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(54) **FAULT DETECTION DEVICE, FAULT DETECTION METHOD, AND PROGRAM**

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(57) **ABSTRACT**

A fault detection device comprises: a measurement data acquirer that acquires measurement data for current flowing on power supply lines that are connected to multiple electrical devices; a clusterer that classifies the measurement data for a past fixed period into multiple clusters based on at least one of frequency and phase with respect to an AC cycle; a pattern analyzer that analyzes each of the clusters for an appearance pattern of measurement data that satisfy a preset standard; and a fault determiner that determines the occurrence of a fault when measurement data is acquired that differs from the analyzed appearance pattern.

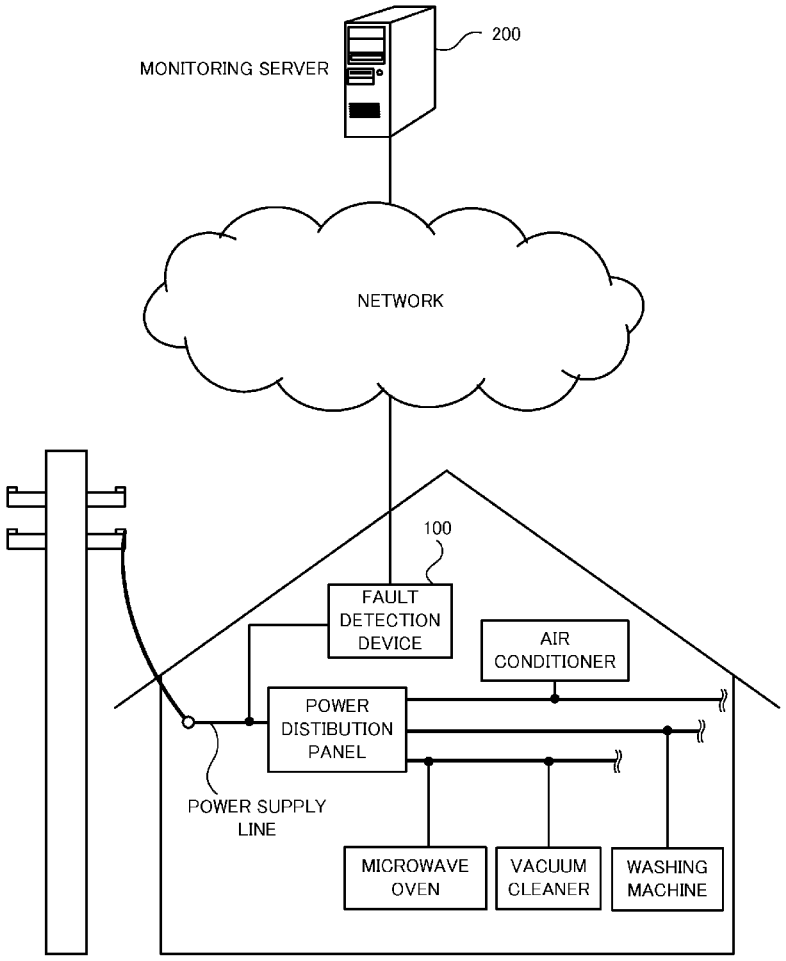

FIG. 1

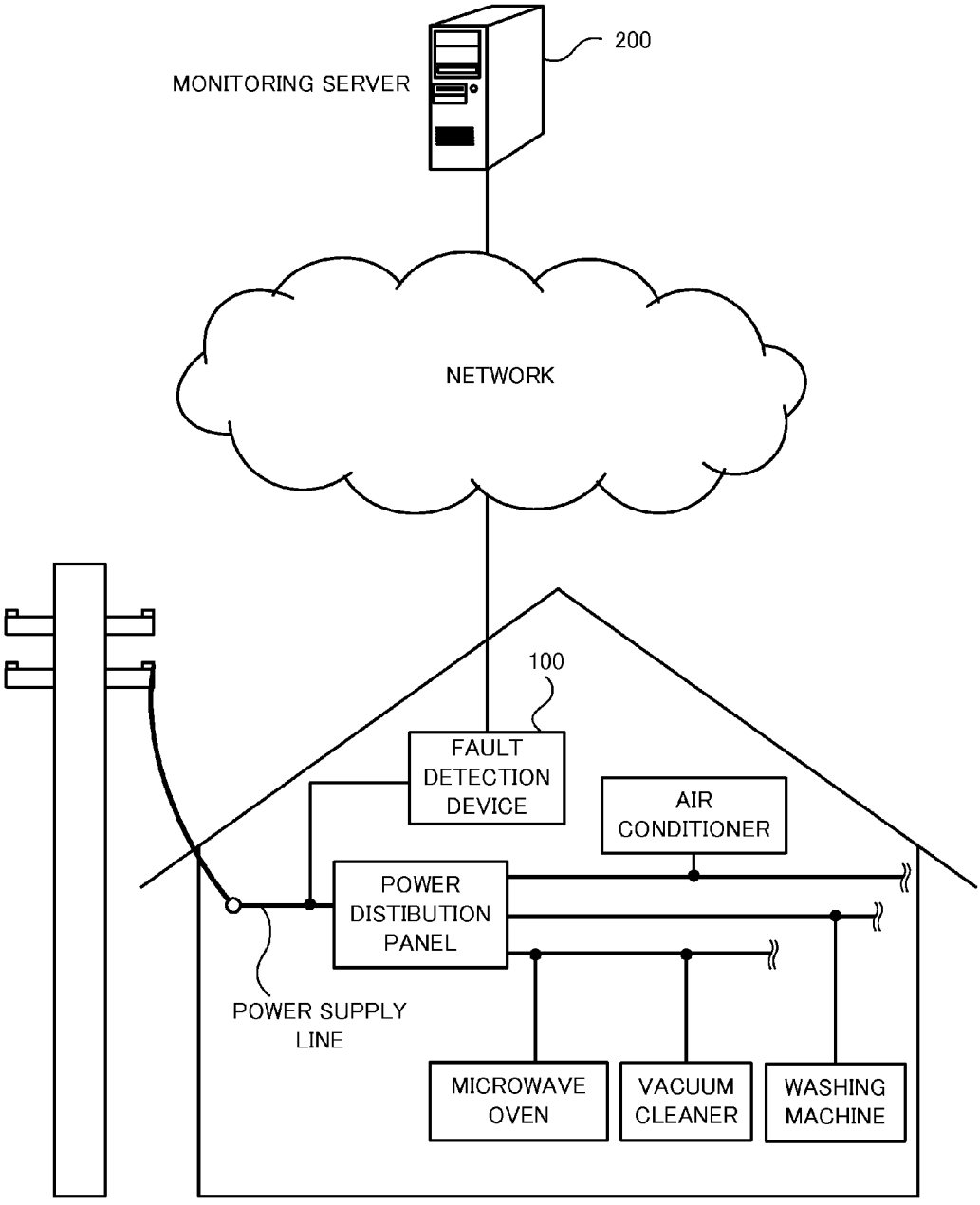
MONITORING SERVER
200
NETWORK
100
FAULT DETECTION DEVICE
AIR CONDITIONER
POWER DISTIBUTION PANEL
POWER SUPPLY LINE
MICROWAVE OVEN
VACUUM CLEANER
WASHING MACHINE

FIG. 2

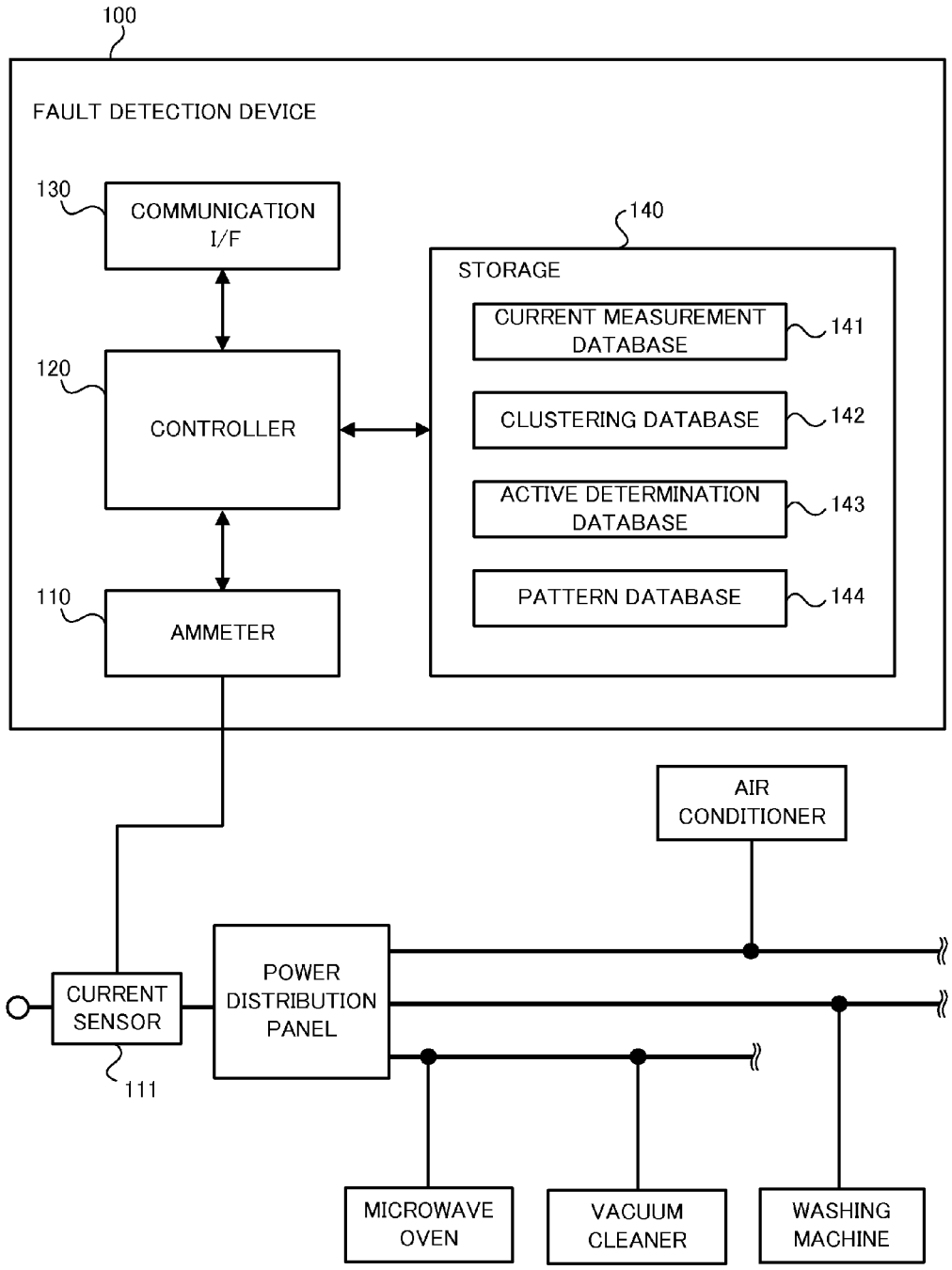
100
FAULT DETECTION DEVICE
130
COMMUNICATION I/F
140
STORAGE
CURRENT MEASUREMENT DATABASE
141
120
CONTROLLER
CLUSTERING DATABASE
142
ACTIVE DETERMINATION DATABASE
143
110
AMMETER
PATTERN DATABASE
144
AIR CONDITIONER
POWER DISTRIBUTION PANEL
CURRENT SENSOR
111
MICROWAVE OVEN
VACUUM CLEANER
WASHING MACHINE

FIG. 3

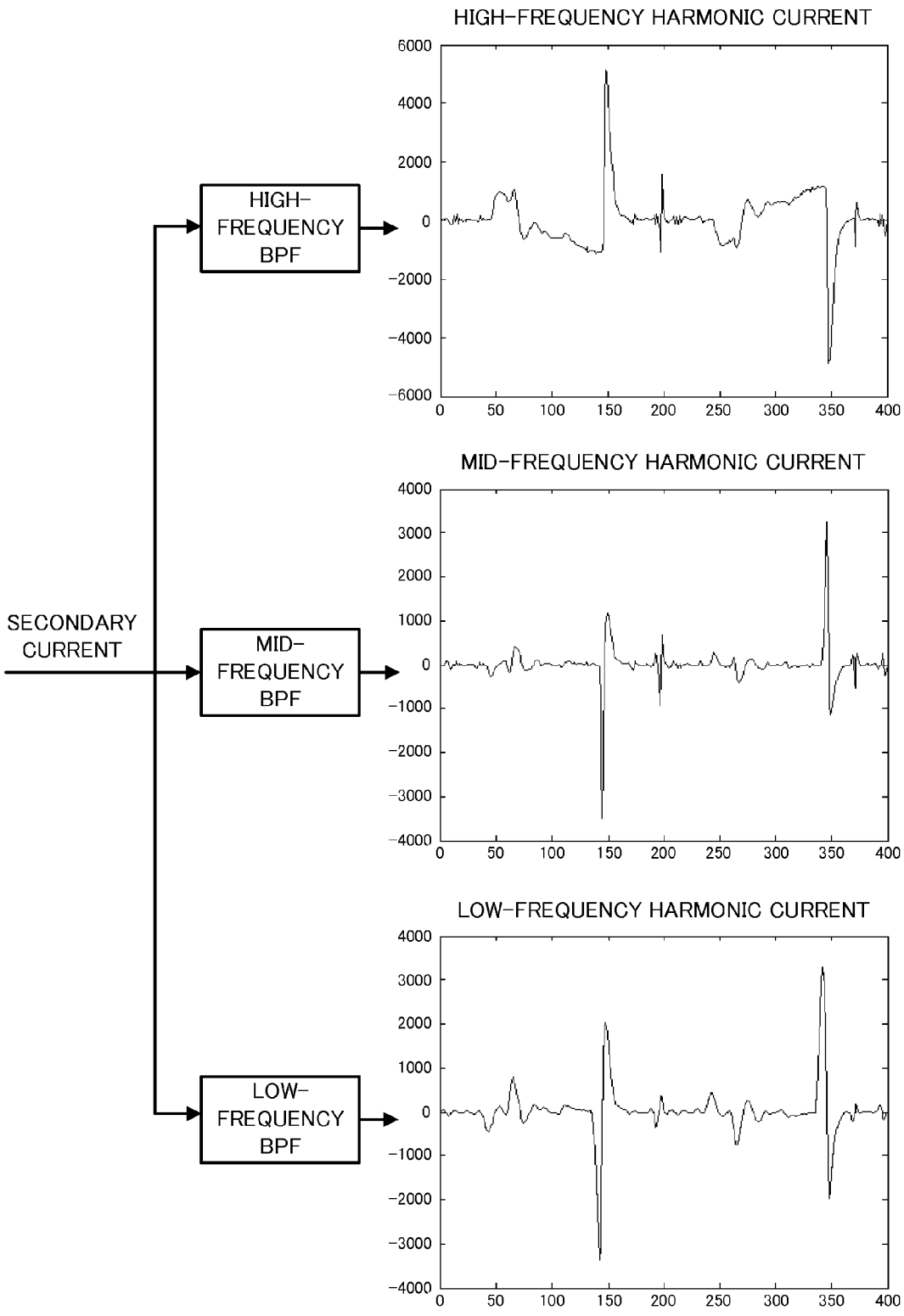
SECONDARY CURRENT
HIGH-FREQUENCY BPF
MID-FREQUENCY BPF
LOW-FREQUENCY BPF
HIGH-FREQUENCY HARMONIC CURRENT
MID-FREQUENCY HARMONIC CURRENT
LOW-FREQUENCY HARMONIC CURRENT
6000
4000
2000
0
-2000
-4000
-6000
3000
1000
-1000
-3000
0
50
100
150
200
250
300
350
400

FIG. 4A

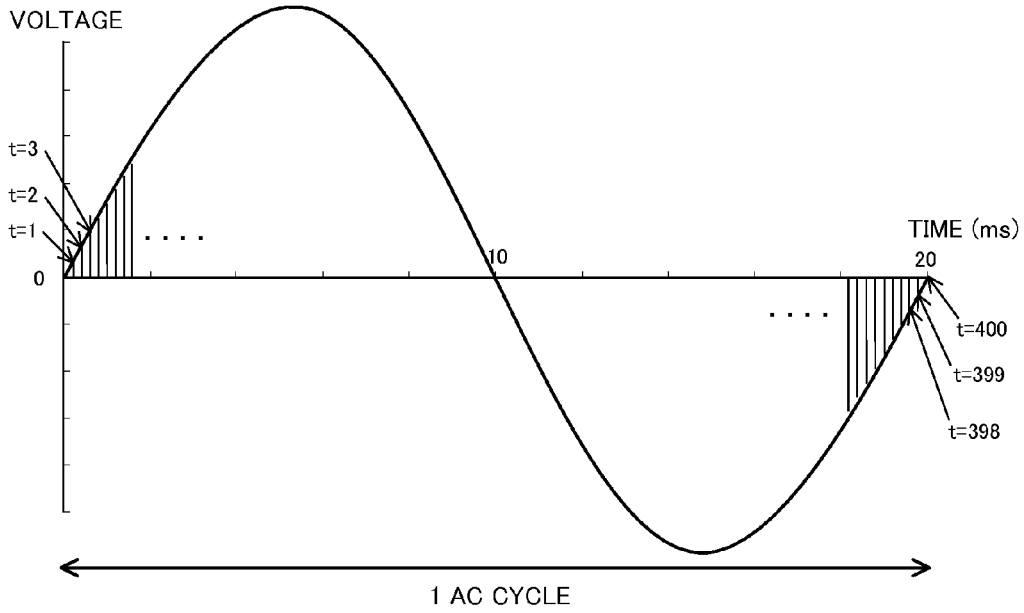
VOLTAGE
t=3
t=2
t=1
0
10
20
TIME (ms)
t=400
t=399
t=398
1 AC CYCLE

FIG. 4B

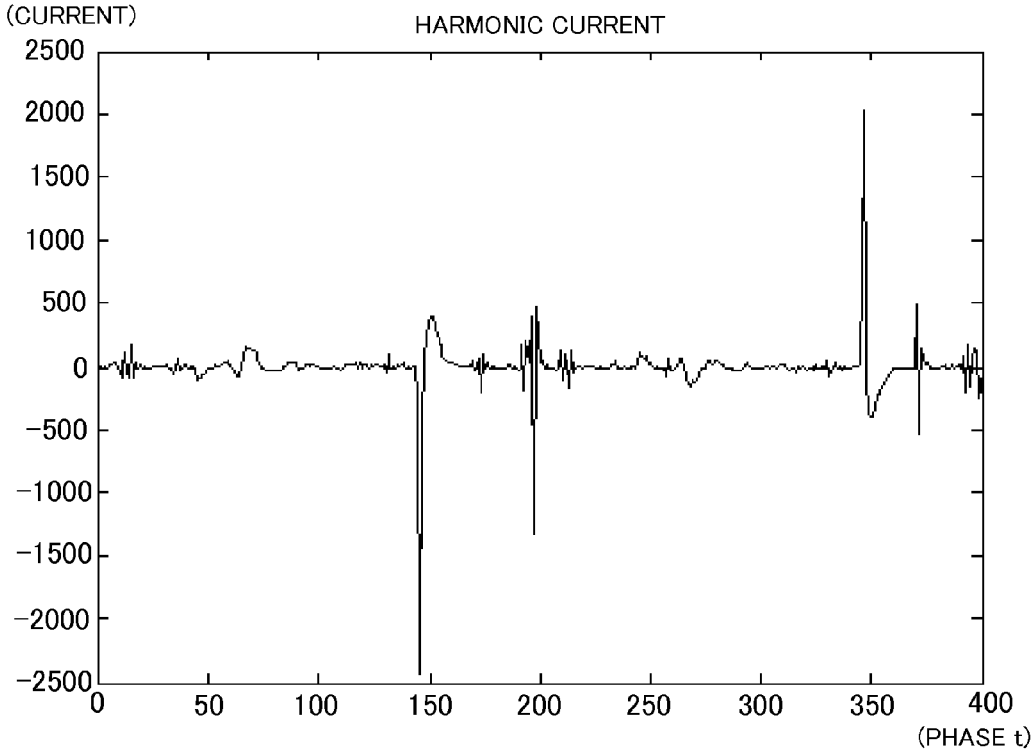
(CURRENT)
HARMONIC CURRENT
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500
0
50
100
150
200
250
300
350
400
(PHASE t)

FIG. 5

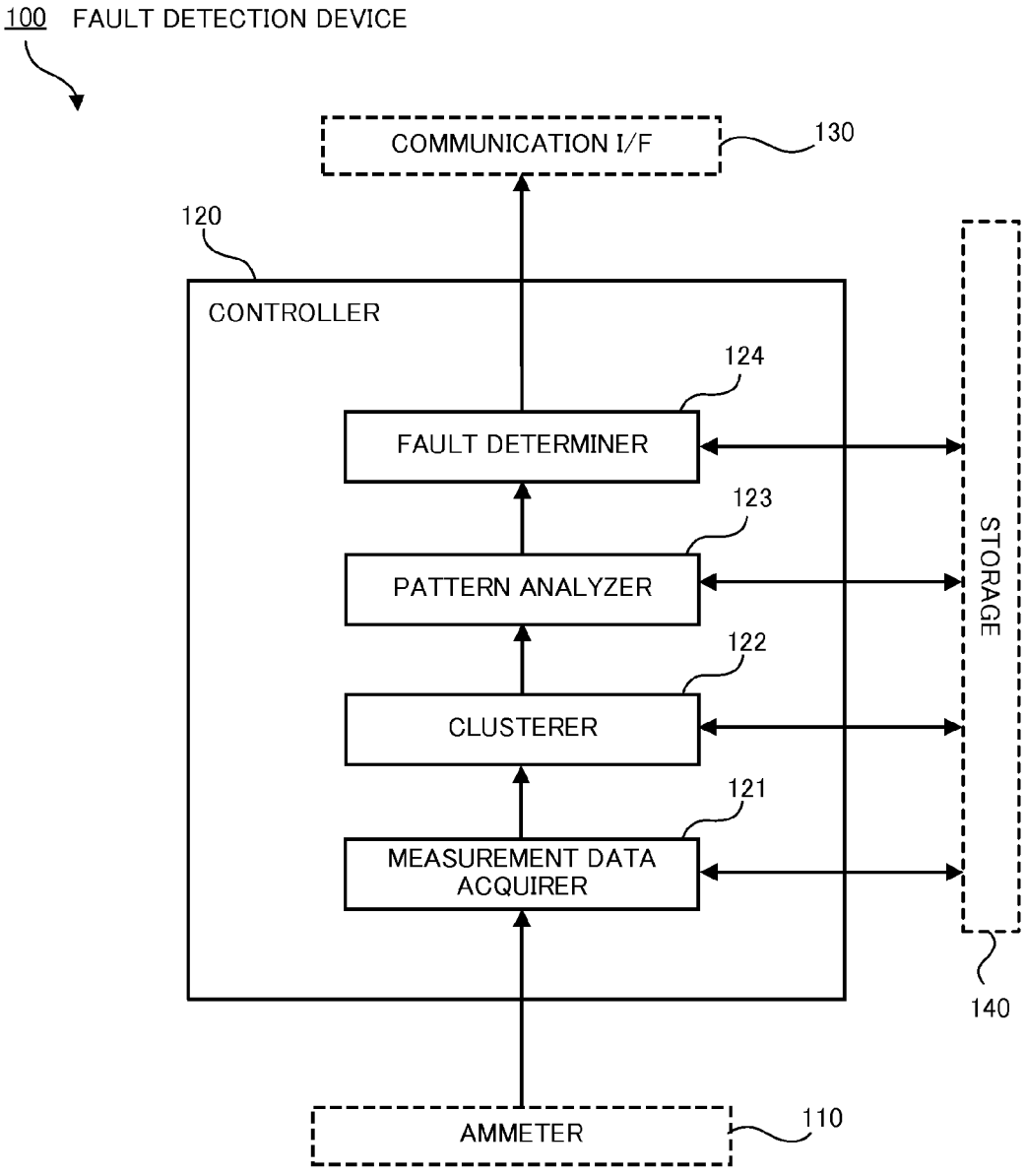
100 FAULT DETECTION DEVICE
COMMUNICATION I/F
130
120
CONTROLLER
124
FAULT DETERMINER
123
PATTERN ANALYZER
122
CLUSTERER
121
MEASUREMENT DATA ACQUIRER
STORAGE
140
AMMETER
110

FIG. 6

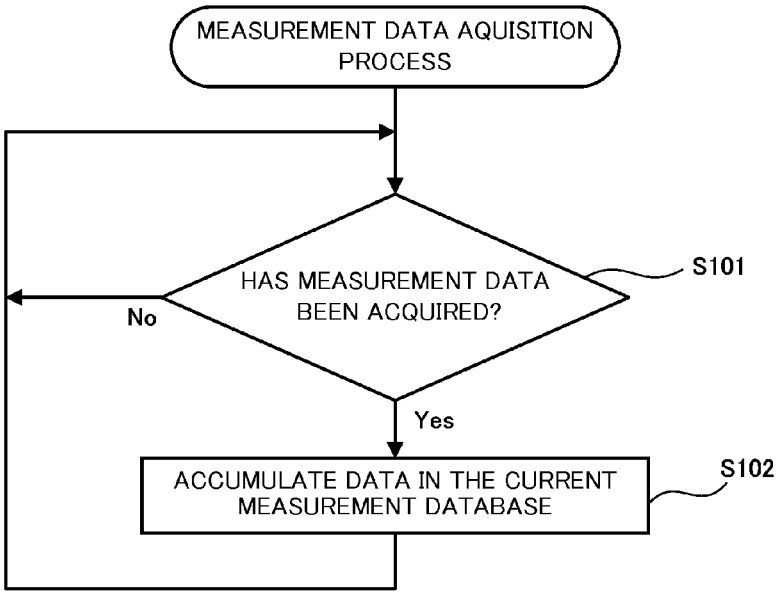

FIG. 7

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CURRENT MEASUREMENT DATABASE

	TIME	FREQUENCY	PHASE	MEASUREMENT DATA
RECORD 1	JANUARY 1 0:00	LOW FREQUENCY	1	0
RECORD 2	JANUARY 1 0:00	LOW FREQUENCY	2	10
:	:	:	:	:
RECORD 400	JANUARY 1 0:00	LOW FREQUENCY	400	0
RECORD 401	JANUARY 1 0:00	MID FREQUENCY	1	20
:	:	:	:	:
RECORD 1200	JANUARY 1 0:00	HIGH FREQUENCY	400	60
RECORD 1201	JANUARY 1 0:01	LOW FREQUENCY	1	0
:	:	:	:	:

FIG. 8

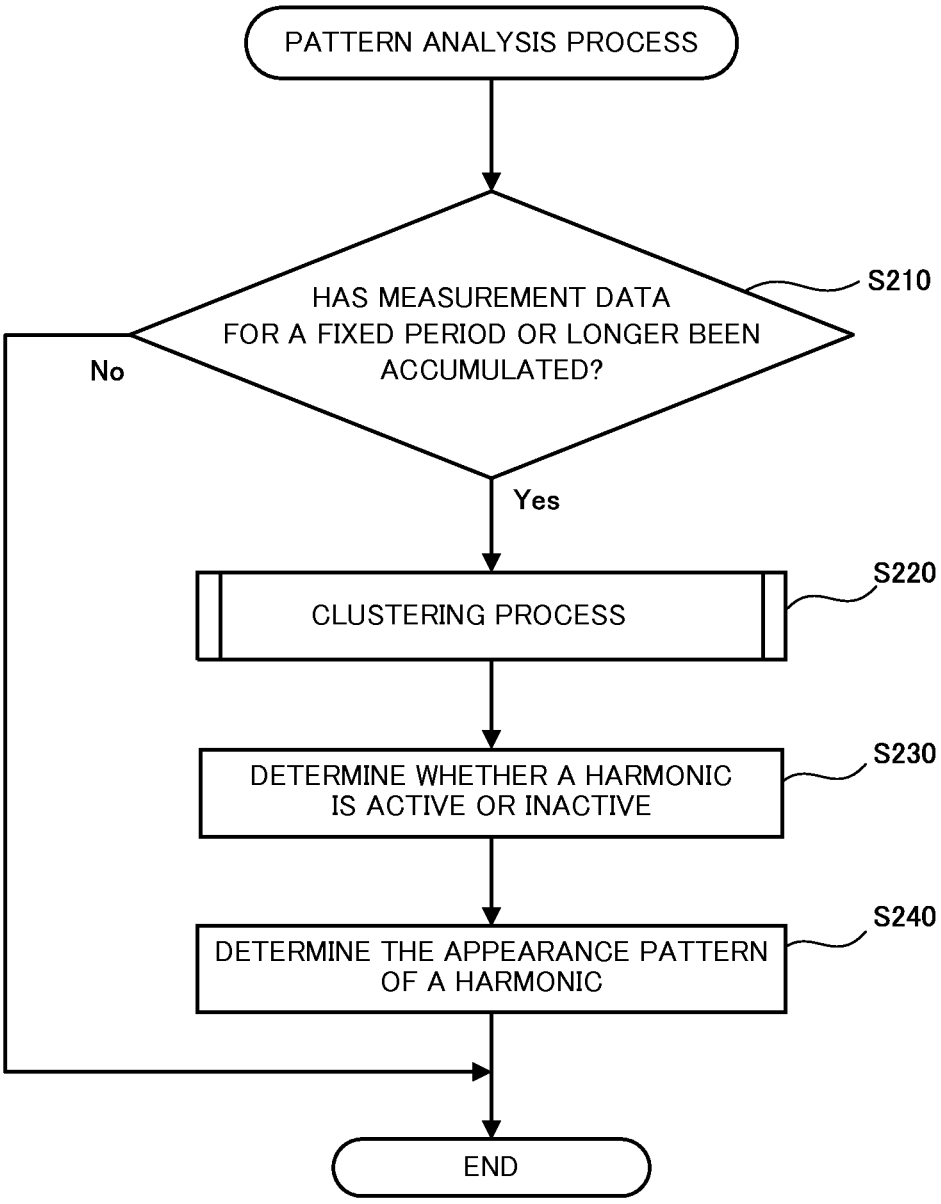
PATTERN ANALYSIS PROCESS
HAS MEASUREMENT DATA FOR A FIXED PERIOD OR LONGER BEEN ACCUMULATED?
S210
No
Yes
CLUSTERING PROCESS
S220
DETERMINE WHETHER A HARMONIC IS ACTIVE OR INACTIVE
S230
DETERMINE THE APPEARANCE PATTERN OF A HARMONIC
S240
END

FIG. 9

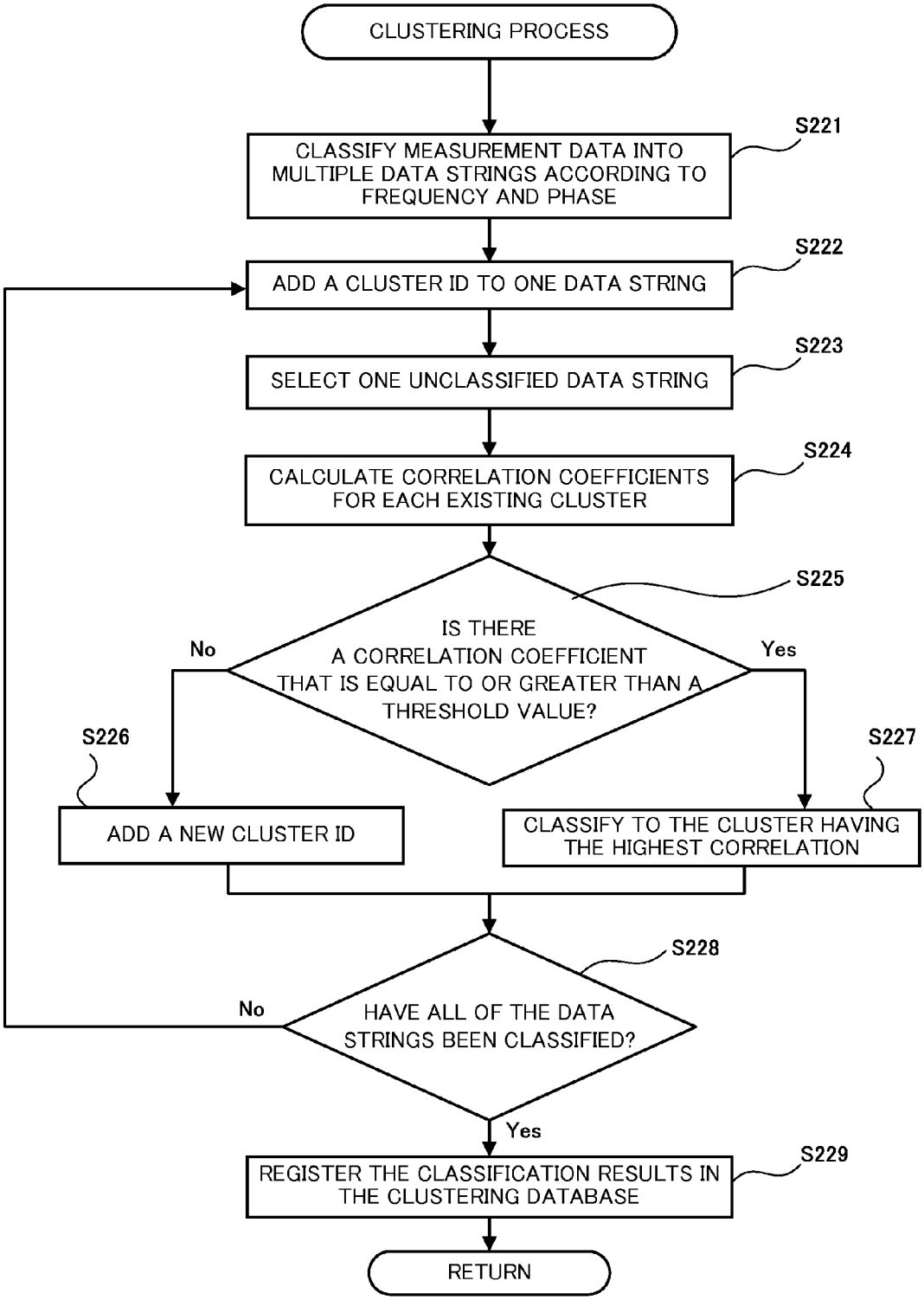
CLUSTERING PROCESS
S221
CLASSIFY MEASUREMENT DATA INTO MULTIPLE DATA STRINGS ACCORDING TO FREQUENCY AND PHASE
S222
ADD A CLUSTER ID TO ONE DATA STRING
S223
SELECT ONE UNCLASSIFIED DATA STRING
S224
CALCULATE CORRELATION COEFFICIENTS FOR EACH EXISTING CLUSTER
S225
IS THERE A CORRELATION COEFFICIENT THAT IS EQUAL TO OR GREATER THAN A THRESHOLD VALUE?
No
Yes
S226
ADD A NEW CLUSTER ID
S227
CLASSIFY TO THE CLUSTER HAVING THE HIGHEST CORRELATION
S228
HAVE ALL OF THE DATA STRINGS BEEN CLASSIFIED?
No
Yes
S229
REGISTER THE CLASSIFICATION RESULTS IN THE CLUSTERING DATABASE
RETURN

FIG. 10A

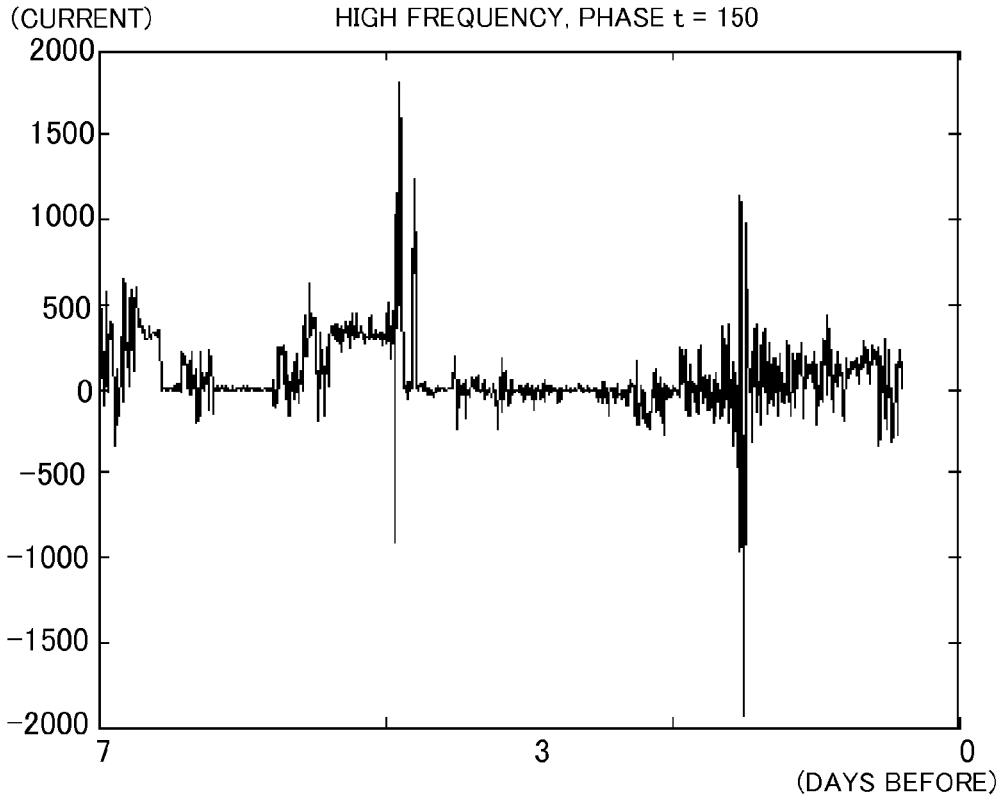

FIG. 10B

	MEASUREMENT DATA
DATA STRING 1	MEASUREMENT DATA FOR LOW-FREQUENCY, PHASE t = 1
DATA STRING 2	MEASUREMENT DATA FOR LOW-FREQUENCY, PHASE t = 2
⋮	⋮
DATA STRING 400	MEASUREMENT DATA FOR LOW-FREQUENCY, PHASE t = 400
DATA STRING 401	MEASUREMENT DATA FOR MID-FREQUENCY, PHASE t = 1
⋮	⋮
DATA STRING 1199	MEASUREMENT DATA FOR HIGH-FREQUENCY, PHASE t = 399
DATA STRING 1200	MEASUREMENT DATA FOR HIGH-FREQUENCY, PHASE t = 400

FIG. 11A

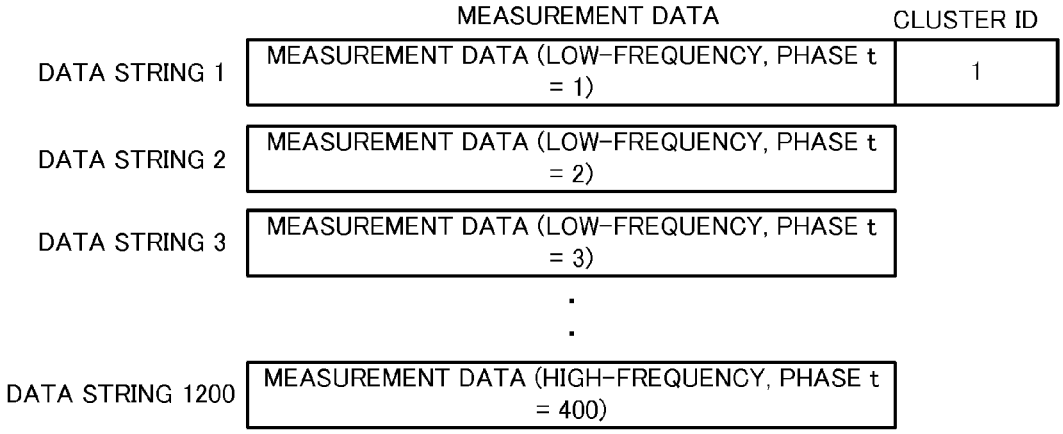

FIG. 11B

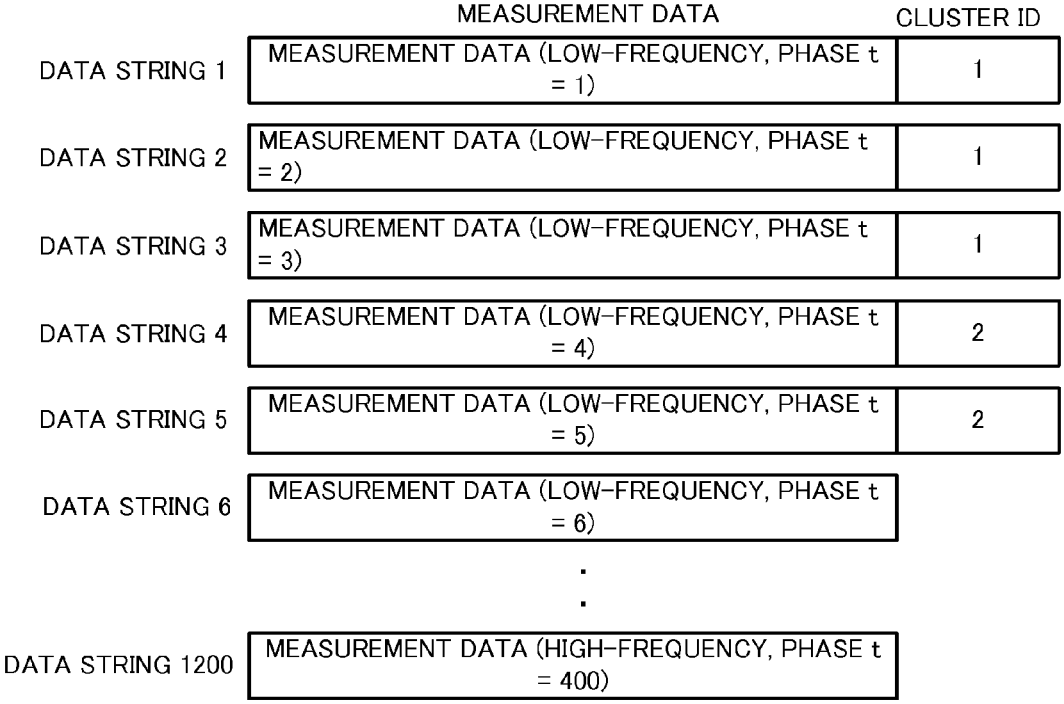

FIG. 12

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CLUSTERING DATABASE

	FREQUENCY	STARTING PHASE	ENDING PHASE	CLUSTER ID
RECORD 1	HIGH FREQUENCY	1	3	1
:	:	:	:	:
RECORD 11	HIGH FREQUENCY	145	160	7
RECORD 12	HIGH FREQUENCY	190	210	7
RECORD 13	HIGH FREQUENCY	340	370	7
RECORD 14	MID FREQUENCY	140	160	7
RECORD 15	MID FREQUENCY	340	360	7
RECORD 16	LOW FREQUENCY	140	160	7
RECORD 17	LOW FREQUENCY	340	360	7
:	:	:	:	:

FIG. 13

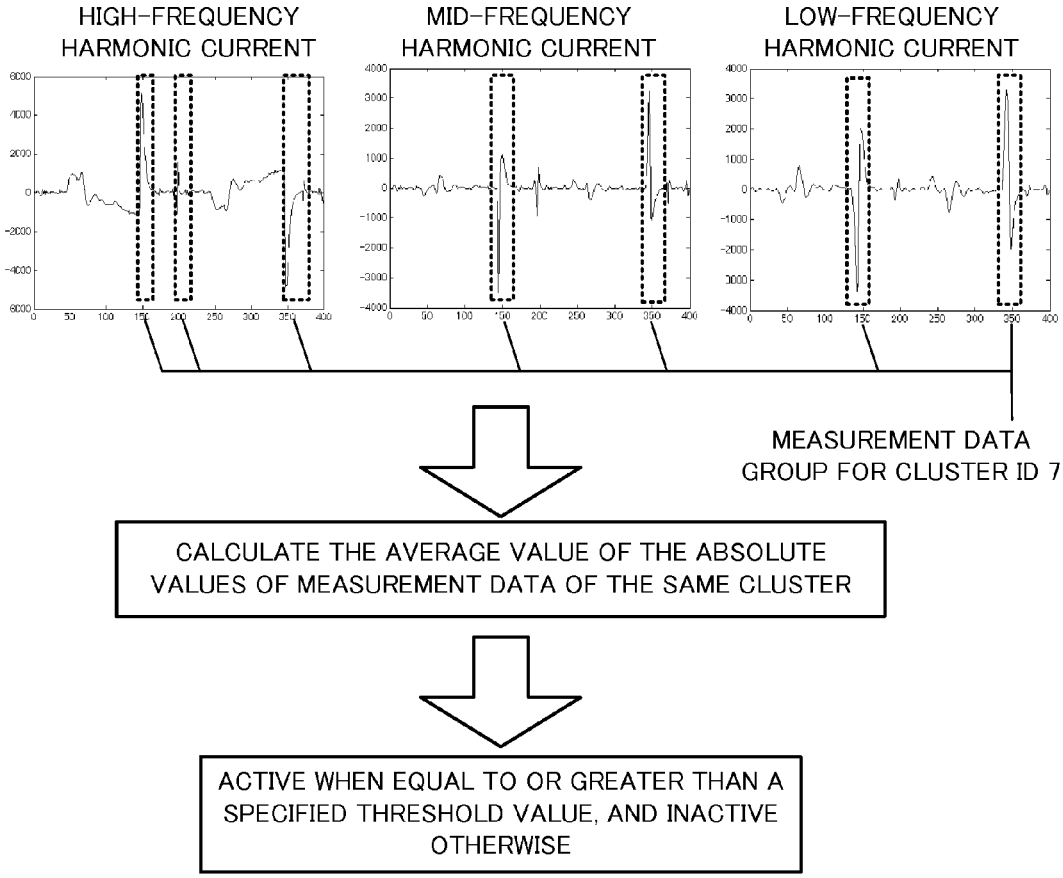

FIG. 14

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ACTIVE DETERMINATION DATABASE

	TIME	CLUSTER ID	STATE
RECORD 1	0:00	1	ACTIVE
RECORD 2	0:01	1	ACTIVE
:	:	:	:

FIG. 15

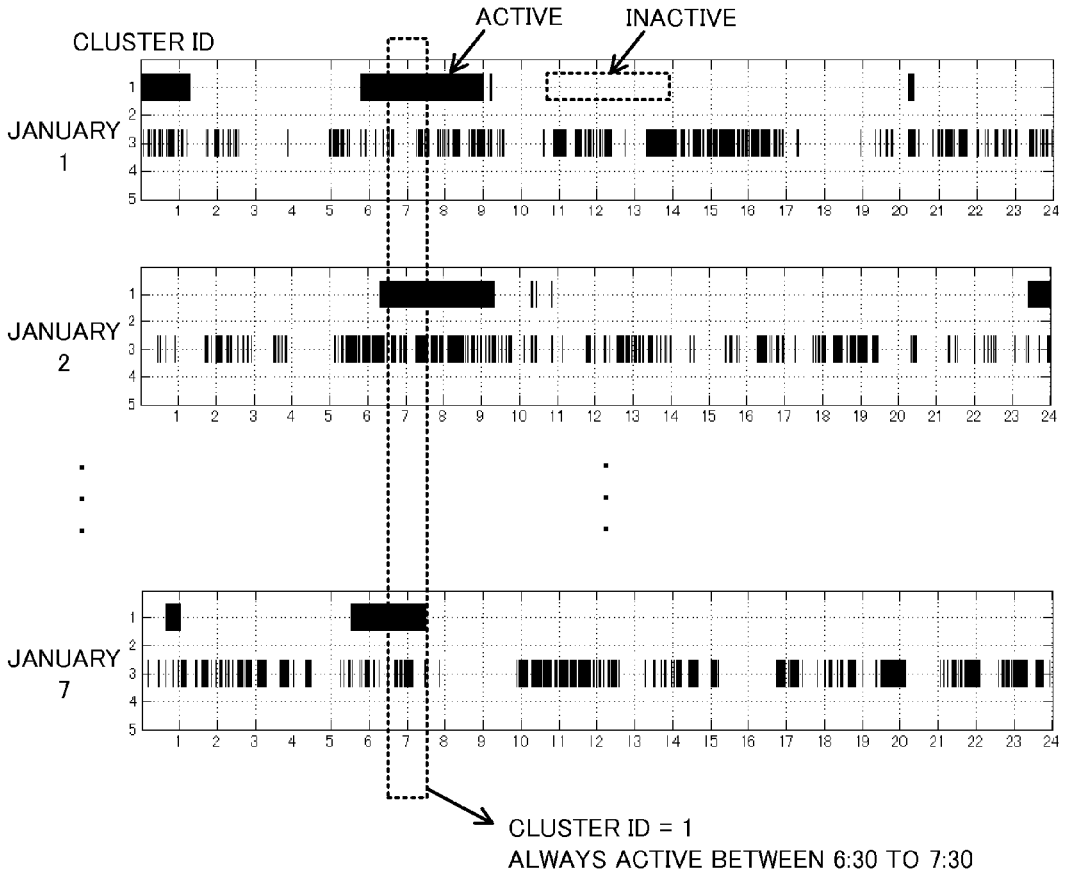

CLUSTER ID
ACTIVE
INACTIVE
JANUARY 1
JANUARY 2
JANUARY 7
CLUSTER ID = 1
ALWAYS ACTIVE BETWEEN 6:30 TO 7:30

FIG. 16

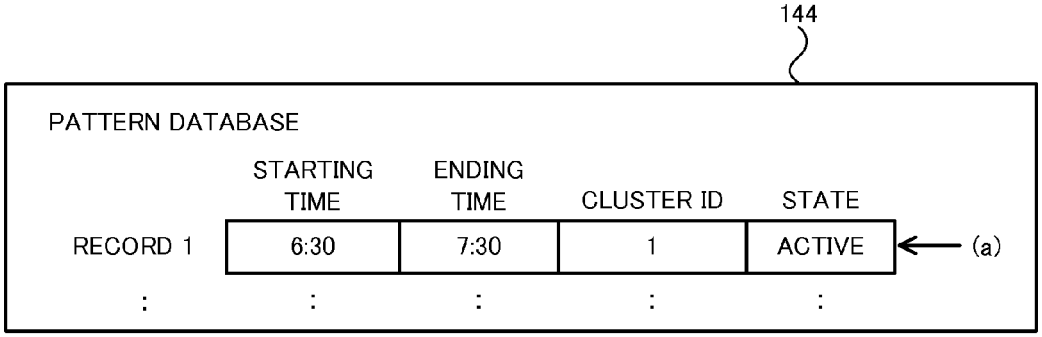

144
PATTERN DATABASE
STARTING TIME
ENDING TIME
CLUSTER ID
STATE
RECORD 1
6:30
7:30
1
ACTIVE
(a)

FIG. 17

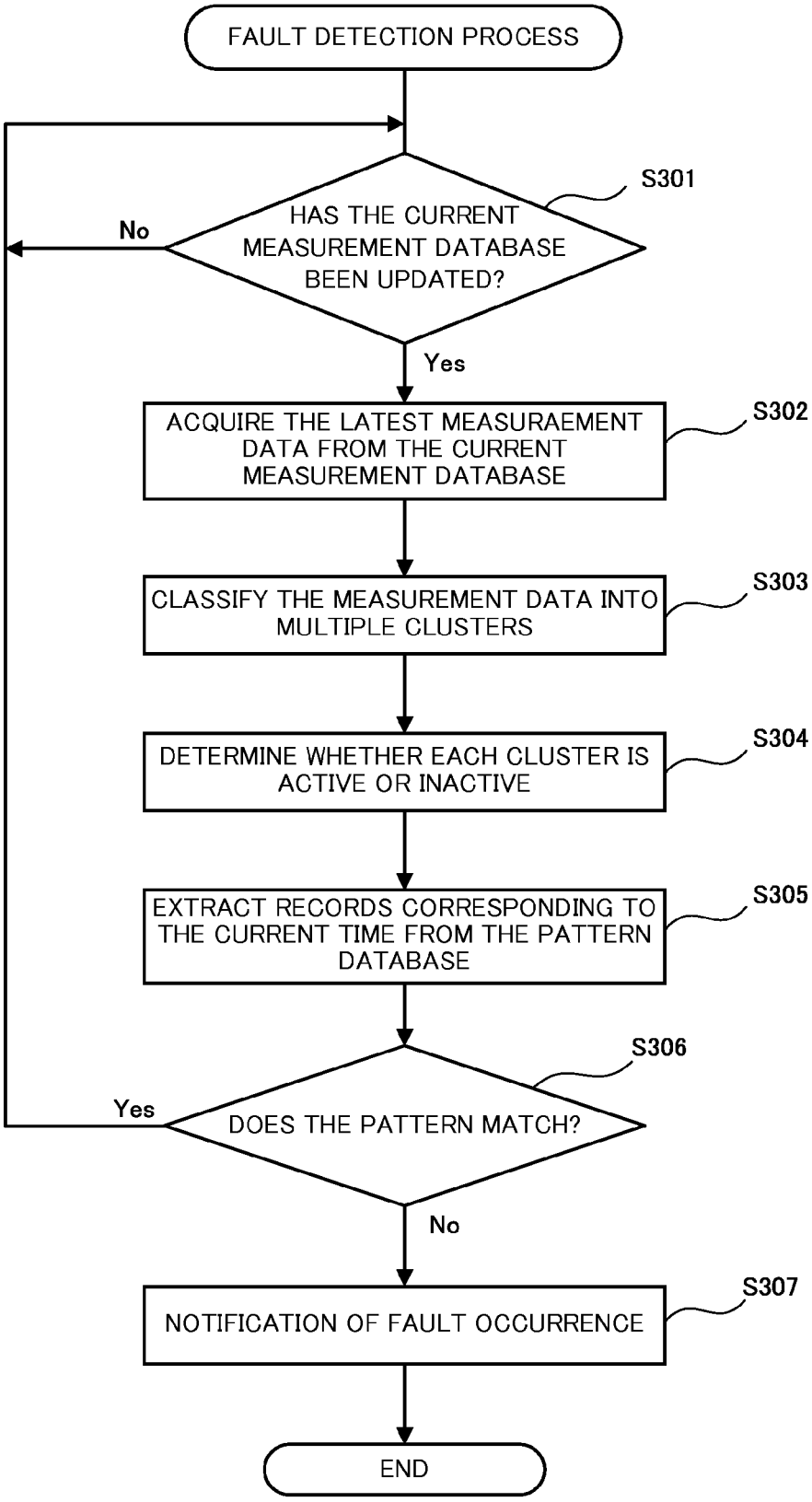
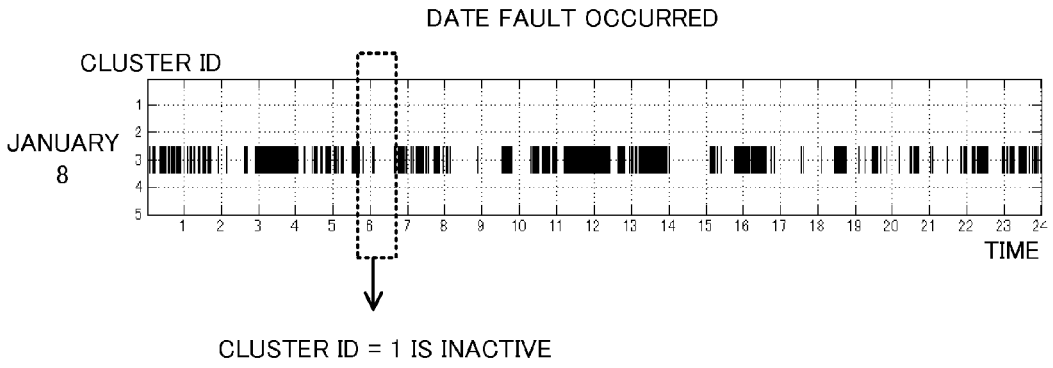

FAULT DETECTION PROCESS
S301
HAS THE CURRENT MEASUREMENT DATABASE BEEN UPDATED?
No
Yes
S302
ACQUIRE THE LATEST MEASURAEMENT DATA FROM THE CURRENT MEASUREMENT DATABASE
S303
CLASSIFY THE MEASUREMENT DATA INTO MULTIPLE CLUSTERS
S304
DETERMINE WHETHER EACH CLUSTER IS ACTIVE OR INACTIVE
S305
EXTRACT RECORDS CORRESPONDING TO THE CURRENT TIME FROM THE PATTERN DATABASE
S306
DOES THE PATTERN MATCH?
Yes
No
S307
NOTIFICATION OF FAULT OCCURRENCE
END

FIG. 18


DATE FAULT OCCURRED
CLUSTER ID
JANUARY 8
1
2
3
4
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TIME
CLUSTER ID = 1 IS INACTIVE

FAULT DETECTION DEVICE, FAULT DETECTION METHOD, AND PROGRAM

TECHNICAL FIELD

[0001] The present disclosure relates to a fault detection device, a fault detection method and a program.

BACKGROUND ART

[0002] There is a need for a system for remotely checking the safety of family members and close relatives. For example, Patent Literatures 1 to 7 disclose a device that performs a safety check of inhabitants based on a change in current that occurs during operation of an electrical device that is installed in a house. Moreover, Patent Literature 8 discloses a device that performs a safety check of inhabitants based on a change in the amount of electric power used.

CITATION LIST

Patent Literature

[0003] Patent Literature 1: Unexamined Japanese Patent Application Kokai Publication No. 2002-109663

[0004] Patent Literature 2: Unexamined Japanese Patent Application Kokai Publication No. 2000-292465

[0005] Patent Literature 3: Unexamined Japanese Patent Application Kokai Publication No. 2008-107885

[0006] Patent Literature 4: Unexamined Japanese Patent Application Kokai Publication No. 2007-48265

[0007] Patent Literature 5: Unexamined Japanese Patent Application Kokai Publication No. 2007-183890

[0008] Patent Literature 6: Unexamined Japanese Patent Application Kokai Publication No. 2009-43141

[0009] Patent Literature 7: Unexamined Japanese Patent Application Kokai Publication No. 2011-43984

[0010] Patent Literature 8: Unexamined Japanese Patent Application Kokai Publication No. 2008-112267

SUMMARY OF INVENTION

Technical Problem

[0011] As the number of electrical devices installed inside a house increases, the current waveform of the current flowing on the power supply lines becomes complex. Normally, many electrical devices are installed inside a house, so as disclosed in Patent Literatures 1 to 7, it is not possible to accurately detect when an inhabitant has a problem by a device that simply monitors only the electric current. Moreover, recently, there are many electrical devices that automatically start and stop without an inhabitant operating the device. Therefore, as disclosed in Patent Literature 8, it is not possible to accurately detect when an inhabitant has a problem simply by a device that monitors only the amount of electric power used.

[0012] Taking into considerations the problems above, the objective of the present disclosure is to provide a fault detection device, a fault detection method and a program that can accurately detect when an inhabitant has a problem.

Solution to Problem

[0013] The fault detection device of the present disclosure, comprises: measurement data acquisition means for acquiring measurement data for current flowing through power supply lines connected to multiple electrical devices; clustering means for classifying the measurement data for a past fixed period into multiple clusters based on at least one of frequency and phase with respect to an AC cycle; pattern analysis means for analyzing each of the clusters for an appearance pattern of the measurement data that satisfy a preset standard; and fault determination means for determining an occurrence of a fault when measurement data that differs from the analyzed appearance pattern is acquired.

Advantageous Effects of Invention

[0014] According to the present disclosure, a fault detection device, fault detection method and program capable of accurately detecting when an inhabitant has a problem can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0015] FIG. **1** is a drawing for explaining the installation state of a fault detection device of an embodiment of the present disclosure;

[0016] FIG. **2** is a block diagram of a fault detection device of an embodiment of the present disclosure;

[0017] FIG. **3** is a diagram illustrating the state when the electric current measured by the ammeter in FIG. **2** is divided into three frequency bands;

[0018] FIG. **4**A is a graph for explaining the harmonic current that is measured by the ammeter in FIG. **2**, and is a graph illustrating the fundamental frequency component that is removed from a secondary current that was generated by a current sensor;

[0019] FIG. **4**B is a graph for explaining the harmonic current that is measured by the ammeter in FIG. **2**; and is a graph illustrating the fundamental frequency component that is removed from the fundamental frequency component;

[0020] FIG. **5** is a function block diagram for explaining the functions of the controller that is illustrated in FIG. **2**;

[0021] FIG. **6** is a flowchart for explaining a measurement data acquisition process;

[0022] FIG. **7** is a diagram for explaining a current measurement database that is stored in the storage illustrated in FIG. **2**;

[0023] FIG. **8** is a flowchart for explaining a pattern analysis process;

[0024] FIG. **9** is a flowchart for explaining a clustering process;

[0025] FIG. **10**A is a graph for explaining one of multiple classified data strings;

[0026] FIG. **10**B is a diagram illustrating a state when measurement data is classified into multiple data strings;

[0027] FIG. **11**A is a diagram for explaining a state in which data strings are classified into multiple clusters;

[0028] FIG. **11**B is a diagram for explaining a state in which data strings are classified into multiple clusters;

[0029] FIG. **12** is a diagram for explaining a clustering database that is stored in the storage illustrated in FIG. **2**;

[0030] FIG. **13** is a diagram for explaining a state in which measurement data for the same time and same cluster is extracted from the current measurement database;

[0031] FIG. **14** is a diagram for explaining an active determination database that is stored in the storage illustrated in FIG. **2**;

[0032] FIG. **15** is a diagram that illustrates the active/inactive determination results for one week for a specific cluster;

[0033] FIG. **16** is a diagram for explaining a pattern database that is stored in the storage that is illustrated in FIG. **2**;

[0034] FIG. **17** is a flowchart for explaining a fault detection process; and

[0035] FIG. **18** is a diagram that illustrates the active/inactive determination results for **24** hours for a specific cluster.

DESCRIPTION OF EMBODIMENTS

[0036] In the following, an embodiment of the present disclosure will be explained while referencing the drawings.

[0037] When an electrical device is connected to an AC power supply, the current waveform does not become a nice sine wave, but becomes a deformed waveform that includes a harmonic component. Deformation of the waveform (in other words, the harmonic component that is included in the waveform) changes according to the operating state of the electrical device. Therefore, by analyzing the waveform of the electric current that flows inside a house, it is possible to check the operating state of electrical devices inside the house.

[0038] A fault detection device **100** of an embodiment of the present disclosure detects when an inhabitant has a problem based on the operating state of electrical devices that are identified by the waveform of current that is flowing inside the house. More specifically, the fault detection device **100** accumulates measurement data for current that flows on the main line (electric power supply line from the service entrance for the electric supply line to the power distribution panel such as illustrated in FIG. **1**) inside the house that is directly or indirectly connected to multiple electrical devices. Then, the fault detection device **100** uses the accumulated measurement data to identify an operating pattern for electrical devices that are installed inside the house. The fault detection device **100** determines that a problem occurred when the operating state of an electrical device that is identified by the current waveform differs from the identified operating pattern, and notifies a monitoring server **200** in a remote location by way of a network. In the following this fault detection device **100** will be explained in detail.

[0039] The fault detection device **100**, as illustrated in FIG. **2**, comprises an ammeter **110**, a controller **120**, a communication interface **130** and a storage **140**.

[0040] The ammeter **110** is a device for measuring the harmonic current that flows on the power supply line. In this embodiment, the "harmonic current" is current that does not include the fundamental frequency component (for example, 50 Hz or 60 Hz commercial frequency component), and not only includes current that comprises just the harmonic component of integral multiples of the fundamental frequency component, but also includes current that includes a noise component that occurs singly.

[0041] The ammeter **110** comprises a load resistor, a filter circuit, an amplifier, an AD converter and a memory. The ammeter **110** is connected to a clamp type current sensor **111**. The current sensor **111** is located on the main line inside the house (for example, as illustrated in FIG. **1**, from the service entrance for the electric supply line to the power distribution panel) so that the total current of all of the electrical devices that are used inside the house can be observed at one location. The current sensor **111**, for example, has a current transformer structure in which a coil is wound around an electromagnetic core, and generates a secondary current by transforming the current that flows on the power supply line with a current transformation ratio of 1 to 3000. The ammeter **110** uses three kinds of band-pass filters (hereafter referred to as "high-frequency BPF", "mid-frequency BPF" and "low-frequency BPF") to separate the generated secondary current into three kinds of harmonic currents (hereafter referred to as, "high-frequency harmonic current", "mid-frequency harmonic current" and "low-frequency harmonic current") having different frequency bands as illustrated in FIG. **3**. Then, the ammeter **110** uses an AD converter to generate digital data for each of the three kinds of harmonic currents. As an example, the ammeter **110** measures harmonic current as described below.

[0042] The ammeter **110** converts fluctuation of the current to fluctuation of the voltage by passing the secondary current that was outputted from the current sensor **111** through a load resistor that has a resistance of tens of Ω to thousands of Ω. The ammeter **110** applies the high-frequency BPF, mid-frequency BPF and low-frequency BPF to the converted voltage and divides the harmonic current into high-frequency harmonic current, mid-frequency harmonic current and low-frequency harmonic current. The high-frequency BPF is a band-pass filter that allows 10 KHz to 5 KHz, for example, to pass. The high-frequency harmonic current that is obtained by passing through the high-frequency BPF includes a harmonic component that is generated particularly by a microwave oven and the like. Moreover, the mid-frequency BPF is a band-pass filter that allows 5 KHz to 2.5 KHz, for example to pass. The mid-frequency harmonic current that is obtained by passing through the mid-frequency BPF includes a harmonic component that is generated particularly by an air conditioner and the like. Furthermore, the low-frequency BPF is a band-pass filter that allows 2.5 KHz to 1.25 KHz, for example to pass. The low-frequency harmonic current that is obtained by passing through the low-frequency BPF includes a harmonic component that is generated particularly by a vacuum cleaner and the like. In this way, the frequencies of the harmonics that are generated by electrical devices differ, so by separating the current according to frequency, it is possible to separate well the characteristics of the harmonics.

[0043] The ammeter **110** uses the AD converter to convert signals of the three frequency bands that passed through the band-pass filters to digital data. When the sampling rate for the data is set to 20 KHz for example, the ammeter **110**, as illustrated in FIG. **4**A, performs simultaneous measurement for the time from the zero-cross point where the voltage changes from negative to positive to the next zero-cross point where the voltage changes from negative to positive (performs measurement for 20 milliseconds in regions where the commercial frequency is 50 Hz). The ammeter **110** divides the phase from 0° to 360° into 400 divisions for example, and in the simultaneous measurement, performs measurements for 400 points. As a result, the ammeter **110** is able to acquire a harmonic waveform such as illustrated in FIG. **4**B. In order to make the following explanation easier to understand, the first point in the AC cycle is taken to be phase t=1, and the point that is measured last is taken to be phase t=400. In the simultaneous measurement, measurement is performed for 400 points for each of the three frequency bands, so the ammeter **110** is able to acquire measurement data for a total of 1200 points (current values or voltage values) in one measurement. The ammeter **110** continually transmits the acquired data for the 1200 points to the controller **120**. The ammeter **110** can also perform measurement each time a zero-cross from negative to positive is detected, or can also perform measurement at specified time intervals. In order to make the explanation below easier to understand, the amme-

ter **110** measures the harmonic current and transmits the results to the controller **120** at 1-minute intervals.

[0044] Returning to FIG. **2**, the controller **120** comprises a processing device such as a processor. The controller **120** operates according to a program that is stored in ROM (Read Only Memory) or RAM (Random Access Memory) (not illustrated in the figure), and executes various processing that includes a "measurement data acquisition process", "pattern analysis process" and "fault detection process" that will be described later. By executing the "measurement data acquisition process", "pattern analysis process" and "fault detection process", the controller **120**, as illustrated in FIG. **5**, functions as a measurement data acquirer **121**, a clusterer **122**, a pattern analyzer **123**, and a fault determiner **124**. These functions will be described later in the explanations of the "measurement data acquisition process", "pattern analysis process" and "fault detection process".

[0045] Returning to FIG. **2**, the communication interface **130** comprises a network connection interface such as a LAN (Local Area Network) device. The communication interface **130**, by way of a network such as a LAN (Local Area Network), WAN (Wide Area Network), telephone lines (mobile telephone network, fixed telephone network, and the like), the Internet and the like, transmits various kinds of data such as fault detection results and the like to a monitoring server **200** that is located at a remote location.

[0046] The storage **140** comprises a readable/writable storage device such as a DRAM (Dynamic Random Access Memory), SRAM (Static Random Access Memory), flash memory, hard disk and the like. The storage **140** stores various kinds of databases such as a "current measurement database", a "clustering database", an "active determination database", a "pattern determination database" and the like. The contents of these databases will be explained later in the explanations of the "measurement data acquisition process", "pattern analysis process" and "fault detection process".

[0047] Next, the operation of a fault detection device **100** having such a construction will be explained.

[0048] The controller **120** of the fault detection device **100** simultaneously executes the "measurement data acquisition process", "pattern analysis process" and "fault detection process" by operating according to a multi-process (multi-task) type of operating system. First the "measurement data acquisition process" will be explained.

[0049] When the power is turned ON to the fault detection device **100**, the controller **120** starts the "measurement data acquisition process". In the following, the "measurement data acquisition process" will be explained with reference to the flowchart in FIG. **6**.

[0050] The measurement data acquirer **121** of the controller **120** determines whether measurement data for 1200 points (400 points each for low frequency, mid frequency and high frequency) in one AC cycle that was transmitted in 1-minute intervals from the ammeter **110** was acquired (step S**101**). When measurement data has not been acquired (step S**101**: NO), the measurement data acquirer **121** repeats step S**101** until measurement data is acquired. When measurement data has been acquired (step S**101**: YES), processing advances to step S**102**.

[0051] The measurement data acquirer **121** adds the "acquisition time", "frequency", and "phase" and creates records for the acquired measurement data of each of the 1200 points, and as illustrated in FIG. **7**, registers those records in a current measurement database **141** (step S**102**). After registration is complete, processing returns to step S**101**, and waits to receive measurement data again.

[0052] Next, the "pattern analysis process" will be explained.

[0053] When the power is turned ON to the fault detection device **100**, the controller **120** executes the "pattern analysis process". The "pattern analysis process" is executed every other day, for example. In the following, the "pattern analysis process" will be explained with reference to the flowchart in FIG. **8**.

[0054] The pattern analyzer **123** of the controller **120** determines whether measurement data for a preset fixed period or more has been accumulated in the current measurement database **141** (for example, measurement data for one week or more) (step S**210**). When measurement data for a fixed period or more has not been accumulated (step S**210**: NO), the pattern analyzer **123** ends the pattern analysis process. When measurement data for a fixed period or more has been accumulated (step S**210**: YES), processing advances to step S**220**.

[0055] The phase in which the harmonics easily appear differs for each electrical device. There are electrical devices for which the harmonics easily appear near the peak of the sine wave (in FIG. **4**A for example, near the phase t=100, or t=300), and there are also electrical devices for which the harmonics easily appear near the zero-cross from positive to negative (in FIG. **4**A for example, near the phase t=200). In other words, the harmonics that electrical devices generate have different frequencies and different phases for each electrical device. By classifying measurement data for each electrical device based on the relationship between the electrical device and the frequency and phase, it is possible to obtain highly accurate analysis results that are equivalent to the analysis results when a measurement device is installed for each electrical device. Therefore, the clusterer **122** of the controller **120** executes a clustering process that classifies measurement data into multiple groups (hereafter, referred to as "clusters") based on frequency and phase information that is correlated with the measurement data (step S**220**). In the following, the "clustering process" will be explained with reference to the flowchart in FIG. **9**.

[0056] The clusterer **122** classifies measurement data for a past fixed period registered in the current measurement database **141** into multiple data strings according to frequency and phase (step S**221**). In order to more easily understand step S**221**, FIG. **10**A is a graph illustrating an example of one of multiple classified data strings, where the vertical axis is the electrical current, and the horizontal axis is the time (days before). More specifically, FIG. **10**A is an example in which a record for which the frequency is "high frequency" and the phase t is "150" is extracted from records for the past one week (seven days of records counting from yesterday) that are registered in the current measurement database **141**, and illustrates a data string that is generated by arranging measurement data that is stored in that extracted record in order of acquisition (order of measured time). When measurement data for 1200 points is acquired in one AC cycle, 1200 data strings such as this are generated as illustrated in FIG. **10**B.

[0057] Returning to the flowchart in FIG. **9**, the clusterer **122** selects one data string from among the classified multiple data strings, and adds an arbitrary cluster ID (step S**222**). FIG. **11**A is an example in which "data string 1" is selected from among 1200 classified data strings, and "1" is added as a cluster ID.

[0058] Returning to the flowchart in FIG. **9**, the clusterer **122** selects one data string from among multiple data strings that does not have a cluster ID added (step S**223**). In the case of the example in FIG. **11**B, one data string is selected from among "data string 6" to "data string 1200" to which a cluster ID has not yet been added.

[0059] Returning to the flowchart in FIG. **9**, the clusterer **122** calculates a correlation coefficient for the correlation between the data string selected in step S**223** and cluster strings to which cluster IDs have already been added. When doing this, the clusterer **122** calculates a correlation coefficient for each cluster (step S**224**). For example, in the example in FIG. **11**B, when data string 6 is selected, the clusterer **122** calculates the correlation between one data string from among data strings 1 to 3 to which the cluster ID "1" has been added and data string 6. Furthermore, the clusterer **122** calculates the correlation between one data string selected from among the data strings 4 and 5 to which the cluster ID "2" has been added and data string 6. The clusterer **122** can also calculate a correlation coefficient for the correlation between a data string that is generated by taking the average of data strings to which the same cluster ID has been added and the data string selected in step S**223**, and in the case where data string 6 is selected in step S**223**, the clusterer **122** generates a new data string by taking the average of data strings 1 to 3, and calculates a correlation coefficient for the correlation between that generated data string and data string 6. Furthermore, the clusterer **122** generates a new data string by taking the average of data strings 4 and 5, and calculates a correlation coefficient for the correlation between that generated data string and data string 6.

[0060] Returning to FIG. **9**, the clusterer **122** determines whether there is a correlation coefficient among the calculated correlation coefficients that is equal to or greater than a threshold value (step S**225**). When there is no correlation coefficient that is equal to or greater than a threshold value (step S**225**: NO), processing advances to step S**226**. When there is a correlation coefficient that is equal to or greater than a threshold value (step S**225**: YES), processing advances to step S**227**.

[0061] When there is no correlation coefficient that is equal to or greater than a threshold value, the clusterer **122** adds a new cluster ID to the selected data string (step S**226**). For example, in the example in FIG. **11**B described above, when none of the data strings with cluster ID "1" or cluster ID "2" has correlation with data string 6 that is equal to or greater than a threshold value, cluster ID "3" is newly added to data string 6.

[0062] Returning to the flowchart in FIG. **9**, when there is a correlation coefficient that is equal to or greater than a threshold value, the clusterer **122** classifies the selected data string to the cluster having the highest correlation coefficient (step S**227**). For example, in the example in FIG. **11**B described above, when the correlation coefficient for the correlation with cluster ID "1" is the highest, the clusterer **122** adds cluster ID "1" to data string 6. On the other hand, when the correlation coefficient for the correlation with cluster ID "2" is the highest, the clusterer **122** adds cluster ID "2" to data string 6.

[0063] Returning to the flowchart in FIG. **9**, the clusterer **122** determines whether classification of all of the data strings is finished, or in other words, determines whether cluster IDs have been added to all of the data strings (step S**228**). When classification of all of the data strings is not finished, (step S**228**: NO), the clusterer **122** repeats the processing from step S**223** to step S**228** until classification of all of the data strings is finished. When classification of all of the data strings is finished (step S**228**: YES), processing advances to step S**229**.

[0064] The clusterer **122** arranges the classification results, and generates a record that correlates the frequency, phase and cluster ID. Then, as illustrated in FIG. **12** for example, the clusterer **122** registers the generated record in a clustering database **142** (step S**229**). After registration is finished, the clusterer **122** ends the clustering process.

[0065] Returning to the flowchart in FIG. **8**, the pattern analyzer **123** determines at each time for each classified cluster whether measurement data that is equal to or greater than a threshold value (in other words, harmonic) has appeared (step S**230**). In order to make the following explanation easier to understand, when a harmonic has appeared, the term "active" will be used, and when a harmonic has not appeared, the term "inactive" will be used. The pattern analyzer **123** determines, active and inactive in the following way, for example.

[0066] First, the pattern analyzer **123** extracts measurement data for the same time and same cluster from the current measurement database **141** based on the contents of the clustering database **142**. FIG. **13** is an example for making it easier to understand step S**230**, and illustrates measurement data for cluster ID "7" from among measurement data of three frequency bands that were measured at 8:30 on January 1 (measurement data that is specified by records 11 to 17 illustrated in FIG. **12**). The pattern analyzer **123** finds the average value of the absolute values of the extracted measurement data, and determines that the average value is "active" when the average value is equal to or greater than a preset threshold value, and determines that the average value is "inactive" when the average value is less than the threshold value. The pattern analyzer **123** creates a record that correlates the determination results, the cluster ID and the time, and as illustrated in FIG. **14** for example, registers the record in an active determination database **143**.

[0067] Harmonics or noise due to external disturbance occurs singly and not periodically. Harmonics or noise due to the lifestyle of the inhabitant, or in other words, due to the operation of electrical devices by the inhabitant is often repeated over a fixed period (for example, 24-hour period). Therefore, returning to FIG. **8**, the pattern analyzer **123**, identifies, based on the contents of the active determination database **143**, the timing at which a harmonic (in other words measurement data that is determined to be active) appears periodically over a 24-hour period to be a pattern of appearance of a harmonic that is due to the lifestyle of the inhabitant (step S**240**). FIG. **15** is an example for making it easier to understand the processing of step S**240**, and illustrates the active/inactive determination results for one week from January 1 to January 7 according to cluster. In this example, cluster ID "1" is always active from 6:30 to 7:30 over the one week period, so the pattern analyzer **123** is able to determine that the electrical device having cluster ID "1" always operates from 6:30 to 7:30 during the day. The pattern analyzer **123** creates a record that indicates the appearance pattern for the determined harmonic, and registers the record in a pattern database **144** as illustrated in FIG. **16**, for example. After registration is finished, the pattern analyzer **123** ends the pattern analysis process.

[0068] Next, the "fault detection process" will be explained.

[0069] When the power is turned ON to the fault detection device **100**, the controller **120** starts the "fault detection process". In the following, the "fault detection process" will be explained with reference to the flowchart in FIG. **17**.

[0070] The fault determiner **124** of the controller **120** determines whether a new record (in other words, measurement data for 400 points each for high frequency, mid frequency and low frequency, or a total of 1200 points) for one AC cycle has been registered in the current measurement database **141** (steps S**301**). When new measurement data has not been registered (step S**301**: NO), the fault determiner **124** repeats step S**301** until new measurement data has been registered (step S**301**: YES), and then processing advances to step S**302**.

[0071] The fault determiner **124** acquires the **1200** records that were newly registered in the current measurement database **141** (step S**302**).

[0072] The fault determiner **124** classifies the **1200** acquired records into multiple clusters according to frequency and phase based on the contents of the clustering database **142** (step S**303**).

[0073] Using the same method as in step S**230**, the fault determiner **124** determines whether each of the classified clusters is active or inactive (step S**304**).

[0074] The fault determiner **124** uses a timer (not illustrated in the figure) for example to identify the current time. Then, the fault determiner **124** extracts all of the records from the pattern database **144** that correspond to the current time (step S**305**).

[0075] The fault determiner **124** determines whether the determination results in step S**304** match the harmonic appearance pattern identified by the records extracted in step S**305** (step S**306**). FIG. **18** is an example for making it easier to understand the operation of step S**306**, and illustrates a collection of active/inactive determination results in step S**304** over a 24-hour period. For example, when the current time is 7:00 and the fault determiner **124** has extracted records (a) illustrated in FIG. **16**, then the active/inactive determination result at the current time 7:00 in FIG. **18** is "inactive", which is different than the appearance pattern indicated by the extracted records ("active" from 6:30 to 7:30 for cluster ID "1"), so the fault determiner **124** determines that the appearance pattern does not match. When the appearance pattern does not match (step S**306**: NO), processing advances to step S**307**. When the appearance pattern matches (step S**306**: YES), processing returns to step S**301**.

[0076] Returning to the flowchart in FIG. **17**, the fault determiner **124** notifies the monitoring server **200** by way of a network that a fault has occurred (step S**307**). After notification has ended, processing returns to step S**301**, and waits for the current measurement database **141** to be updated.

[0077] Frequencies or phases at which harmonics easily appear differ according to electrical devices. With this embodiment, measurement data is classified into multiple clusters based on frequency and phase, and the appearance patterns of harmonics are analyzed using the classified measurement data, so it is possible to obtain highly precise analysis results that are equivalent to the analysis results when a measurement device is installed for each electrical device in a house. As a result, it is possible to accurately detect when an inhabitant has a problem.

[0078] Moreover, in the conventional technology, characteristics of harmonics were analyzed by analyzing the harmonics for each frequency by method such as a Fourier transform method, however, such a method has a large disadvantage in that it is difficult to obtain information in the timeline direction. However, with this embodiment, the characteristics of harmonics are analyzed by analyzing the harmonics for each frequency using three kinds of band-pass filters, so it is possible to make the most of the information in the timeline direction. As a result, it is possible to accurately and in detail assign the type of harmonic (cluster ID), and thus it is possible to obtain accurate appearance pattern analysis results.

[0079] Moreover, faults are determined by paying attention to timing (for example, time period) when a specified harmonic occurs regardless of what kind of device for which a harmonic occurred, so it is possible to obtain highly accurate determination results even without following the procedure of "learning device harmonics" that was necessary in the conventional technology.

[0080] The embodiment described above is an example, and various modifications and applications are possible.

[0081] For example, in the embodiment described above, the ammeter **110** separated current into three frequency bands by using three kinds of band-pass filters, however, the frequency bands for separation are not limited to three, and for example, it is possible to use two, or four or more. Moreover, the filters that are used for separating the current are not limited to being band-pass filters, and for example, the filters could be low-pass filters, or high-pass filters.

[0082] Furthermore, the method for separating the current is not limited to a method of using a filter circuit, and for example, separation could be performed by digital signal processing that uses a processor. For example, in the ammeter **110** it is possible for the clusterer **122** of the controller **120** to separate the measurement data into multiple frequency bands without using a filter circuit.

[0083] In the embodiment described above, the clusterer **122** classified measurement data of different frequency bands to multiple data strings based on phase, however, the measurement data that is classified, does not necessarily have to be frequency band measurement data. Measurement data that is not separated according to frequency can simply be classified according to phase. Moreover, the clusterer **122** does not necessarily have to classify measurement data based on phase; for example, it is also possible to only separate measurement data according to frequency by digital signal processing. It is possible to obtain analysis results having sufficient accuracy even when the measurement data is classified into multiple clusters based on only the frequency, or based on only the phase.

[0084] Moreover, in the embodiment described above, the clusterer **122** classified classified data strings into multiple clusters based on the correlation between data, however, it is also possible to classify all of the classified data strings into different clusters.

[0085] The pattern analyzer **123** always identified an active time period in a 24-hour period during as an appearance pattern of a harmonic. However, the pattern analyzer **123** can also identify a time period as an appearance pattern of a harmonic even when there is a day or a part of the time during the time period that is not active. For example, the pattern analyzer **123** acquires all of the active/inactive information of a specified cluster (for example, cluster ID "1") for a specified time period (for example, 6:30 to 7:30) during the past one week from the active determination database **143**, and transfers that information to a memory not illustrated in the figure. Then the pattern analyzer **123** calculates the active ratio P by

dividing the number of active data transferred to the memory by the total number of data transferred to the memory. Moreover, the pattern analyzer **123** similarly calculates a ratio of the inactive data as the inactive ratio Q. The relationship P+Q=1 is established. Furthermore, when the active ratio P is greater than an active determination threshold value Pth, the pattern analyzer **123** creates a record that correlates the time period, the cluster ID and the state (active) and registers that record in the pattern database **144**. When the inactive ratio Q is greater than an inactive determination threshold value Qth, the pattern analyzer **123** creates a record that correlates the time period, the cluster ID and the state (inactive) and registers that record in the pattern database **144**.

[0086] The appearance pattern that the pattern analyzer **123** identifies does not necessarily have to be a time period every day. For example, the appearance pattern could be a time period on a specified day of the week, or a time period on weekdays or on weekends.

[0087] The installation location of the current sensor **111** is not limited to being on the power supply line from the electric supply line service entrance to the power distribution panel. The current sensor **111** could be installed in only a specified power supply system (one of multiple power supply lines that branch out from the power distribution panel), or could also be installed near the electric supply line service entrance on the outside of the house. Moreover, the location where the current sensor **111** is installed is not limited to one location. For example, a current sensor **111** could be installed on all of the multiple power supply lines that branch out from the power distribution panel.

[0088] Furthermore, the current sensor **111** is not limited to being a clamp type current sensor, and could be another non-contact type of current sensor such as a Hall current sensor, or a contact-type of current sensor whose terminal makes contact with a power supply line.

[0089] The fault detection device **100** of this embodiment can be achieved by a dedicated system, or can also be achieved by a normal computer system. For example, the fault detection device **100** can be constructed by storing a program for executing the operation described above on a computer-readable recording medium and distributing that recording medium, then installing that program onto a computer and executing the processing described above. Moreover, it is also possible to store the program on a disc drive of a server device on a network such as the Internet, and download that program to a computer. Furthermore, the functions described above can also be achieved by sharing between the OS and application software. In that case, only the part other than the OS can be stored and distributed on a medium, or can be downloaded onto a computer.

[0090] As the recording medium on which the program is recorded, it is possible to use a USB memory, a flexible disk, a CD (Compact disc), a DVD (Digital Versatile Disc), a Blu-ray Disc (registered trademark), a MO (Magneto-Optical disk), a SD memory card (Secure Digital memory card), a memory stick (registered trademark), a magnetic disk, an optical disk, and magneto-optical disk, a semiconductor memory, a magnetic tape and the like that can be read by a computer.

[0091] Various embodiments and variations of the present disclosure are possible within the wide spirit and range of the disclosure. Moreover, the embodiments described above are for explanation of the present disclosure and do not limit the range of the disclosure. In other words, the range of the present disclosure is as presented in the Claims and not the embodiments. Various variations that are within the range of the Claims and within the range of significance of an equivalent disclosure are considered to be within the range of the present disclosure.

[0092] This specification claims priority over Japanese Patent Application No. 2012-264369, as filed on Dec. 3, 2012. Japanese Patent Application No. 2012-264369 is included in its entirety in this specification by reference.

INDUSTRIAL APPLICABILITY

[0093] The present disclosure can be employed for a fault detection device, fault detection method and program that are capable of accurately detecting when an inhabitant has a problem.

REFERENCE SIGNS LIST

[0094] **100** Fault detection device
[0095] **110** Ammeter
[0096] **111** Current sensor
[0097] **120** Controller
[0098] **121** Measurement data acquirer
[0099] **122** Clusterer
[0100] **123** Pattern analyzer
[0101] **124** Fault determiner
[0102] **130** Communication interface
[0103] **140** Storage
[0104] **141** Current measurement database
[0105] **142** Clustering database
[0106] **143** Active determination database
[0107] **144** Pattern database
[0108] **200** Monitoring server

1. A fault detection device, comprising:
a measurement data acquirer configured to acquire measurement data for current flowing through power supply lines connected to multiple electrical devices;
a clusterer configured to classify the measurement data for a past fixed period into multiple clusters based on at least one of frequency and phase with respect to an AC cycle;
a pattern determiner configured to determine, for each cluster of the multiple clusters, an appearance pattern of the measurement data satisfying a preset standard; and
a fault determiner configured to determine that a fault has occurred to an inhabitant when measurement data additionally acquired does not match the appearance pattern determined by the pattern determiner.

2. The fault detection device according to claim **1**, wherein
the clusterer separates or classifies the measurement data for the past fixed period based on at least one of frequency and phase with respect to the AC cycle, and classifies the separated or classified data into the multiple clusters based on a correlation of the data.

3. The fault detection device according to claim **2**, wherein
the clusterer classifies the measurement data for the past fixed period based on the phase with respect to the AC cycle, and classifies the classified data into the multiple clusters based on the correlation of the data.

4. The fault detection device according to claim **2**, wherein
the clusterer classifies the measurement data for the past fixed period based on the frequency, and classifies the classified data into the multiple clusters based on the correlation of the data.

5. The fault detection device according to claim **2**, wherein

the clusterer separates the measurement data for the past fixed period into multiple data based on the frequency, classifies the separated data based on the phase with respect to the AC cycle, and classifies the classified data into the multiple clusters based on the correlation of the data.

6. The fault detection device according to claim **2**, wherein

the measurement data is measurement data measured according to the frequency band by separating the current into two or more frequency bands; and

the clusterer classifies the measurement data of each of the frequency bands based on the phase with respect to the AC cycle, and classifies the classified data into the multiple clusters based on the correlation of the data.

7. (canceled)

8. A fault detection method, comprising:

acquiring measurement data for current flowing on power supply lines connected to multiple electrical devices;

classifying the measurement data for a past fixed period into multiple clusters based on at least one of frequency and phase with respect to an AC cycle;

determining, for each cluster of the multiple clusters, an appearance pattern of the measurement data satisfying a preset standard; and

determining that a fault has occurred to an inhabitant when measurement data additionally acquired does not match the appearance pattern.

9. A non-transitory recording medium storing a program allowing a computer to function as:

a measurement data acquirer configured to acquire measurement data for current flowing on power supply lines connected to multiple electrical devices;

a clusterer configured to classify the measurement data for a past fixed period into multiple clusters based on at least one of frequency and phase with respect to an AC cycle;

a pattern determiner configured to determine, for each cluster of the multiple clusters, an appearance pattern of the measurement data satisfying a preset standard; and

a fault determiner configured to determine that a fault has occurred to an inhabitant when measurement data additionally acquired does not match the appearance pattern determined by the pattern determiner.

10. The fault detection device according to claim **1**, wherein

the pattern determiner determines, as the appearance pattern, a time period during which a rate that the measurement data equal to or greater than a data threshold value periodically appears during a predetermined time period is equal to or greater than a rate threshold value, and

the fault determiner determines that a fault has occurred when the measurement data is less than the data threshold value, the measurement data belonging to a corresponding cluster and being additionally acquired during the time period determined by the pattern determiner.

11. The fault detection device according to claim **10**, wherein

the pattern determiner determines, for each measurement data belonging to the same cluster and acquired at a same time, whether an average value of absolute values of the measurement data is equal to or greater than the data threshold value or not, and determines the time period during which the rate determined to be equal to or greater than the data threshold value periodically during the predetermined time period is equal to or greater than the rate threshold value, and

the fault determiner determines that a fault has occurred when the average value of the absolute values of the measurement data is less than the data threshold value, the measurement data belonging to the corresponding cluster and additionally acquired during the time period determined by the pattern determiner.

* * * * *