the index items to the target values using the target values of the setting items with a high order and the input values of the setting items with a high order,

25 wherein the estimation means inputs the target values of the plurality of index

items to a Bayesian network, in which each of the setting items is a master node and each of the index items is a slave node, to calculate probability values, which are the degree of influence of the plurality of setting items on the index items, and the target values of the setting items, and

- 5 the ordering means orders the plurality of setting items using the probability values.