US 20160118803A1

(19) **United States**

(12) **Patent Application Publication**

TAKAHASHI et al.

(10) **Pub. No.: US 2016/0118803 A1**

(43) **Pub. Date: Apr. 28, 2016**

(54) **ELECTRICAL GRID CONTROL SYSTEM, ELECTRICAL GRID CONTROL METHOD, AND POWER CONVERSION APPARATUS**

(71) Applicant: **Hitachi, Ltd.**, Tokyo (JP)

(72) Inventors: **Jun TAKAHASHI**, Tokyo (JP); **Masashi TOYOTA**, Tokyo (JP); **Hiroshi YATABE**, Tokyo (JP)

(21) Appl. No.: **14/884,146**

(22) Filed: **Oct. 15, 2015**

(30) **Foreign Application Priority Data**

Oct. 17, 2014 (JP) 2014-212613

Publication Classification

(51) **Int. Cl.**

H02J 4/00	(2006.01)
G05B 15/02	(2006.01)
H02M 3/04	(2006.01)
H02M 7/44	(2006.01)
H02J 3/38	(2006.01)

(52) **U.S. Cl.**

CPC .. ***H02J 4/00*** (2013.01); ***H02M 7/44*** (2013.01); ***H02J 3/383*** (2013.01); ***H02J 3/386*** (2013.01); ***H02M 3/04*** (2013.01); ***G05B 15/02*** (2013.01)

(57) **ABSTRACT**

An electrical grid control system includes a plurality of power conversion apparatuses each storing active power relationship information indicating a relationship between an active power control level representing a level of control for active power output to an electrical grid, and a connection point frequency being a frequency at a connection point to the electrical grid; and a control apparatus that repeatedly receives information indicating a system frequency measured in the electrical grid, determines the active power control level based on the system frequency, and transmits the active power control level to the plurality of power conversion apparatuses. Each power conversion apparatus repeatedly measures the connection point frequency, receives the active power control level from the control apparatus, and controls the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information.

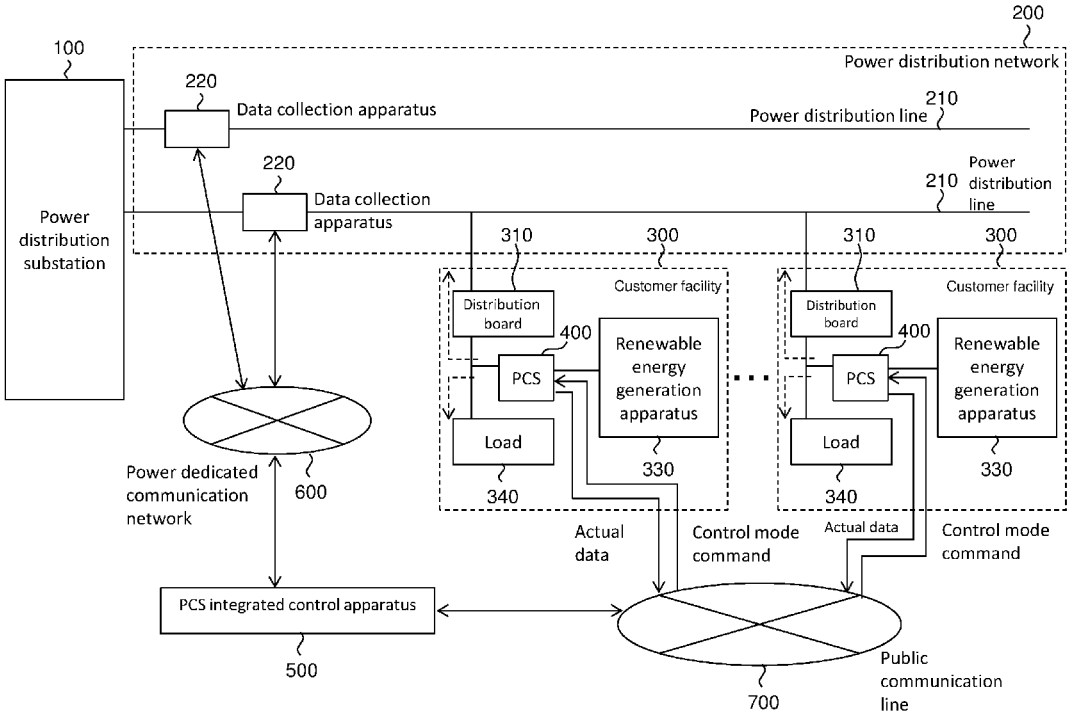


FIG. 1

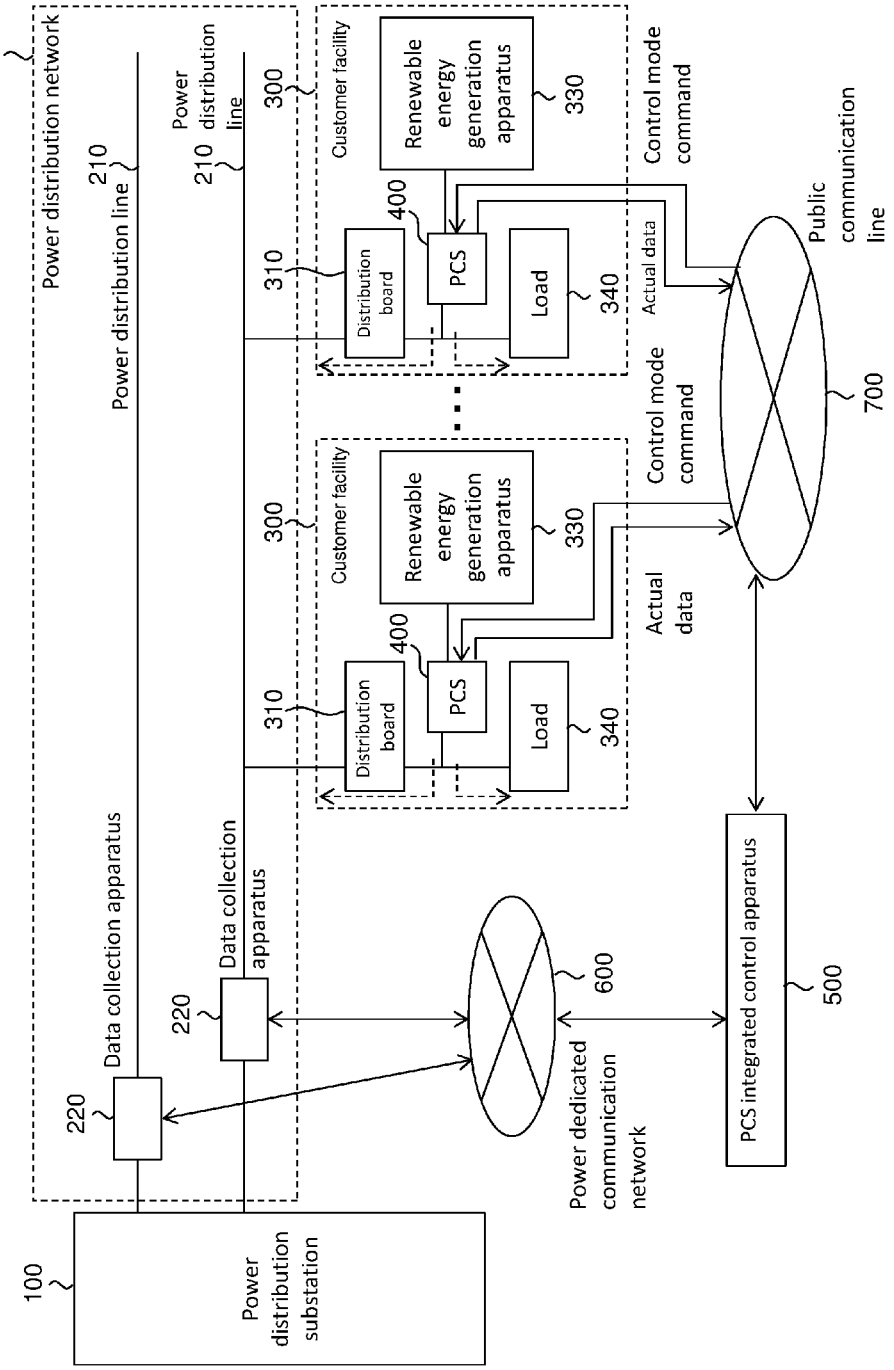

200
Power distribution network
210
Power distribution line
210
Power distribution line
300
Customer facility
Renewable energy generation apparatus
330
400
PCS
Distribution board
310
Load
340
Control mode command
Actual data
Public communication line
700
Data collection apparatus
220
Data collection apparatus
220
600
Power dedicated communication network
PCS integrated control apparatus
500
100
Power distribution substation

FIG. 2

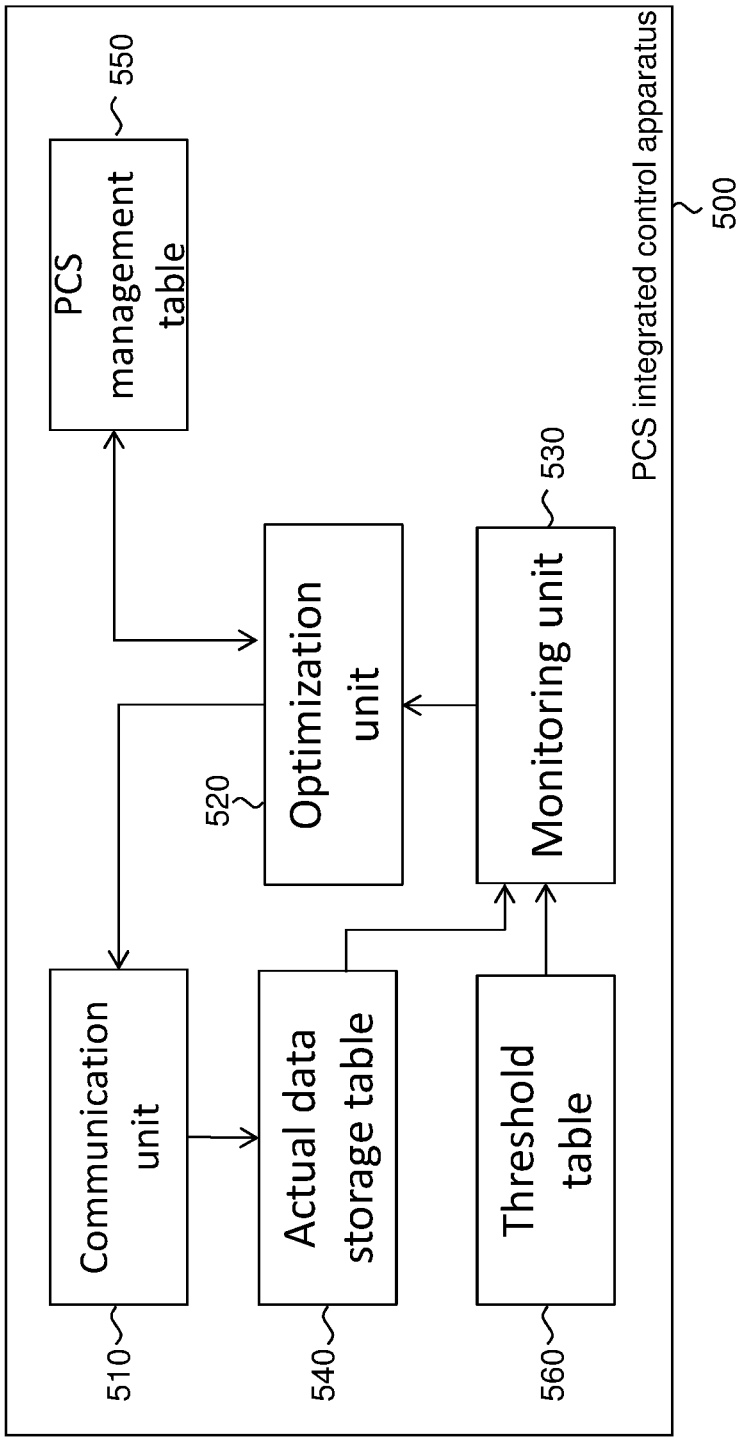

PCS integrated control apparatus
500
PCS management table
550
Optimization unit
520
Monitoring unit
530
Communication unit
510
Actual data storage table
540
Threshold table
560

FIG. 3

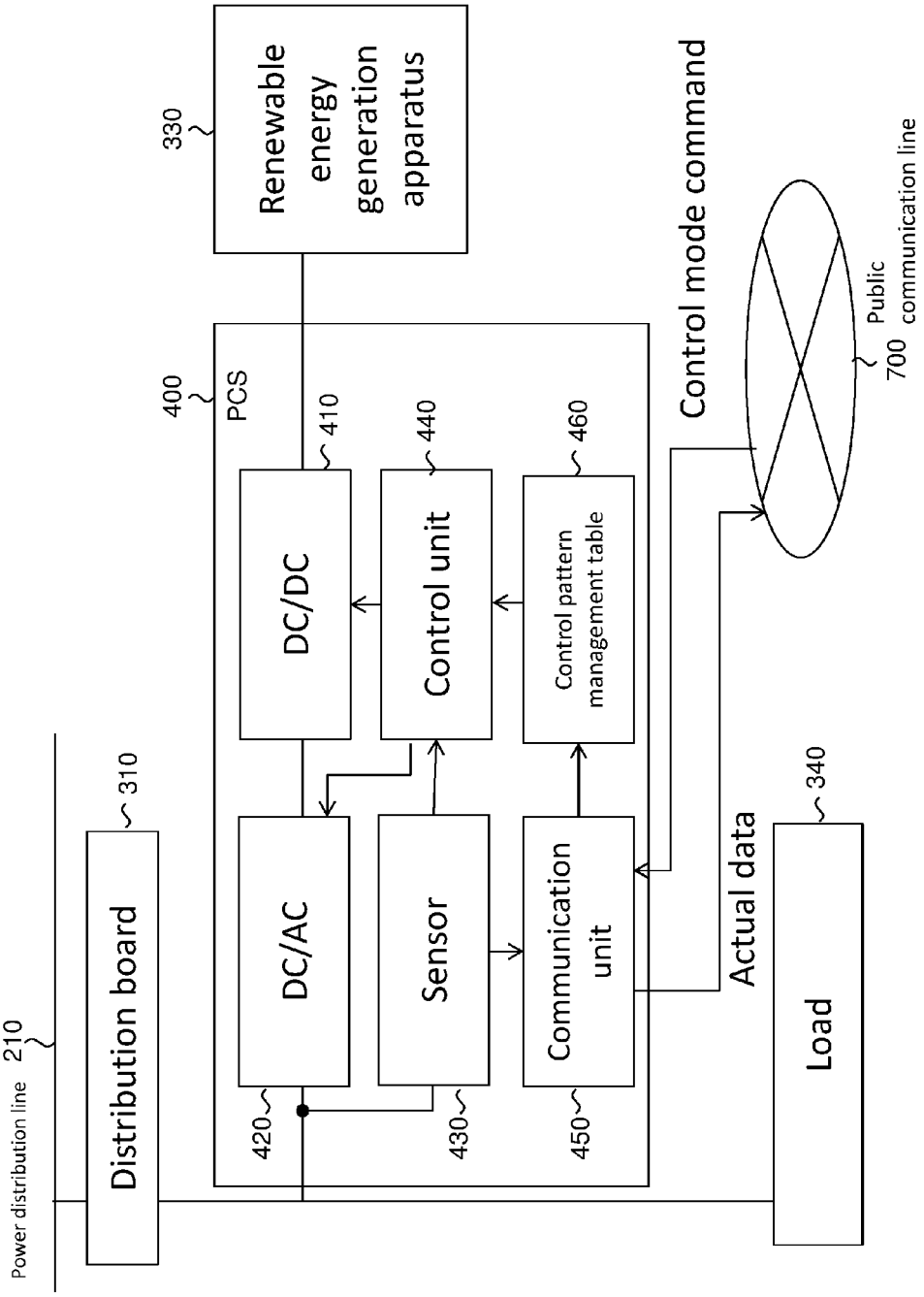

Power distribution line
210
Distribution board
310
330
Renewable energy generation apparatus
400
PCS
410
DC/DC
440
Control unit
460
Control pattern management table
420
DC/AC
430
Sensor
450
Communication unit
Control mode command
Actual data
Public communication line
700
340
Load

FIG. 4

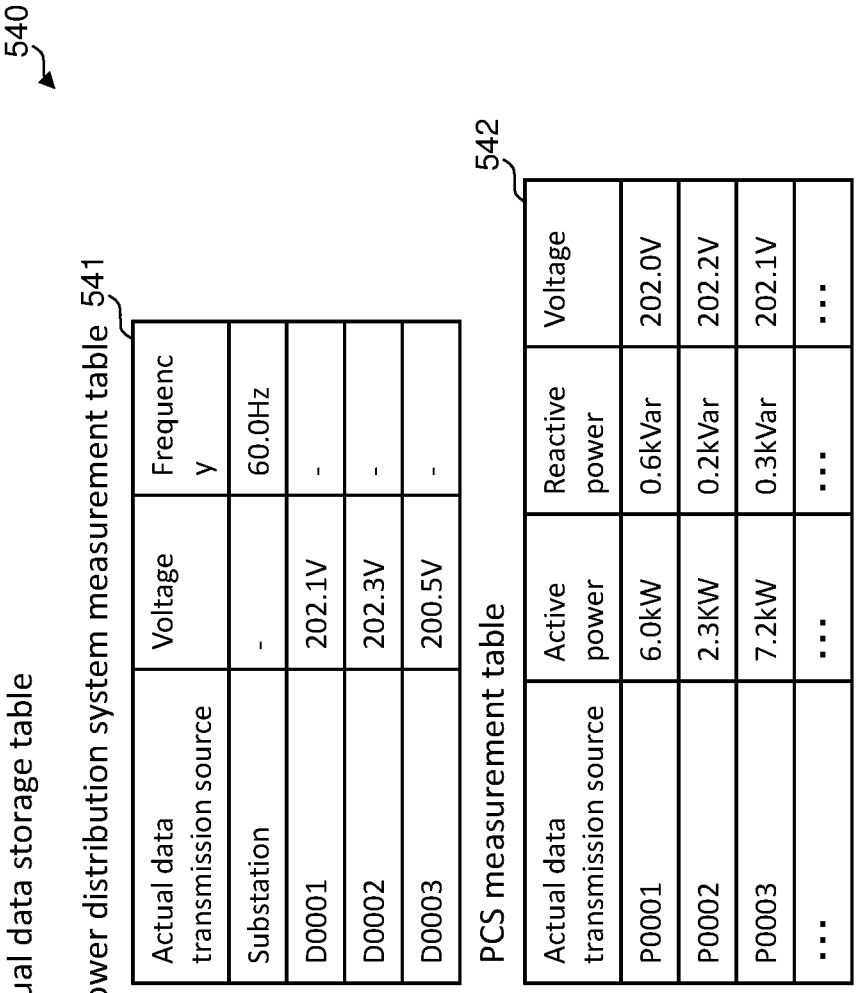

540
Actual data storage table
Power distribution system measurement table
541
Actual data transmission source
Voltage
Frequency
Substation
-
60.0Hz
D0001
202.1V
-
D0002
202.3V
-
D0003
200.5V
-
PCS measurement table
542
Actual data transmission source
Active power
Reactive power
Voltage
P0001
6.0kW
0.6kVar
202.0V
P0002
2.3KW
0.2kVar
202.2V
P0003
7.2kW
0.3kVar
202.1V
...
...
...
...

FIG. 5

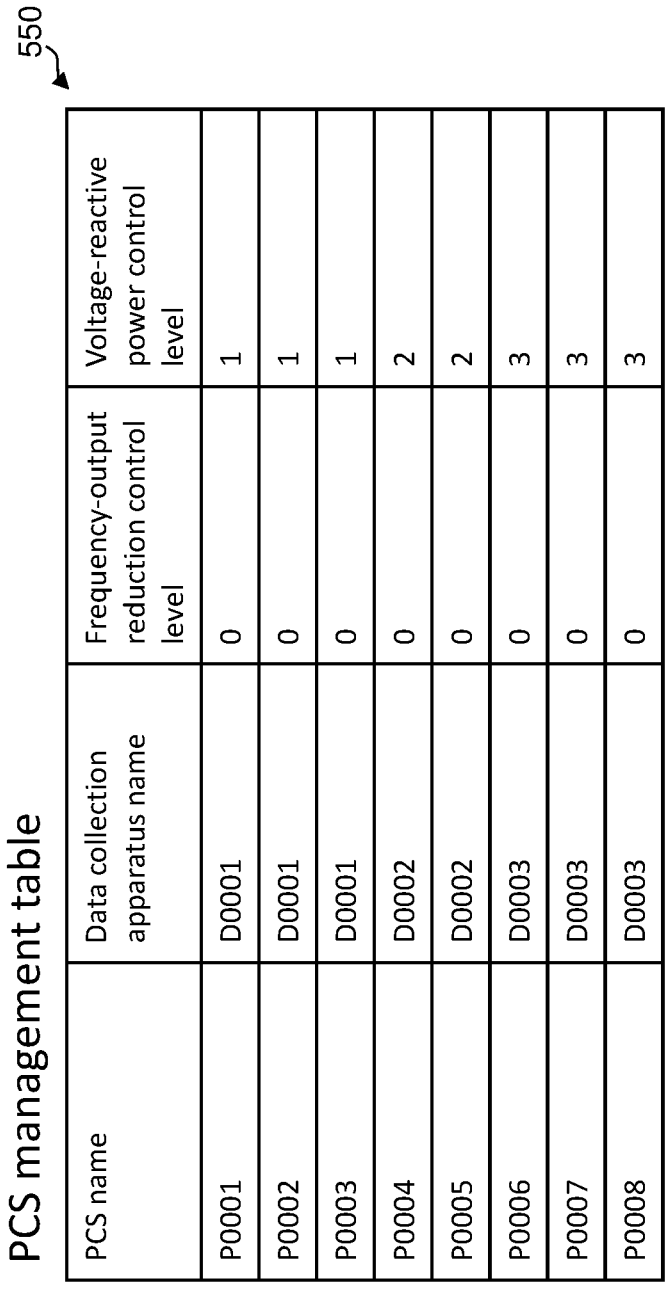

550
PCS management table
PCS name
Data collection apparatus name
Frequency-output reduction control level
Voltage-reactive power control level
P0001 D0001 0 1
P0002 D0001 0 1
P0003 D0001 0 1
P0004 D0002 0 2
P0005 D0002 0 2
P0006 D0003 0 3
P0007 D0003 0 3
P0008 D0003 0 3

FIG. 6

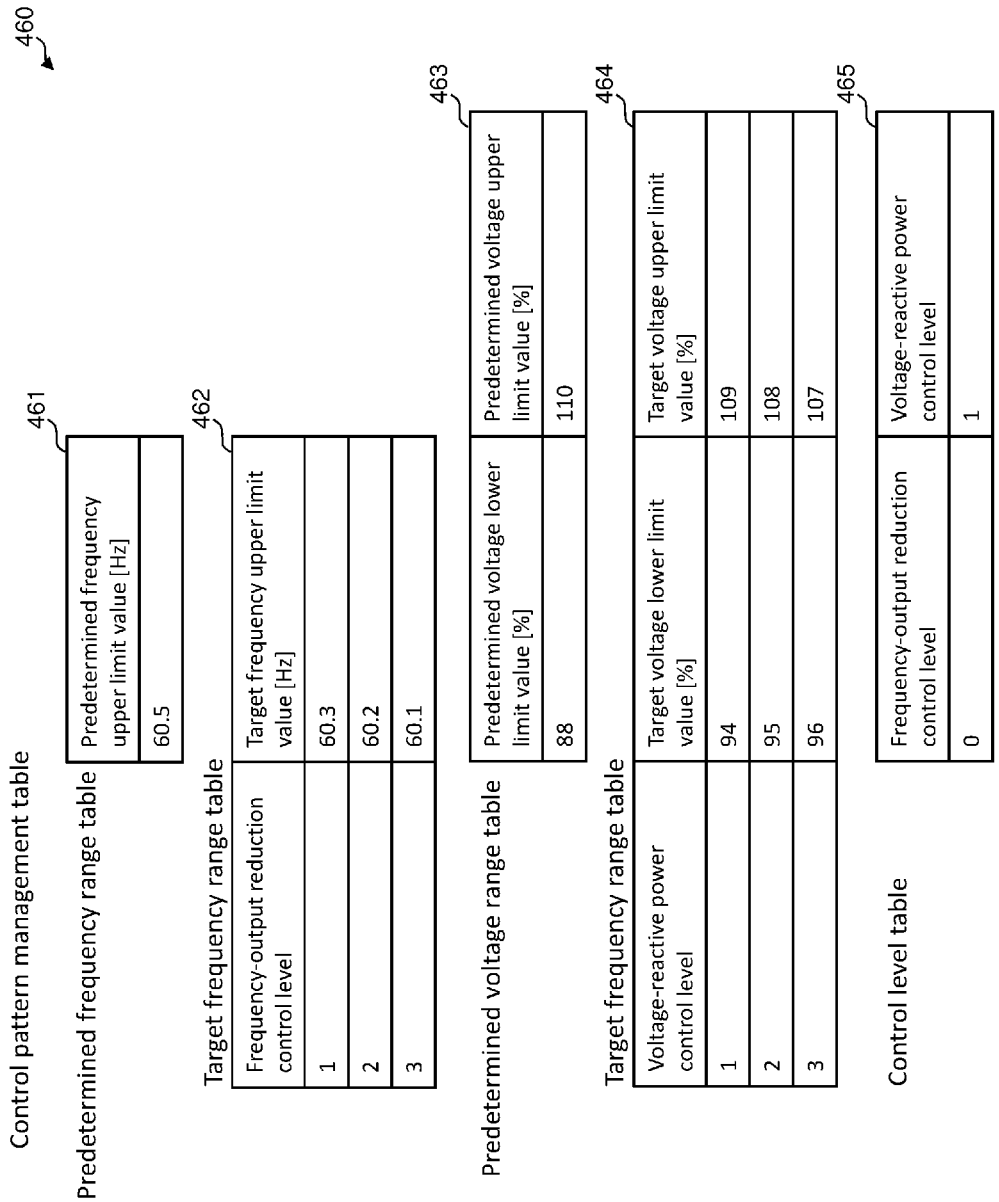

460
Control pattern management table
461
Predetermined frequency range table
Predetermined frequency upper limit value [Hz]
60.5
462
Target frequency range table
Frequency-output reduction control level
Target frequency upper limit value [Hz]
1
60.3
2
60.2
3
60.1
463
Predetermined voltage range table
Predetermined voltage lower limit value [%]
Predetermined voltage upper limit value [%]
88
110
464
Target frequency range table
Voltage-reactive power control level
Target voltage lower limit value [%]
Target voltage upper limit value [%]
1
94
109
2
95
108
3
96
107
465
Control level table
Frequency-output reduction control level
Voltage-reactive power control level
0
1

FIG. 7

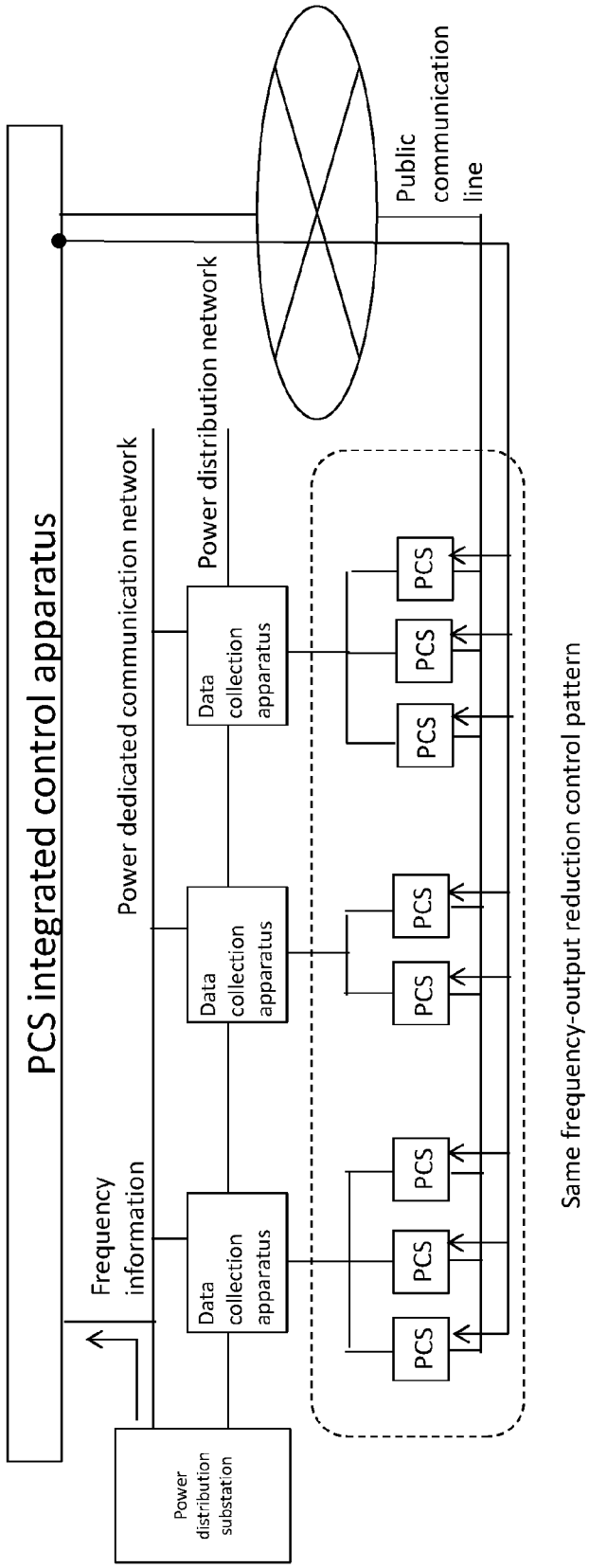

PCS integrated control apparatus
Power distribution substation
Frequency information
Power dedicated communication network
Power distribution network
Public communication line
Data collection apparatus
Data collection apparatus
Data collection apparatus
PCS
PCS
PCS
PCS
PCS
PCS
PCS
PCS
PCS
Same frequency-output reduction control pattern

FIG. 8

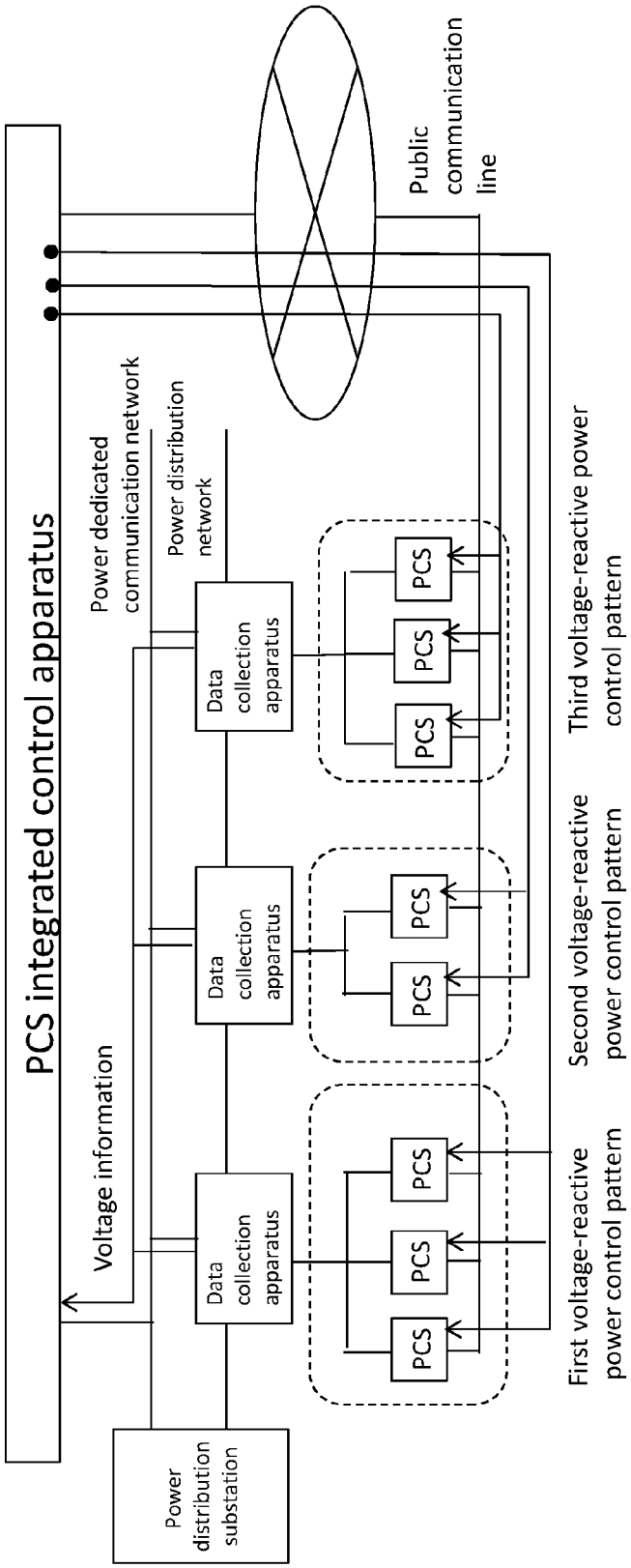

PCS integrated control apparatus
Public communication line
Power dedicated communication network
Power distribution network
Voltage information
Data collection apparatus
Data collection apparatus
Data collection apparatus
PCS
PCS
PCS
PCS
PCS
PCS
PCS
PCS
PCS
Power distribution substation
First voltage-reactive power control pattern
Second voltage-reactive power control pattern
Third voltage-reactive power control pattern

FIG. 9

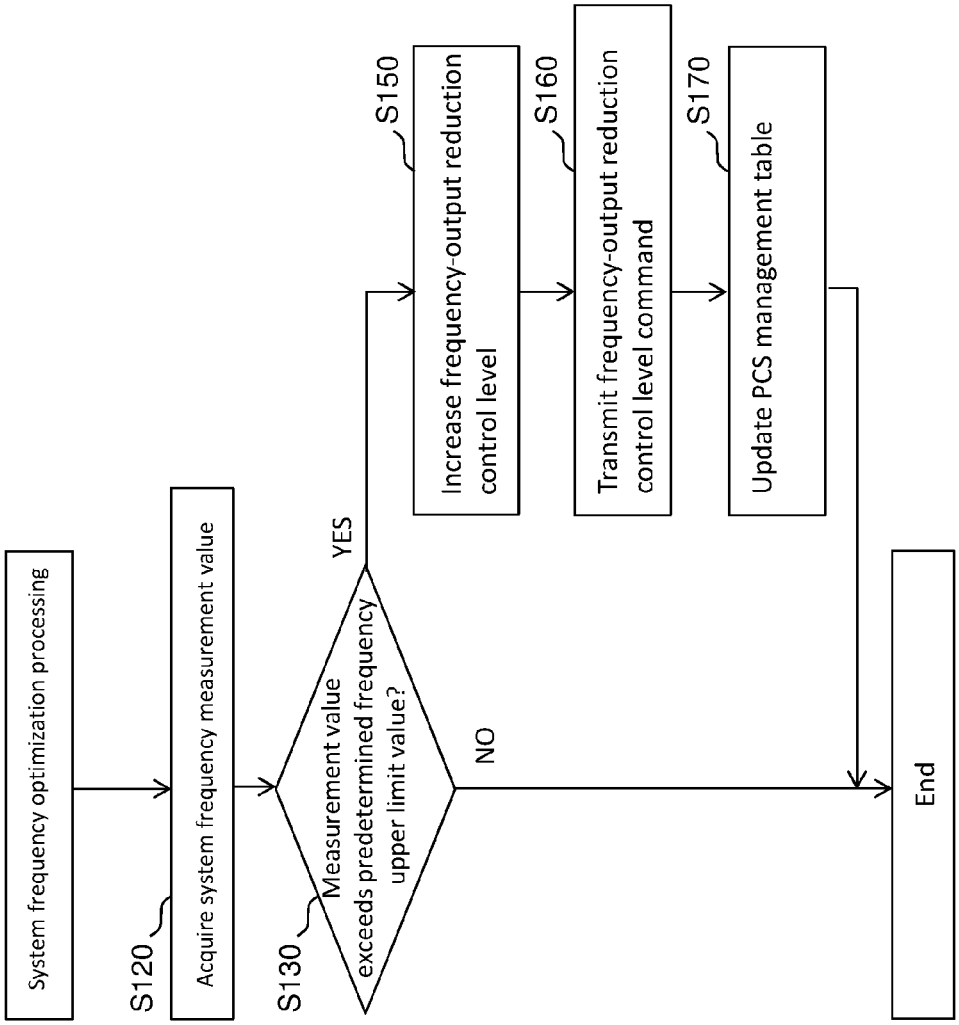

System frequency optimization processing
S120
Acquire system frequency measurement value
S130
Measurement value exceeds predetermined frequency upper limit value?
YES
NO
S150
Increase frequency-output reduction control level
S160
Transmit frequency-output reduction control level command
S170
Update PCS management table
End

FIG. 10

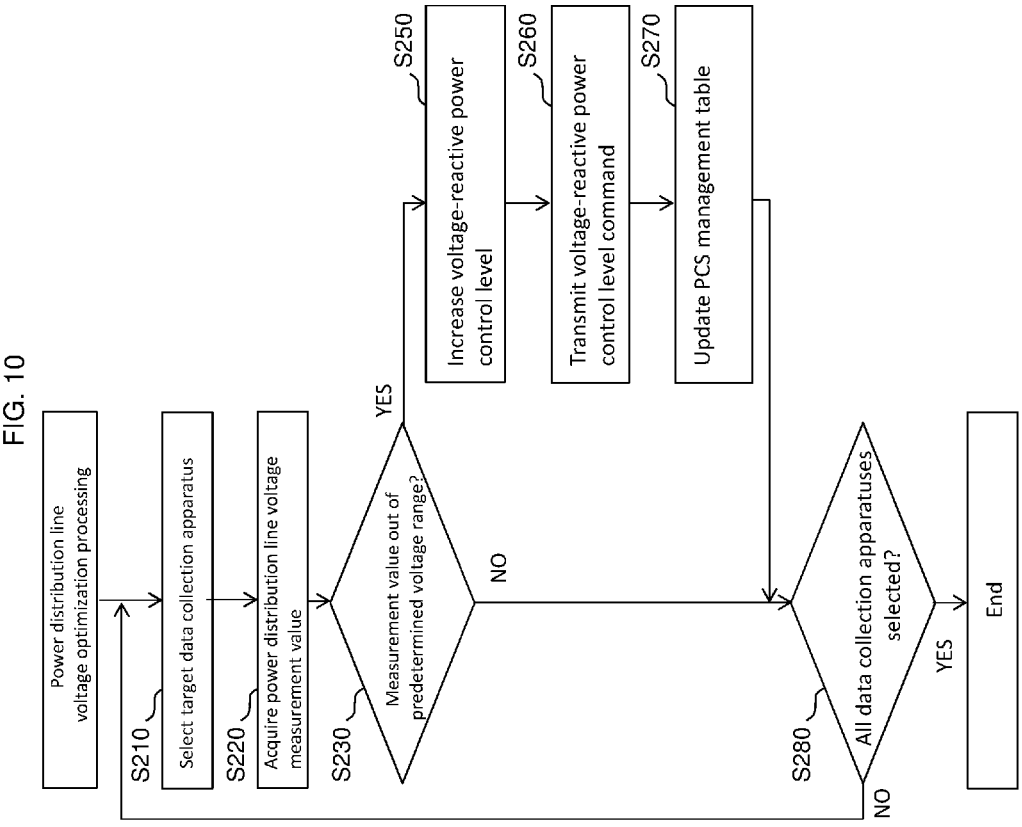

Power distribution line voltage optimization processing
S210
Select target data collection apparatus
S220
Acquire power distribution line voltage measurement value
S230
Measurement value out of predetermined voltage range?
YES
S250
Increase voltage-reactive power control level
S260
Transmit voltage-reactive power control level command
S270
Update PCS management table
NO
S280
All data collection apparatuses selected?
YES
End
NO

FIG. 11

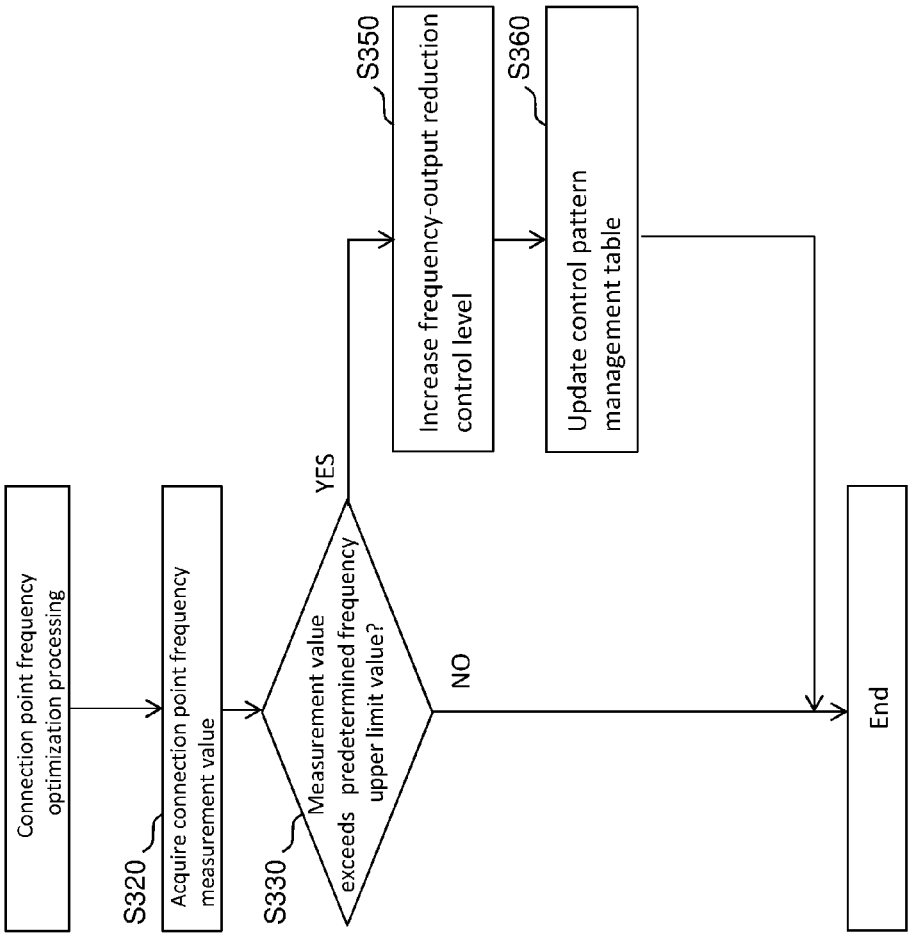

Connection point frequency optimization processing
S320
Acquire connection point frequency measurement value
S330
Measurement value exceeds predetermined frequency upper limit value?
YES
NO
S350
Increase frequency-output reduction control level
S360
Update control pattern management table
End

FIG. 12

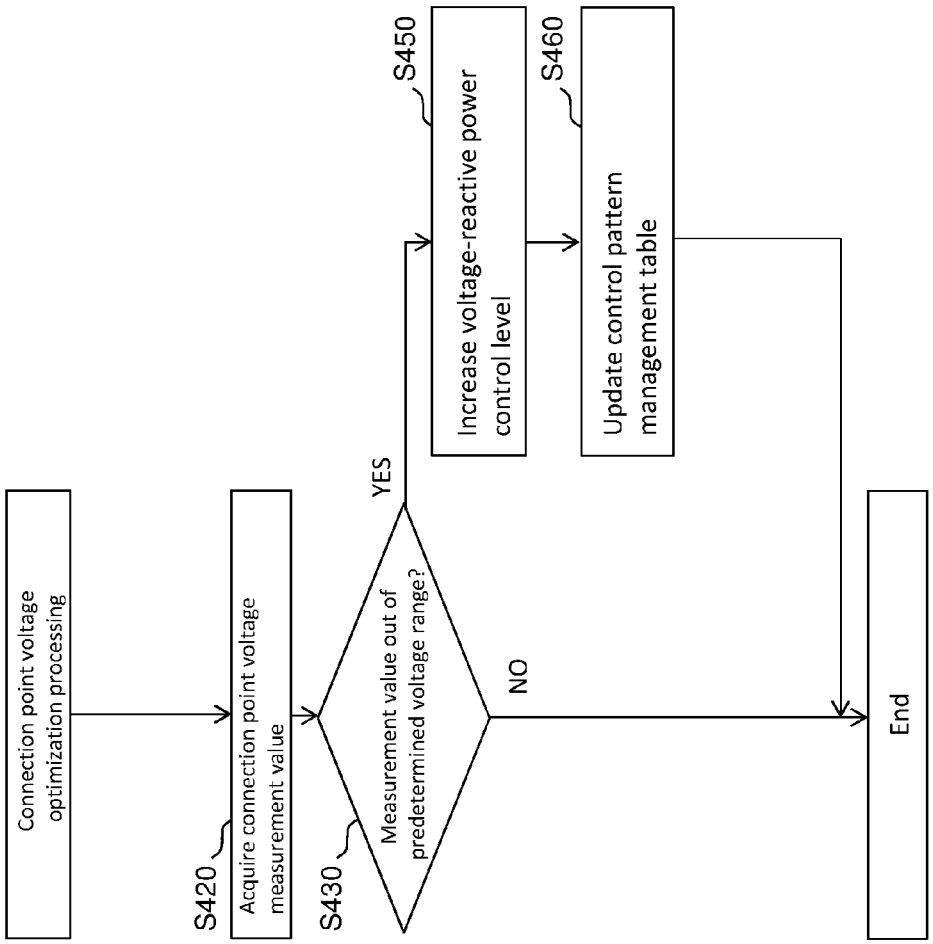

Connection point voltage optimization processing
S420
Acquire connection point voltage measurement value
S430
Measurement value out of predetermined voltage range?
YES
NO
S450
Increase voltage-reactive power control level
S460
Update control pattern management table
End

FIG. 13

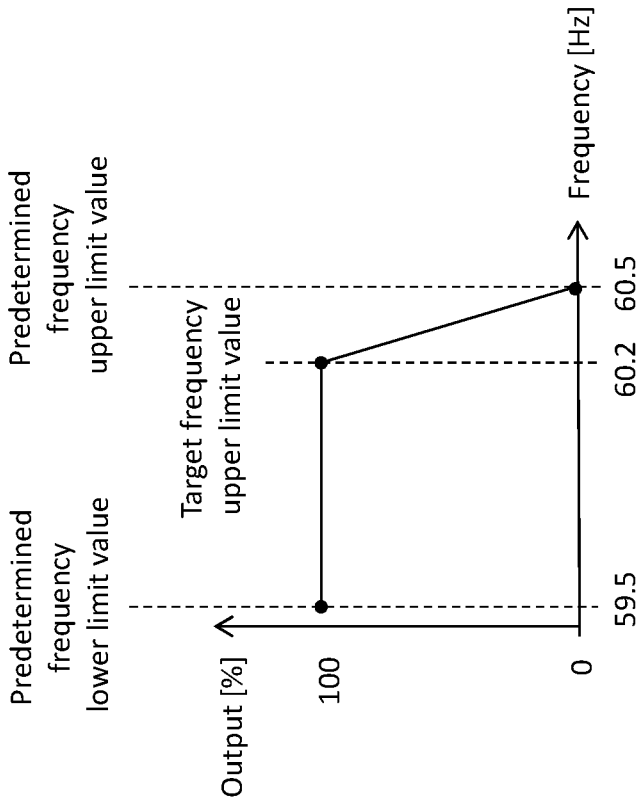

Frequency [Hz]
Predetermined frequency upper limit value
Target frequency upper limit value
Predetermined frequency lower limit value
60.5
60.2
59.5
Output [%]
100
0

FIG. 14

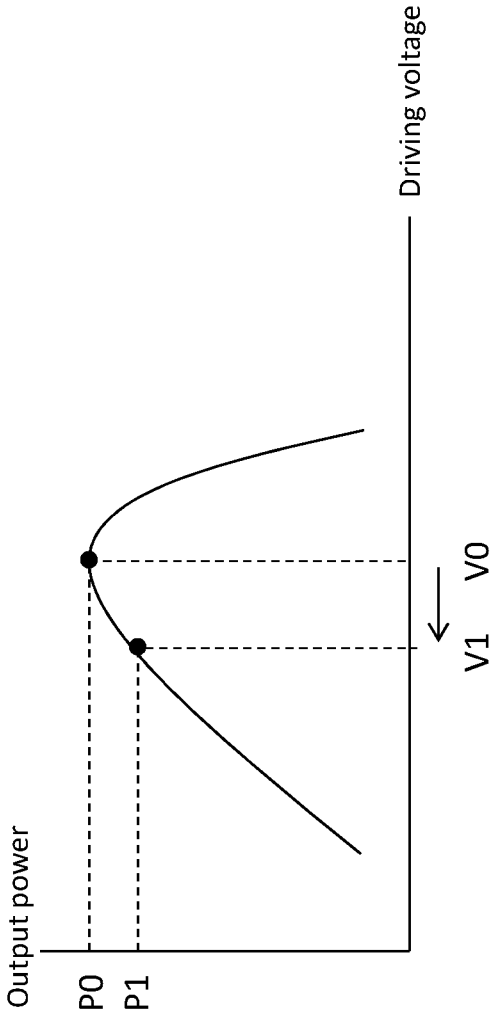


FIG. 15

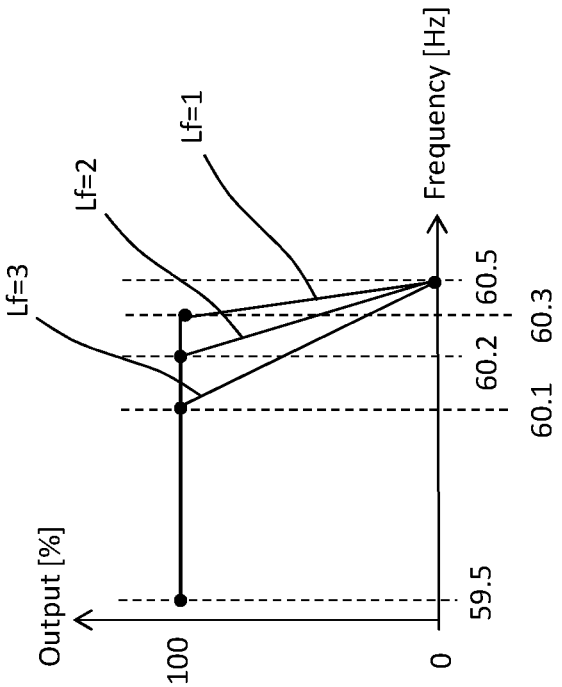


FIG. 16

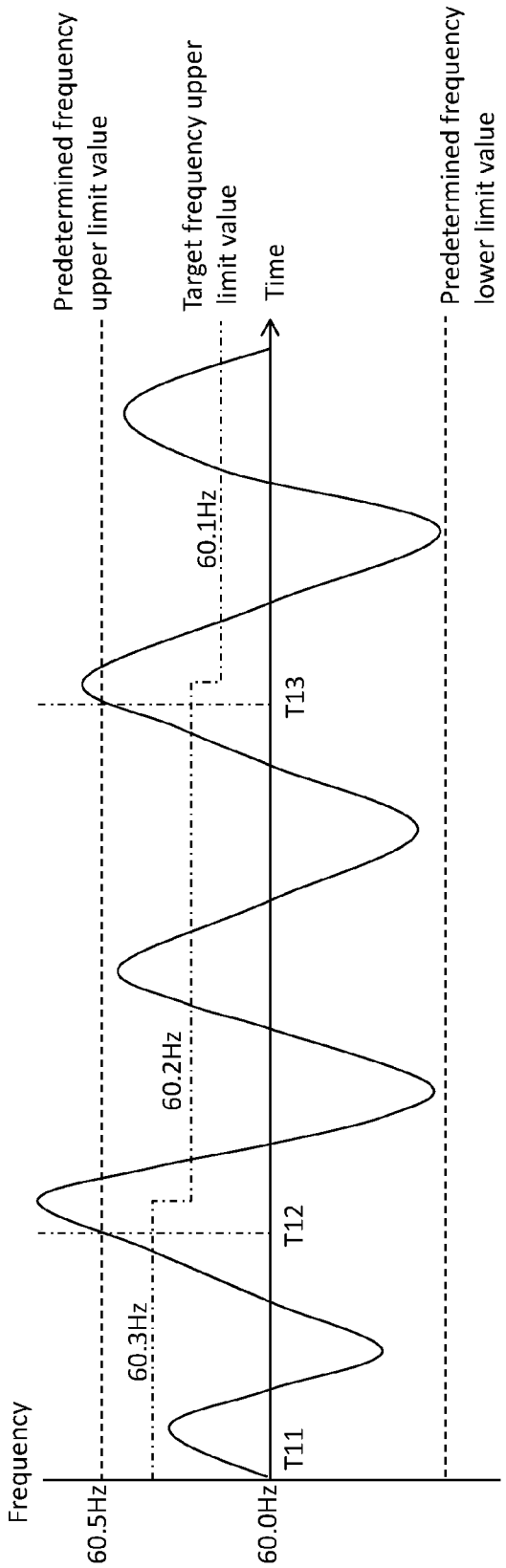

Predetermined frequency upper limit value
Target frequency upper limit value
Time
Predetermined frequency lower limit value
60.1Hz
T13
60.2Hz
T12
60.3Hz
T11
Frequency
60.5Hz
60.0Hz

FIG. 17

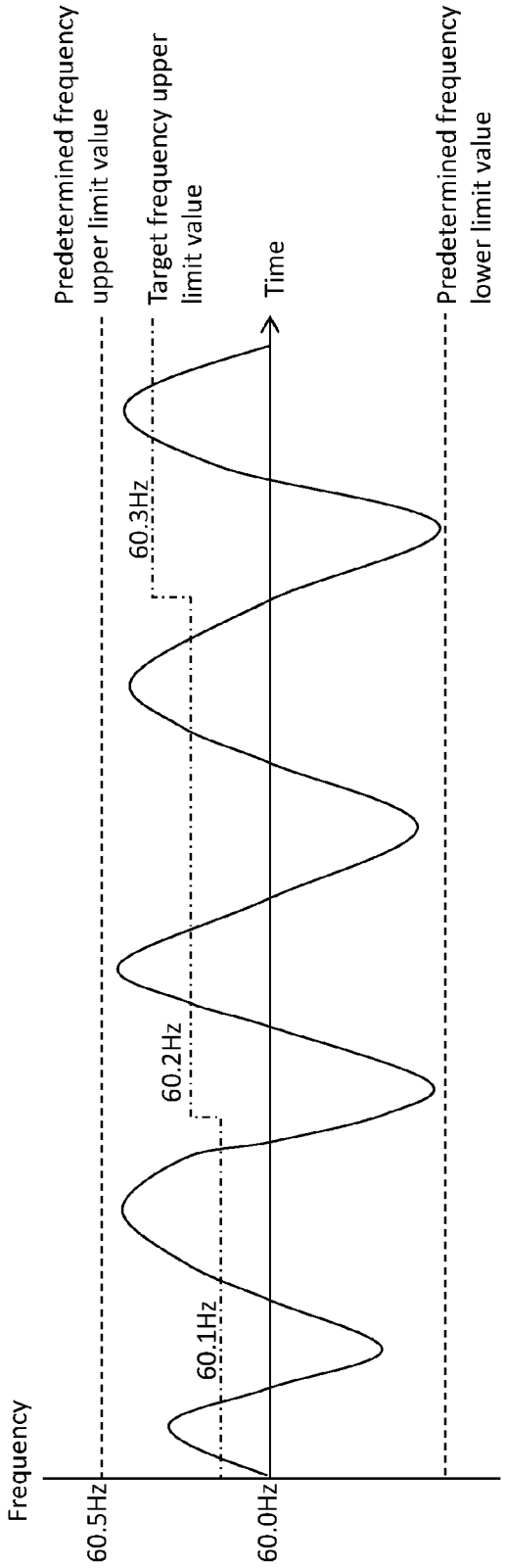

Predetermined frequency upper limit value
Target frequency upper limit value
Time
Predetermined frequency lower limit value
60.3Hz
60.2Hz
60.1Hz
Frequency
60.5Hz
60.0Hz

FIG. 18

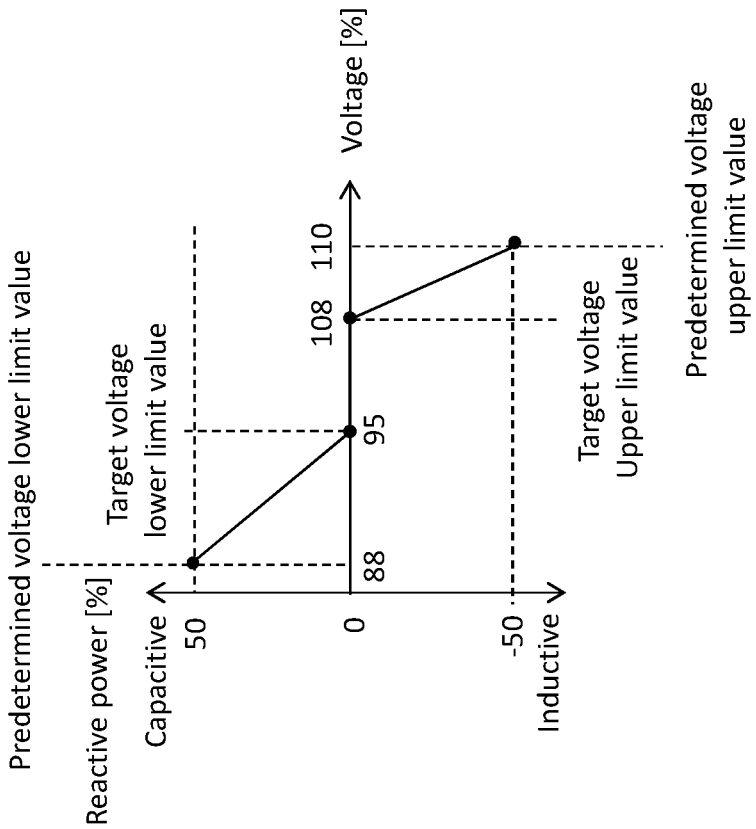

Predetermined voltage lower limit value
Reactive power [%]
Capacitive
50
0
-50
Inductive
Target voltage
lower limit value
Voltage [%]
88
95
108
110
Target voltage
Upper limit value
Predetermined voltage
upper limit value

FIG. 19

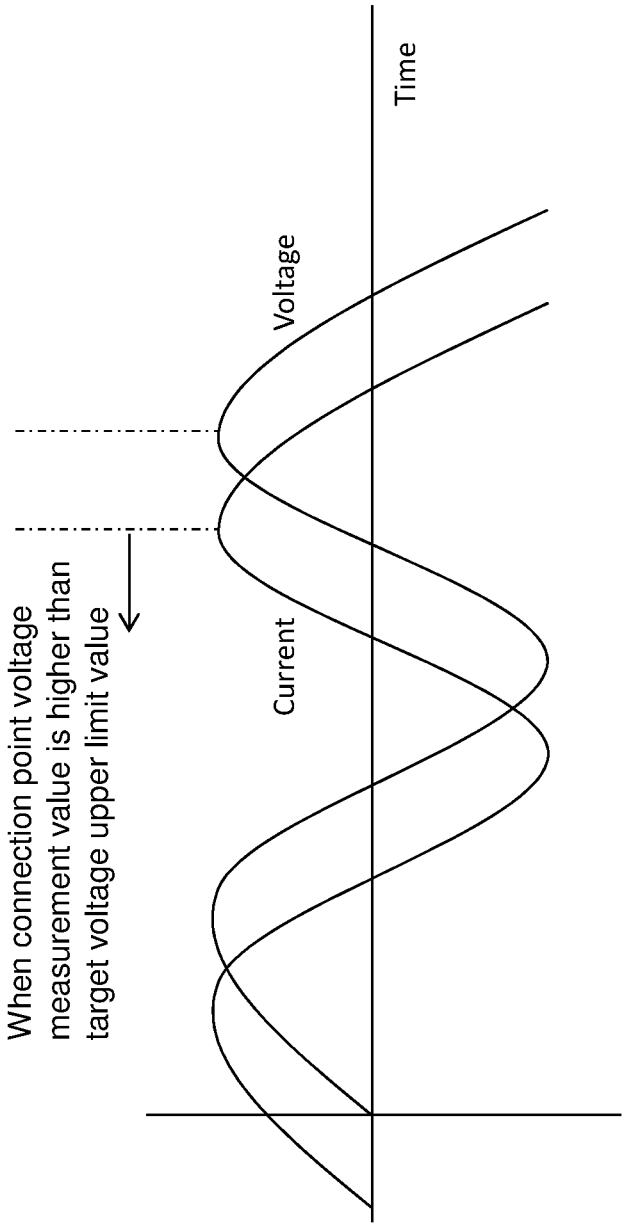

Time
Voltage
Current
When connection point voltage measurement value is higher than target voltage upper limit value

FIG. 20

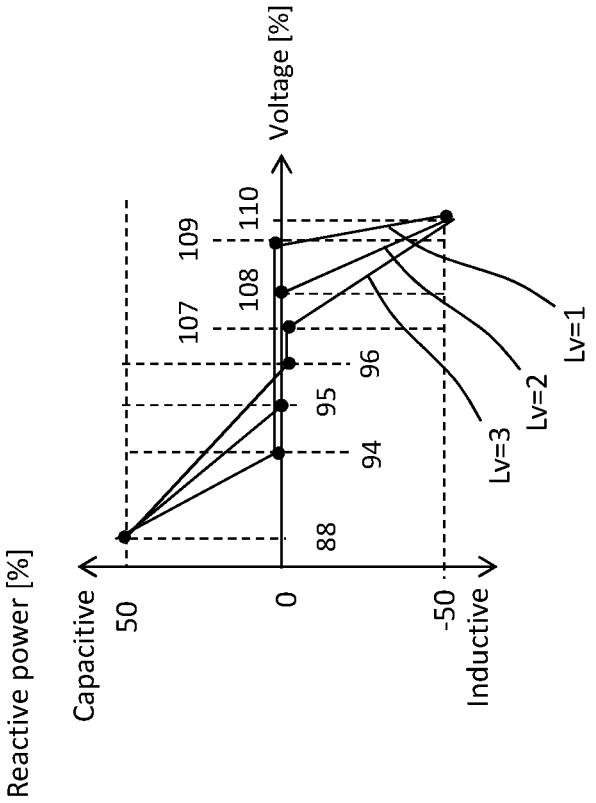

Voltage [%]
110
109
108
107
96
95
94
88
Lv=1
Lv=2
Lv=3
Reactive power [%]
Capacitive
50
0
-50
Inductive

FIG. 21

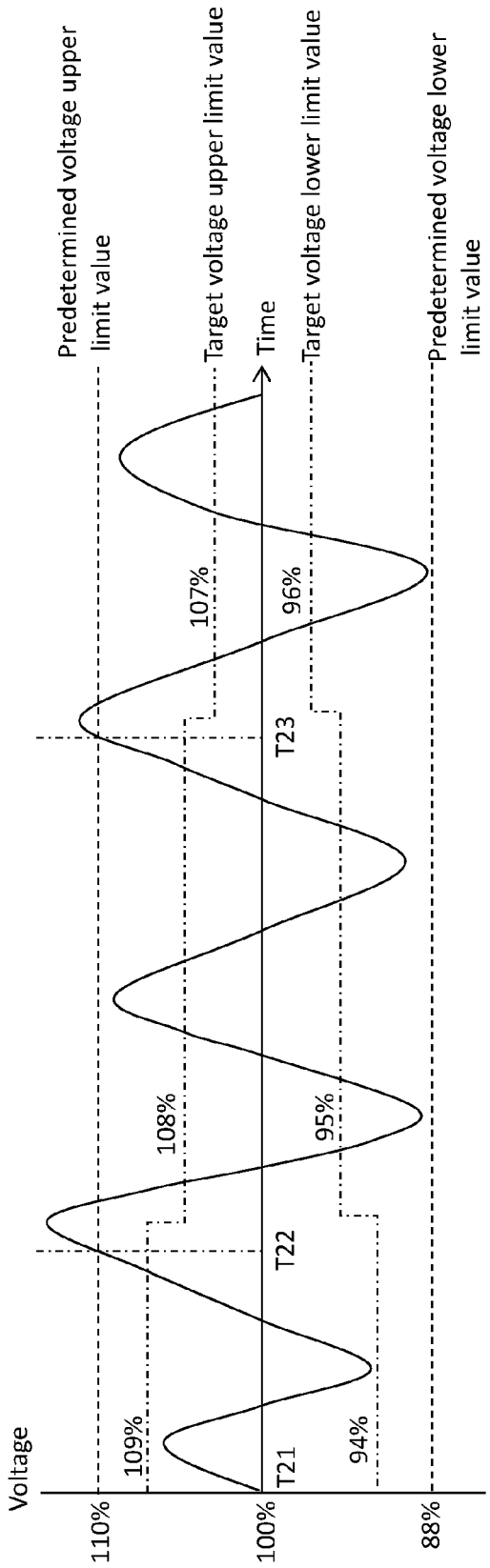
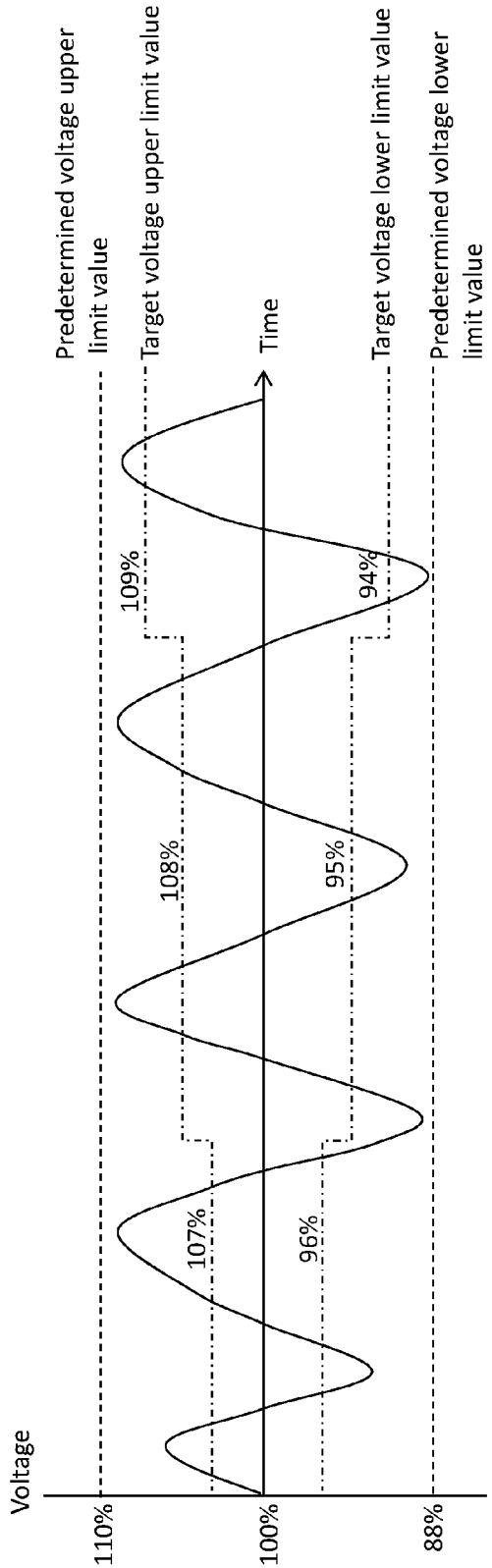

Predetermined voltage upper limit value
Target voltage upper limit value
Time
Target voltage lower limit value
Predetermined voltage lower limit value
107%
96%
T23
108%
95%
T22
Voltage
109%
94%
T21
110%
100%
88%

FIG. 22


Predetermined voltage upper limit value
Target voltage upper limit value
Time
Target voltage lower limit value
Predetermined voltage lower limit value
Voltage
109%
94%
108%
95%
107%
96%
110%
100%
88%

ELECTRICAL GRID CONTROL SYSTEM, ELECTRICAL GRID CONTROL METHOD, AND POWER CONVERSION APPARATUS

FIELD

[0001] The present invention relates to a technique of controlling an electrical grid.

BACKGROUND

[0002] Recent active introduction of renewable energy, such as photovoltaics (PV: solar power generation) and wind power generation, has resulted in sharp increase in a reverse current causing problems in a system such as frequency fluctuation (lack of back up capacity in the system) and voltage rise, especially in islands where a grid is small. Due to such problems, an application for the PV connection might take time or installation of the PV might not even be permitted.

[0003] Countermeasures to address such problems include reducing an output from the PV or even stopping the output from the PV for a predetermined period of time when a frequency or voltage of a power distribution system increases. In recent years, a system that cooperates with higher level systems to address the problems has been proposed.

[0004] In an automatic power distribution system in disclosed in PTL 1, a dispersed power source (PV) is connected with a power distribution line through a smart meter, and a voltage value at a node at which the dispersed power source is connected with the power distribution line and a voltage value of a power distribution substation are collected, and an amount of power that is transmitted to the power distribution line and measured by the smart meter is collected through a meter data management system. When the voltage value at the node exceeds a voltage target value, the automatic power distribution system calculates a reactive power control amount by using the voltage value at the node, a voltage value of a power distribution substation, the voltage target value, a power amount acquired by the smart meter, and a power distribution line impedance of the node. Then the automatic power distribution system transmits a command value indicating the reactive power control amount distributed to the dispersed power sources to the smart meter through a meter data management system, and thus controls the reactive power of a solar light inverter.

CITATION LIST

Patent Literature

[0005] [PTL 1] Japanese Patent Application Laid-open No. 2013-183622

[0006] The automatic power distribution system described above transmits the reactive power control amount to the inverter to control the inverter. Thus, the automatic power distribution system and the inverter need to communicate at a short time interval, and thus a large amount of communications is required. As a result, due to an increase in a load on the automatic power distribution system and a communication path, the inverter might not be able to be controlled.

SUMMARY

[0007] The present invention is made in view of the above problem, and an object of the present invention is to provide a technique of reducing an amount of communications performed between a control apparatus and a power conversion apparatus.

[0008] To solve the above problem, an electrical grid control system according to an aspect of the present invention includes a plurality of power conversion apparatuses each connected with an electrical grid, converting DC power from a power source into AC power, outputting the AC power to the electrical grid, and storing active power relationship information indicating a relationship between an active power control level representing a level of control for active power output to the electrical grid and a connection point frequency, which is a frequency at a connection point to the electrical grid, and a control apparatus that repeatedly receives information indicating a system frequency as a frequency of power measured in the electrical grid, determines the active power control level based on the system frequency, and transmits the active power control level to the plurality of power conversion apparatuses. Each of the plurality of power conversion apparatuses repeatedly measures the connection point frequency, receives the active power control level from the control apparatus, and controls the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a diagram illustrating a configuration of a power distribution system according to an embodiment of the present invention.

[0010] FIG. **2** illustrates a configuration of a PCS integrated control apparatus **500**.

[0011] FIG. **3** illustrates a configuration of a PCS **400**.

[0012] FIG. **4** illustrates an actual data storage table **540**.

[0013] FIG. **5** illustrates a PCS management table **550**.

[0014] FIG. **6** illustrates a control pattern management table **460**.

[0015] FIG. **7** illustrates a region controlled by system frequency optimization processing.

[0016] FIG. **8** illustrates a region controlled by power distribution line voltage optimization processing.

[0017] FIG. **9** illustrates the system frequency optimization processing.

[0018] FIG. **10** illustrates the power distribution line voltage optimization processing.

[0019] FIG. **11** illustrates connection point frequency optimization processing.

[0020] FIG. **12** illustrates connection point voltage optimization processing.

[0021] FIG. **13** illustrates an example of a frequency-output reduction control pattern.

[0022] FIG. **14** illustrates P-V characteristics of a solar power generation apparatus.

[0023] FIG. **15** illustrates a frequency-output reduction control pattern for each frequency-output reduction control level.

[0024] FIG. **16** illustrates how a frequency-output reduction control level is increased.

[0025] FIG. **17** illustrates how the frequency-output reduction control level is reduced.

[0026] FIG. **18** illustrates an example of a voltage-reactive power control pattern.

[0027] FIG. **19** illustrates how voltage and current, output from a DC/AC inverter **420**, change over time.

[0028] FIG. **20** illustrates a voltage-reactive power control pattern for each voltage-reactive power control level.

[0029] FIG. **21** illustrates how the voltage-reactive power control level is increased.

[0030] FIG. **22** illustrates how the voltage-reactive power control level is reduced.

DESCRIPTION OF EMBODIMENT

[0031] An embodiment of the present invention is described below with reference to the drawings.

[0032] FIG. **1** illustrates a configuration of a power distribution system according to the embodiment of the present invention.

[0033] A power distribution system control system according to the present embodiment controls the power distribution system. The power distribution system includes a power distribution substation **100**, a power distribution network **200**, and customer facilities **300**. The power distribution network **200** includes a plurality of power distribution lines **210**. A data collection apparatus **220** is provided on the power distribution line **210**. The data collection apparatus **220** measures voltage of the power distribution line **210**. For example, the data collection apparatus **220** is a sensor that is provided on a pole transformer, and measures secondary voltage of the pole transformer. A plurality of the customer facilities **300** are connected to the power distribution line **210** on the downstream side of the data collection apparatus **220**. The customer facility **300** includes a distribution board **310**, a power conditioning system (PCS) **400**, a renewable energy power generation apparatus **330**, and a load **340**. The distribution board **310** is connected to the power distribution line **210**, and supplies power from the power distribution line **210** to the load **340** and power from the PCS **400** to the power distribution line **210**. The renewable energy power generation apparatus **330** generates DC power by using renewable energy. The renewable energy power generation apparatus **330** is a solar power generation apparatus, a wind power generation apparatus, or the like. The PCS **400** converts the DC power from the renewable energy power generation apparatus **330** into AC power. The load **340** consumes the power from the distribution board **310** or the PCS **400**, and is an illumination lamp, an air conditioner, or the like.

[0034] The power distribution system control system includes a PCS integrated control apparatus **500** and a plurality of the PCSs **400**. The PCS integrated control apparatus **500** is connected to the power distribution substation **100** and the data collection apparatus **220** through a power-dedicated communication line **600**, and is connected to the plurality of PCSs **400** through a public communication line **700**. The PCS integrated control apparatus **500** may be provided in a distribution management system (DMS), an energy management system (EMS), or the like. The power-dedicated communication line **600** and the public communication line **700** may be the same communication line.

[0035] The power distribution substation **100** measures a frequency and the like of the power distribution line **210**, and transmits a measurement value thus obtained to the PCS integrated control apparatus **500**. The data collection apparatus **220** measures voltage and the like and transmits a measurement value thus obtained to the PCS integrated control apparatus **500**. The PCS **400** measures output active power, reactive power, voltage, and the like, and transmits measurement values thus obtained to the PCS integrated control apparatus **500**. Based on the measurement values from the power distribution substation **100** and the data collection apparatus **220**, the PCS integrated control apparatus **500** determines a control level, indicating a magnitude of a range to be controlled in accordance with a state of a connection point of each PCS **400**, and transmits a command indicating the control level to the PCS **400**. The PCS **400** controls the power to the power distribution line in accordance with a control pattern corresponding to the control level.

[0036] The control pattern includes: a frequency-output reduction control pattern defining output reduction in accordance with a frequency; and a voltage-reactive power control pattern defining reactive power control in accordance with voltage. The control pattern is designated with the control level. The frequency-output reduction control pattern is designated with a frequency-output reduction control level. The voltage-reactive power control pattern is designated with a voltage-reactive power control level. A higher frequency-output reduction control level leads to a larger range of frequencies for which the output reduction is executed. A higher voltage-reactive power control level leads to a larger range of voltage for which the reactive power control is executed.

[0037] A configuration of the power distribution system control system is described below.

[0038] FIG. **2** illustrates a configuration of the PCS integrated control apparatus **500**.

[0039] The PCS integrated control apparatus **500** includes a communication unit **510**, an optimization unit **520**, a monitoring unit **530**, an actual data storage table **540**, a PCS management table **550**, and a threshold table **560**.

[0040] The communication unit **510** is connected to and communicates with the power distribution substation **100** and the data collection apparatus **220**, and is further connected to and communicates with the PCS **400**.

[0041] The actual data storage table **540** stores the measurement values received through the communication unit **510** from the power distribution substation **100**, the data collection apparatus **220**, and the PCS **400**. The PCS management table **550** stores information for managing the PCS **400**. The threshold table **560** stores a threshold for determining a frequency and voltage of the power distribution system. For example, the threshold table **560** stores a prescribed frequency range and a prescribed voltage range. The prescribed frequency range is defined by a prescribed frequency lower limit value and a prescribed frequency upper limit value. The prescribed frequency lower limit value is lower than a frequency reference value as a reference value set in advance for the frequency of the power distribution system. The prescribed frequency upper limit value is higher than the frequency reference value. For example, the prescribed frequency lower limit value is a value obtained by adding a predetermined margin to a frequency lower limit value determined by a power company or by law. For example, the prescribed frequency upper limit value is a value obtained by subtracting the predetermined margin from a frequency upper limit value determined by a power company or by law. The prescribed voltage range is defined by a prescribed voltage lower limit value and a prescribed voltage upper limit value. The prescribed voltage lower limit value is lower than a voltage reference value as a reference value set in advance for voltage of the power distribution system. The prescribed voltage upper limit value is higher than the voltage reference value. For example, the prescribed voltage lower limit value is a value obtained by adding a predetermined margin to a voltage lower limit value determined by a power company or

by law. For example, the prescribed voltage upper limit value is a value obtained by subtracting the predetermined margin from a voltage upper limit value determined by a power company or by law.

[0042] The monitoring unit **530** monitors the frequency and the voltage of the power distribution system based on the actual data storage table **540**. The optimization unit **520** determines the control level based on a monitoring result obtained by the monitoring unit **530**.

[0043] The PCS integrated control apparatus **500** may be implemented by a computer including a central processing unit (CPU), a memory, and the communication unit **510**. In this case, the memory stores the actual data storage table **540**, the PCS management table **550**, the threshold table **560**, and a program. The program causes the CPU to function as the optimization unit **520** and the monitoring unit **530**. The program may be stored in a computer readable storage medium and read by the CPU.

[0044] The PCS integrated control apparatus **500** may be connected to a display apparatus and an input apparatus. The PCS integrated control apparatus **500** may cause the display apparatus to display information on any one of the actual data storage table **540**, the PCS management table **550**, and the threshold table **560**. Thus, a manager of the PCS integrated control apparatus **500** can check the control level of each PCS **400**, and recognize the state of the current output reduction and reactive power control.

[0045] FIG. **3** illustrates a configuration of the PCS **400**.

[0046] The PCS **400** includes a DC/DC converter **410**, a DC/AC inverter **420**, a sensor **430**, a control unit **440**, a communication unit **450**, and a control pattern management table **460**.

[0047] The DC/DC converter **410** is connected to the renewable energy power generation apparatus **330**, controls the voltage of the renewable energy power generation apparatus **330**, and supplies boosted voltage to the DC/AC inverter **420**. The DC/AC inverter **420** is connected to the DC/DC converter **410**, converts DC power output from the DC/DC converter **410** into AC power, and outputs the AC power to the load **340** and the distribution board **310**. The sensor **430** measures active power, reactive power, voltage, frequency, and the like at a connection point between the DC/AC inverter **420** and the power distribution line **210**. Hereinafter, the frequency measured by the sensor **430** will be referred to as a connection point frequency, and the voltage measured by the sensor **430** will be referred to as connection point voltage. The control unit **440** controls the DC/DC converter **410** and the DC/AC inverter **420** based on the measurement result obtained by the sensor **430** and the control pattern management table **460**. The communication unit **450** is connected to the public communication line **700**, transmits the measurement result obtained by the sensor **430** to the PCS integrated control apparatus **500**, and receives a command from the PCS integrated control apparatus **500**. The control pattern management table **460** stores a set value for a predetermined control pattern for each control level.

[0048] The control unit **440** and the control pattern management table **460** may be implemented by a computer including a CPU and a memory. In this case, the memory stores the control pattern management table **460** and a program. The program causes the CPU to function as the control unit **440**. The program may be stored in a computer readable storage medium and read by the CPU.

[0049] FIG. **4** illustrates the actual data storage table **540**.

[0050] The actual data storage table **540** includes a power distribution system measurement table **541** and a PCS measurement table **542**.

[0051] The power distribution system measurement table **541** includes an entry for each measurement value transmission source. An entry corresponding to one transmission source includes: an actual data transmission source name as an identifier of the transmission source; voltage measured by the transmission source; and a frequency measured by the transmission source. Each entry may include one of the voltage and the frequency. For example, an entry with the power distribution substation **100** as the transmission source includes the frequency measured by the power distribution substation **100**. An entry with the data collection apparatus **220** as the transmission source includes the voltage measured by the data collection apparatus **220**. Still the data collection apparatus **220** may also measure the frequency.

[0052] The PCS measurement table **542** includes an entry for each PCS **400** as the transmission source of the measurement value. An entry corresponding to one transmission source includes: an actual data transmission source name as an identifier of the transmission source; active power measured by the transmission source; reactive power measured by the transmission source; and voltage measured by the transmission source.

[0053] FIG. **5** illustrates the PCS management table **550**.

[0054] The PCS management table **550** includes an entry for each PCS **400**. An entry corresponding to one PCS **400** includes: a PCS name as an identifier of the PCS; a data collection apparatus name as an identifier of the data collection apparatus **220** on the upstream side of the PCS on the power distribution line **210**; the frequency-output reduction control level of the PCS; and the voltage-reactive power control level of the PCS.

[0055] In the present embodiment, the frequency-output reduction control level and the voltage-reactive power control level each indicates any one of 0, 1, 2, and 3. More specifically, the frequency-output reduction control level upper limit value, as the upper limit value of the frequency-output reduction control level, is 3, and the voltage-reactive power control level upper limit value, as the upper limit value of the voltage-reactive power control level, is 3. An initial value of the frequency-output reduction control level of each PCS is 0. With this value the PCS does not execute the output reduction in accordance with the frequency. The PCS having the frequency-output reduction control level set to 1 or higher executes the output reduction in accordance with the frequency. An initial value of the voltage-reactive power control level of each PCS is 0. With this value the PCS does not execute the reactive power control in accordance with the voltage. The PCS having the voltage-reactive power control level set to 1 or higher executes the reactive power control in accordance with the voltage.

[0056] FIG. **6** illustrates the control pattern management table **460**.

[0057] The control pattern management table **460** includes a prescribed frequency range table **461**, a target frequency range table **462**, a prescribed voltage range table **463**, a target voltage range table **464**, and a control level table **465**. The target frequency range is defined by a target frequency upper limit value. The target voltage range is defined by a target voltage lower limit value and a target voltage upper limit value.

[0058] The prescribed frequency range table **461** includes the prescribed frequency upper limit value. The target frequency range table **462** includes an entry for each frequency-output reduction control level. An entry for one frequency-output reduction control level includes the frequency-output reduction control level and the target frequency upper limit value. The target frequency upper limit value is higher than the frequency reference value and is lower than the prescribed frequency upper limit value.

[0059] The prescribed voltage range table **463** includes the prescribed frequency lower limit value and the prescribed frequency upper limit value. The target frequency range table **462** includes an entry for each voltage-reactive power control level. An entry for one voltage-reactive power control level includes the voltage-reactive power control level, the target voltage lower limit value, and the target voltage upper limit value. The target voltage lower limit value is higher than the prescribed voltage lower limit value and lower than the voltage reference value. The target voltage upper limit value is higher than the voltage reference value and lower than the prescribed voltage upper limit value.

[0060] The control level table **465** stores the frequency-output reduction control level and the voltage-reactive power control level set for the PCS **400**.

[0061] The control pattern management table **460** may be information that has been input for the PCS **400** in advance, or may be information input to the PCS integrated control apparatus **500** and transmitted to the PCS **400**.

[0062] An operation of determining the control level performed by the PCS integrated control apparatus **500** is described below.

[0063] In the PCS integrated control apparatus **500**, the optimization unit **520** executes system frequency optimization processing of optimizing the frequency of the power distribution network **200**, and power distribution line voltage optimization processing of optimizing the voltage for each power distribution line **210**, at a predetermined time interval that is several seconds to several tens of seconds for example. The size of a region controlled by the system frequency optimization processing and the size of a region controlled by the power distribution line voltage optimization processing are different from each other.

[0064] FIG. **7** illustrates the region controlled by the system frequency optimization processing.

[0065] In the system frequency optimization processing, based on a system frequency measurement value as the frequency measured by the power distribution substation **100**, the optimization unit **520** sets the same frequency-output reduction control level to all the PCSs **400** that can communicate with the PCS integrated control apparatus **500**. Thus, the PCS integrated control apparatus **500** can control the frequency of the power distribution system.

[0066] FIG. **8** illustrates the region controlled by the power distribution line voltage optimization processing.

[0067] In the power distribution line voltage optimization processing, based on the voltage measured by one data collection apparatus, the optimization unit **520** performs the voltage-reactive power control for the PCSs **400** that can communicate with the PCS integrated control apparatus **500** in the PCSs **400** corresponding to the power distribution line of the data collection apparatus. Thus, the PCS integrated control apparatus **500** can control the voltage for each power distribution line of the data collection apparatus.

[0068] FIG. **9** illustrates the system frequency optimization processing.

[0069] In S**120**, the optimization unit **520** acquires the system frequency measurement value from the actual data storage table **540**. Then, in S**130**, the optimization unit **520** determines whether the system frequency measurement value exceeds the prescribed frequency upper limit value.

[0070] When it is determined that the system frequency measurement value does not exceed the prescribed frequency upper limit value, the optimization unit **520** terminates the flow.

[0071] When it is determined that the system frequency measurement value exceeds the prescribed frequency upper limit value, the optimization unit **520** increments the frequency-output reduction control level by one in S**150**. In the processing, when the frequency-output reduction control level before being changed is at the maximum value, the optimization unit **520** does not change the frequency-output reduction control level. Then, in S**160**, the optimization unit **520** transmits a frequency-output reduction control level command indicating the changed frequency-output reduction control level to all the PCSs **400**. Then, in S**170**, the optimization unit **520** sets the changed frequency-output reduction control level in the entries for all the PCSs **400** in the PCS management table **550**, and terminates the flow.

[0072] When it is determined that the system frequency measurement value exceeds the prescribed frequency upper limit value in S**130**, the optimization unit **520** may count the number of times such a state is consecutively determined. In this case, the optimization unit **520** moves the processing to S**150** when the number of times exceeds a predetermined number of times and terminates the flow when the number of times does not exceed the predetermined number of times. The optimization unit **520** can perform the determination in S**130** through this statistical processing. Thus, the frequency-output reduction control level can be prevented from changing due to a temporary fluctuation of the measurement value.

[0073] With the system frequency optimization processing described above, the PCS integrated control apparatus **500** can increase the frequency-output reduction control level for all the PCSs **400** when the system frequency measurement value exceeds the prescribed frequency upper limit value. Thus, the level of the output reduction can be gradually increased.

[0074] FIG. **10** illustrates the power distribution line voltage optimization processing.

[0075] In S**210**, the optimization unit **520** selects one data collection apparatus **220** as a target data collection apparatus based on the power distribution system measurement table **541** in the actual data storage table **540**. Then, the optimization unit **520** selects as a target PCS the PCS **400** corresponding to the power distribution line of the target data collection apparatus, based on the PCS management table **550**. Then, in S**220**, the optimization unit **520** acquires the power distribution line voltage measurement value, as voltage measured by the target data collection apparatus, from the power distribution system measurement table **541** in the actual data storage table **540**. Then, in S**230**, the optimization unit **520** determines whether the power distribution line voltage measurement value is out of the prescribed voltage range. In this processing, the optimization unit **520** determines that the power distribution line voltage measurement value is out of the prescribed voltage range, when the power distribution line

voltage measurement value is higher than the prescribed voltage upper limit or lower than the prescribed voltage lower limit value.

[0076] When it is determined that the power distribution line voltage measurement value is within the prescribed voltage range, the optimization unit **520** moves the processing to S**280**.

[0077] When it is determined that the power distribution line voltage measurement value is out of the prescribed voltage range, in S**250**, the optimization unit **520** increments the voltage-reactive power control level of the target PCS stored in the PCS management table **550** by one. In this processing, when the voltage-reactive power control level of the target PCS stored in the PCS management table **550** is at the voltage-reactive power control level upper limit value, the optimization unit **520** does not change the voltage-reactive power control level. Then, in S**260**, the optimization unit **520** transmits a voltage-reactive power control level command indicating the changed voltage-reactive power control level to the target PCS. Then, in S**270**, the optimization unit **520** sets the changed voltage-reactive power control level to the entry for the target PCS in the PCS management table **550**, and moves the processing to S**280**.

[0078] In S**280**, the optimization unit **520** determines whether all the data collection apparatuses **220** have been selected. When it is determined that there is an unselected data collection apparatus **220** (No), the optimization unit **520** moves the processing to S**210**, and selects the next target data collection apparatus and target PCS. When it is determined that all the data collection apparatus **220** have been selected (Yes), the optimization unit **520** terminates the flow.

[0079] As in S**130** described above, when it is determined that the power distribution line voltage measurement value exceeds the prescribed voltage upper limit value in S**230**, the optimization unit **520** may count the number of times such a state is consecutively determined. In this case, the optimization unit **520** moves the processing to S**250** when the number of times exceeds a predetermined number of times and terminates the flow when the number of times does not exceed the predetermined number of times. The optimization unit **520** can perform the determination in S**230** through this static processing. Thus, the output reduction due to the temporary fluctuation of the measurement value can be prevented.

[0080] With the power distribution line voltage optimization processing described above, the PCS integrated control apparatus **500** can increment the voltage-reactive power control level of the PCS corresponding to the power distribution line of the target data collection apparatus, when the power distribution line voltage measurement value, measured by the target data collection apparatus, falls out of the prescribed voltage range. Thus, the PCS integrated control apparatus **500** can gradually increase the level of the control on the reactive power.

[0081] The PCS integrated control apparatus **500** may execute the power distribution line voltage optimization processing after the system frequency optimization processing.

[0082] An operation of determining the control level performed by the PCS **400** is described below.

[0083] Here, a case is described where the communicate with the PCS integrated control apparatus **500** cannot be established, because the PCS **400** is not connected to the PCS integrated control apparatus **500** or due to a failure of the PCS integrated control apparatus **500** or the public communication line **700**. In this case, the control unit **440** of the PCS **400** periodically executes connection point frequency optimization processing of optimizing the frequency at the connection point and connection point voltage optimization processing of optimizing the voltage at the connection point, instead of receiving the command from the PCS integrated control apparatus **500**.

[0084] FIG. **11** illustrates the connection point frequency optimization processing.

[0085] In S**320**, the control unit **440** acquires an connection point frequency measurement value as a frequency measured by the sensor **430**. In S**330**, the control unit **440** determines whether the connection point frequency measurement value exceeds the prescribed frequency upper limit value.

[0086] When it is determined that the connection point frequency measurement value does not exceed the prescribed frequency upper limit value, the control unit **440** terminates the flow.

[0087] When it is determined that the connection point frequency measurement value exceeds the prescribed frequency upper limit value, in S**350**, the control unit **440** acquires the frequency-output reduction control level stored in the control pattern management table **460**, and increments the frequency-output reduction control level by one. In this processing, when the frequency-output reduction control level stored in the control pattern management table **460** is at the frequency-output reduction control level upper limit value, the control unit **440** does not change the frequency-output reduction control level. Then, in S**360**, the control unit **440** writes the changed frequency-output reduction control level to the control pattern management table **460**, and terminates the flow.

[0088] With the connection point frequency optimization processing described above, the PCS **400** that cannot communicate with the PCS integrated control apparatus **500** can change the own frequency-output reduction control pattern, when the connection point frequency measurement value exceeds the prescribed frequency upper limit value.

[0089] The control unit **440** that cannot communicate with the PCS integrated control apparatus **500** periodically executes the connection point voltage optimization processing.

[0090] FIG. **12** illustrates the connection point voltage optimization processing.

[0091] In S**420**, the control unit **440** acquires the connection point voltage measurement value as the voltage measured by the sensor **430**. In S**430**, the control unit **440** determines whether the connection point voltage measurement value is out of the prescribed voltage range.

[0092] When it is determined that the connection point voltage measurement value is within the prescribed voltage range, the control unit **440** terminates the flow.

[0093] When it is determined that the connection point voltage measurement value is out of the prescribed voltage range, in S**450**, the control unit **440** acquires the voltage-reactive power control level stored in the control pattern management table **460**, and increments the voltage-reactive power control level by one. In this processing, when the voltage-reactive power control level stored in the control pattern management table **460** is at the voltage-reactive power control level upper limit value, the control unit **440** does not change the voltage-reactive power control level. Then, in S**360**, the control unit **440** writes the changed voltage-reactive power control level to the control pattern management table **460**, and terminates the flow.

[0094] With the connection point voltage optimization processing described above, the PCS **400** that cannot communicate with the PCS integrated control apparatus **500** can change the voltage-reactive power control pattern when the connection point voltage measurement value falls out of the prescribed voltage range.

[0095] The PCS **400** may store a history of past data for the command received from the PCS integrated control apparatus **500**, the determined control level, a power generation amount, an insolation amount, weather, temperature, and the like. In this case, in the connection point frequency optimization processing and the connection point voltage optimization processing, the control unit **440** executes statistic processing with the history of the past data, and thus determines the control level by using a control level of the preceding day, a control level of the same season, a control level of the same day of the week, a control level of the day with a similar history of the power generation amount, and the like.

[0096] With the connection point frequency optimization processing and the connection point voltage optimization processing described above, the PCS **400** that cannot communicate with the PCS integrated control apparatus **500** can perform autonomous dispersed control. Thus, the constrain on output and control on reactive power by the PCS **400** is less likely to be affected by a load on and failure in a communication path between the PCS integrated control apparatus **500** and the PCS **400**.

[0097] Frequency-output reduction control performed by the PCS **400** is described below.

[0098] FIG. **13** illustrates an example of the frequency-output reduction control pattern.

[0099] In the figure, the horizontal axis represents the connection point frequency measurement value and the vertical axis represents an output from the PCS **400**. The output is the active power output from the PCS **400** and is illustrates as a percentage with respect to the maximum value. In this example, the frequency reference value is 60.0 Hz.

[0100] When the connection point frequency measurement value is not higher than the target frequency upper limit value, the control unit **440** does not reduce the output power from the PCS **400**. Thus, the control unit **440** maintains the output from the PCS **400** at the maximum level. When the connection point frequency measurement value is higher than the target frequency upper limit value, the power is excessively supplied relative to the power demand in the power distribution system. Thus, the output power from the PCS **400** is reduced by the control unit **440** as the connection point frequency measurement value increases. By reducing the output power from the PCS **400** connected with the power distribution system, the frequency of the power distribution system can be reduced. The PCS **400** uses the target frequency upper limit value lower than the prescribed frequency upper limit value, and thus can perform the output reduction before the connection point frequency reaches the prescribed frequency upper limit value.

[0101] Here, an output reduction method in a case where the renewable energy power generation apparatus **330** is a solar power generation apparatus is described.

[0102] FIG. **14** illustrates P-V characteristics of the solar power generation apparatus.

[0103] The characteristics indicate that the output power from the solar power generation apparatus is changed by controlling driving voltage of the solar power generation apparatus by the control unit **440** using the DC-DC converter **410**. The P-V characteristics of the solar power generation apparatus include a maximum power point at which the maximum output power is achieved. The output power from the solar power generation apparatus changes in accordance with the insolation amount and the temperature. For example, the control unit **440** controls the driving voltage by using the DC-DC converter **410** through maximum power point tracking (MPPT). The MPPT is carried out with optimum driving voltage V**0**, achieving the maximum output power P**0** as the output power, as the target. When no output reduction is executed, the control unit **440** controls the driving voltage by using the DC-DC converter **410** with the optimum driving voltage V**0**, achieving the maximum output power P**0** as the output power, as the target. When the output reduction is executed, the control unit **440** uses the DC-DC converter **410** to reduce the driving voltage from V**0** to V**1**, so that the output power is reduced from P**0** to P**1**.

[0104] By thus controlling the driving voltage, the PCS **400** can reduce the output power.

[0105] FIG. **15** illustrates a frequency-output reduction control pattern for each frequency-output reduction control level.

[0106] When the system frequency measurement value exceeds the prescribed frequency upper limit value, the PCS integrated control apparatus **500** increments a frequency-output reduction control level Lf by one. As the frequency-output reduction control level Lf increases, the target frequency upper limit value decreases and thus becomes closer to the frequency reference value. With a higher frequency-output reduction control level Lf increases, the PCS **400** performs the output reduction for a smaller deviation of the connection point frequency measurement value from the frequency reference value. Thus, the system frequency can be more effectively increased. The PCS **400** may calculate the target frequency upper limit value and the output power from the frequency-output reduction control level by using a predetermined formula. The PCS **400** may calculate the driving voltage from the frequency-output reduction control level.

[0107] FIG. **16** illustrates how the frequency-output reduction control level is increased.

[0108] In the figure, the horizontal axis represents time and the vertical axis represents the system frequency measurement value. The frequency reference value is 60.0 Hz, and the prescribed frequency upper limit value is 60.5 Hz. At a time point T**11**, the frequency-output reduction control level is 1, and the target frequency upper limit value in the corresponding frequency-output reduction control pattern is 60.3 Hz. Then, at a time point T**12** where the system frequency measurement value exceeds the prescribed frequency upper limit value, the PCS integrated control apparatus **500** increases the frequency-output reduction control level to 2, and transmits the frequency-output reduction control level to the PCS **400**. Thus, the PCS **400** reduces the target frequency upper limit value to 60.2 Hz in accordance with the corresponding frequency-output reduction control pattern. Then, when the system frequency measurement value again exceeds the prescribed frequency upper limit value at a time point T**13**, the PCS integrated control apparatus **500** increases the frequency-output reduction control level to 3, and transmits the frequency-output reduction control level to the PCS **400**. Thus, the PCS **400** reduces the target frequency upper limit value to 60.1 Hz in accordance with the corresponding frequency-output reduction control pattern. As described above, when the PCS **400** cannot communicate with the PCS inte-

grated control apparatus **500** in the system frequency optimization processing, the connection point frequency measurement value is used instead of the system frequency measurement value.

[0109] With the system frequency optimization processing, the target frequency upper limit value can be prevented from sharply dropping, and thus excessive output reduction can be prevented. The output reduction leads to reduction of a power selling amount of a customer. Thus, with the system frequency optimization processing, the customer can regulate the reduction of the power selling amount with the renewable energy power generation apparatus **330**. When the frequency exceeds the prescribed frequency upper limit value after the frequency-output reduction control is performed, the frequency-output reduction control level is increased and the target frequency upper limit value is further reduced, whereby the frequency can be more effectively stabilized. Thus, even though the power selling amount of the customer is largely affected, the power distribution system can be more effectively stabilized.

[0110] FIG. **17** illustrates how the frequency-output reduction control level is reduced.

[0111] When a state in which the system frequency measurement value does not exceed the prescribed frequency upper limit value is maintained over a predetermined frequency restoration time period, the PCS integrated control apparatus **500** decrements the frequency-output reduction control level by one. For example, the frequency restoration time period is one day and the like, and thus is sufficiently longer than a cycle of the system frequency optimization processing. The frequency restoration time period may be set by a manager. Similarly, when the control unit **440** of the PCS **400** cannot communicate with the PCS integrated control apparatus **500** and the state where the connection point frequency measurement value does not exceed the prescribed frequency upper limit value is maintained over the frequency restoration time period, the frequency-output reduction control level is decremented by one. As described above, the PCS integrated control apparatus **500** gradually decreases the frequency-output reduction control level in a time period longer than the time for increasing the frequency-output reduction control level, whereby the frequency-output reduction control level can be prevented from immediately increasing after decreasing.

[0112] The voltage-reactive power control performed by the PCS **400** is described below.

[0113] FIG. **18** illustrates an example of the voltage-reactive power control pattern.

[0114] In the figure, the horizontal axis represents the connection point voltage measurement value and the vertical axis represents the reactive power supplied from the PCS **400** to the power distribution line **210**. The reactive power is represented by a percentage with respect to the maximum value. The reactive power of a positive value is capacitive and indicates that lagging reactive power is generated. The reactive power of a negative value is inductive and indicates that the lagging reactive power is absorbed (advanced reactive power is generated). The voltage reference value in this example is represented by 100%.

[0115] When the connection point voltage measurement value is within the target voltage range, the control unit **440** does not control the reactive power of the PCS **400**. When the connection point voltage measurement value is smaller than the target voltage lower limit value, the control unit **440** increases the reactive power in the positive direction as the connection point voltage measurement value decreases, and thus the lagging reactive power is generated from the DC/AC inverter **420** to the power distribution line **210**. Thus, with the PCS **400**, connected with the power distribution line **210**, generating the lagging reactive power, the voltage of the power distribution line **210** can be raised. When the connection point voltage measurement value is larger than the target voltage upper limit value, the control unit **440** increases the reactive power in the negative direction as the connection point voltage measurement value increases, whereby the lagging reactive power is absorbed from the power distribution line **210** to the DC/AC inverter **420**. With the PCS **400**, connected with the power distribution line **210**, absorbing the lagging reactive power, the voltage of the power distribution line **210** can be lowered. The PCS **400** uses the target voltage range smaller than the prescribed voltage range, whereby the reactive power can be controlled before the connection point voltage falls out of the prescribed range.

[0116] Now, a reactive power control method is described.

[0117] FIG. **19** illustrates how voltage and current, output from the DC/AC inverter **420**, change over time.

[0118] In the figure, the horizontal axis represents time and the vertical axis represents voltage or current. When the connection point voltage measurement value is larger than the target voltage upper limit value, the control unit **440** advances the phase of the current with respect to the voltage output from the DC/AC inverter **420**, whereby the advanced reactive power is supplied to the power distribution line **210** so that the voltage of the power distribution line **210** drops. When the connection point voltage measurement value is smaller than the target voltage lower limit value, the control unit **440** makes the phase of the current lagged from the voltage output from the DC/AC inverter **420**, whereby the lagging reactive power is supplied to the power distribution line **210** so that the voltage of the power distribution line **210** rises.

[0119] FIG. **20** illustrates a voltage-reactive power control pattern for each voltage-reactive power control level.

[0120] When the power distribution line voltage measurement value falls out of the prescribed voltage range, the PCS integrated control apparatus **500** increments the voltage-reactive power control level Lv by one. As the voltage-reactive power control level Lv rises, the target voltage range decreases, whereby the target voltage lower limit value and the target voltage upper limit value become closer to the voltage reference value. With higher voltage-reactive power control level Lv, the PCS **400** performs the reactive power control for smaller deviation of the connection point frequency measurement value from the frequency reference value.

[0121] FIG. **21** illustrates how the voltage-reactive power control level is increased.

[0122] In the figure, the horizontal axis represents time and the vertical axis represents the power distribution line voltage measurement value measured by the target data collection apparatus. The prescribed voltage lower limit value is 88%, the voltage reference value is 100%, and the prescribed voltage upper limit value is 110%. At a time point T**21**, the voltage-reactive power control level is 1, the target voltage lower limit value and the target voltage upper limit value in the corresponding voltage-reactive power control pattern are 94% and 109%, respectively. Then, when the power distribution line voltage measurement value falls out of the prescribed voltage range at a time point T**22**, the PCS integrated

control apparatus **500** increases the voltage-reactive power control pattern control level to 2, and transmits the voltage-reactive power control pattern control level to the PCS **400**. Thus, the PCS **400** increases the target voltage lower limit value to 95% and decreases the target voltage upper limit value to 108%, in accordance with the corresponding voltage-reactive power control pattern. Then, when the power distribution line voltage measurement value falls out of the prescribed voltage range again at a time point T**23**, the PCS integrated control apparatus **500** increases the voltage-reactive power control pattern control level to 3, and transmits the voltage-reactive power control pattern control level to the PCS **400**. Thus, the PCS **400** increases the target voltage lower limit value to 96% and decreases the target voltage upper limit value to 107% in accordance with the corresponding voltage-reactive power control pattern. As described above, in the power distribution line voltage optimization processing, when the PCS **400** cannot communicate with the PCS integrated control apparatus **500**, the connection point voltage measurement value is used instead of the power distribution line voltage measurement value.

[0123] With the power distribution line voltage optimization processing, the target voltage range can be prevented from rapidly decreasing and the reactive power can be prevented from being excessively supplied. When the voltage falls out of the prescribed voltage range after the voltage-reactive power control is performed, the voltage-reactive power control level is increased to further reduce the target voltage range. Thus, the power distribution line voltage can be more effectively stabilized.

[0124] FIG. **22** illustrates how the voltage-reactive power control level is reduced.

[0125] When the state where the power distribution line voltage measurement value stays within the prescribed voltage range is maintained over a predetermined voltage restoration time period, the optimization unit **520** of the PCS integrated control apparatus **500** reduces the voltage-reactive power control level. The voltage restoration time period is several hours for example, and thus is sufficiently longer than a cycle of the power distribution line voltage optimization processing, and is shorter than the frequency restoration time period. The voltage restoration time period may be set by the manager. Similarly, when the communication with the PCS integrated control apparatus **500** cannot be established and the state where the connection point voltage measurement value stays within the prescribed voltage range is maintained over the voltage restoration time period, the control unit **440** of the PCS **400** decrements the voltage-reactive power control level by one. As described above, the PCS integrated control apparatus **500** gradually decreases the voltage-reactive power control level in a time period longer than the time for increasing the voltage-reactive power control level, whereby the voltage-reactive power control level can be prevented from immediately increasing after decreasing.

[0126] The frequency restoration time period and the voltage restoration time period may be set based on the scale of the PCS **400**. For example, the large scale PCS **400** avoids a change in the control level in a short period of time as such a change largely affects the power distribution system and the power distribution line **210**.

[0127] The technique described in the embodiment can be expressed as follows.

[0128] (Expression 1)

[0129] A control apparatus controlling a plurality of power conversion apparatuses each connected with an electrical grid, converting DC power from a power source into AC power, and transmitting the AC power to the electrical grid, the control apparatus including:

[0130] a communication unit configured to repeatedly receive a system frequency as a frequency of power measured in the electrical grid, and

[0131] a determination unit configured to determine based on the system frequency an active power control level indicating a level of control for active power output to the electrical grid by each power conversion apparatus, wherein

[0132] the communication unit is configured to transmit the active power control level to the plurality of power conversion apparatuses,

[0133] each power conversion apparatus is configured to store active power relationship information indicating a relationship between the active power control level and a connection point frequency as a frequency at a connection point to the electrical grid, repeatedly measure the connection point frequency, receive the active power control level from the control apparatus, and control the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information.

[0134] Terms for describing the present invention are described. The power distribution system and the like may be used as an electrical grid. The renewable energy power generation apparatus **330** and the like may be used as a power source. The PCS **400** and the like may be used as a power conversion apparatus. The PCS integrated control apparatus **500** and the like may be used as a control apparatus. The control pattern management table **460** and the like may be used as active power relationship information. The control pattern management table **460** and the like may be used as reactive power relationship information. The frequency-output reduction control level and the like may be used as an active power control level. The voltage-reactive power control level and the like may be used as a reactive power control level. The system frequency measurement value and the like may be used as a system frequency. The power distribution line voltage measurement value and the like may be used as power distribution line voltage. The connection point frequency measurement value and the like may be used as a connection point frequency. The connection point voltage measurement value and the like may be used as connection point voltage. The control pattern management table **460** and the like may be used as a storage unit. The sensor **430** and the like may be used as a measurement unit. The communication unit **450** and the like may be used as a communication unit in the power conversion apparatus. The DC/DC converter **410** and the like may be used as a DC/DC conversion unit. The DC/AC inverter **420** and the like may be used as a DC/AC conversion unit. The communication unit **510** may be used as a communication unit in the control apparatus. An optimization unit **520** and the like may be used as a determination unit.

[0135] The present invention is not limited to the embodiment described above, and may be modified in various ways without departing from the gist of the present invention.

What is claimed is:

1. An electrical grid control system comprising:

a plurality of power conversion apparatuses each connected with an electrical grid and each configured to convert DC power from a power source into AC power, output the AC power to the electrical grid, and store active power relationship information indicating a relationship between an active power control level representing a level of control for active power outputted to the electrical grid and a connection point frequency being a frequency at a connection point to the electrical grid; and

a control apparatus configured to repeatedly receive information indicating a system frequency measured in the electrical grid, determine the active power control level based on the system frequency, and transmit the active power control level to the plurality of power conversion apparatuses, wherein

each power conversion apparatus is configured to repeatedly measure the connection point frequency, receive the active power control level from the control apparatus, and control the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information.

2. The electrical grid control system according to claim **1**, wherein

the electrical grid includes a plurality of power distribution lines,

the plurality of power distribution lines are respectively disposed for a plurality of measurement apparatuses,

each power conversion apparatus is connected with one of the plurality of power distribution lines, and is configured to store reactive power relationship information indicating a relationship between a reactive power control level indicating a level of control on the reactive power outputted to the electrical grid, and the connection point voltage being voltage at the connection point,

for each power distribution line, the control apparatus is configured to repeatedly receive information indicating power distribution line voltage being voltage of the power distribution line and measured by the measurement apparatus corresponding to the power distribution line, determine a reactive power control level of the power conversion apparatus connected with the power distribution line based on the power distribution line voltage, and transmit the reactive power control level to the power conversion apparatus, and

each power conversion apparatus is configured to repeatedly measure the connection point voltage, receive the reactive power control level from the control apparatus, and control the reactive power based on the measured connection point voltage, the received reactive power control level, and the reactive power relationship information.

3. The electrical grid control system according to claim **2**, wherein

the active power relationship information includes a relationship between the active power control level and a target frequency upper limit value being an upper limit of a target range of the connection point frequency, and

the power conversion apparatus determines the target frequency upper limit value based on the received active power control level and the active power relationship information, determines whether the connection point frequency exceeds the target frequency upper limit value, and reduces the active power in accordance with the connection point frequency, upon determining that the connection point frequency exceeds the target frequency upper limit value.

4. The electrical grid control system according to claim **3**, wherein

the reactive power relationship information includes a relationship between the reactive power control level and a target voltage range being a target range of the connection point voltage, and

the power conversion apparatus determines the target voltage range based on the received reactive power control level and the reactive power relationship information, determines whether the connection point voltage is out of the target voltage range, and increases the reactive power in accordance with the connection point voltage, upon determining that the connection point voltage is out of the target voltage range.

5. The electrical grid control system according to claim **4**, wherein

the control apparatus determines whether the system frequency exceeds a prescribed frequency upper limit value set in advance, and increases the active power control level, upon determining that the system frequency exceeds the prescribed frequency upper limit value, and

the power conversion apparatus reduces the target frequency upper limit value, upon receiving the increased active power control level.

6. The electrical grid control system according to claim **5**, wherein

the control apparatus determines whether the power distribution line voltage is out of a prescribed voltage range set in advance, and increases the reactive power control level, upon determining that the power distribution line voltage is out of the prescribed voltage range, and

the power conversion apparatus narrows the target voltage range, upon receiving the increased reactive power control level.

7. The electrical grid control system according to claim **6**, wherein

the target frequency upper limit value is lower than the prescribed frequency upper limit value,

a lower limit of the target voltage range is higher than a lower limit of the prescribed voltage range, and

an upper limit of the target voltage range is lower than an upper limit of the prescribed voltage range.

8. The electrical grid control system according to claim **1**, wherein

each power conversion apparatus determines whether communication is able to be established with the control apparatus, selects an active power control level based on the measured connection point frequency, upon determining that the communication is not able to be established with the control apparatus, and controls the active power based on the measured connection point frequency, the selected active power control level, and the active power relationship information.

9. The electrical grid control system according to claim **8**, wherein

each power conversion apparatus determines whether communication is able to be established with the control apparatus, selects a reactive power control level based on

the measured connection point voltage, upon determining that the communication is not able to be established with the control apparatus, and controls the reactive power based on the measured connection point voltage, the selected reactive power control level, and the reactive power relationship information.

10. The electrical grid control system according to claim **2**, wherein the control apparatus causes a display apparatus to display the active power control level and the reactive power control level transmitted to each power conversion apparatus.

11. An electrical grid control method comprising:

converting, using each of a plurality of power conversion apparatuses connected with an electrical grid, DC power from a power source into AC power;

outputting, using each power conversion apparatus, the AC power to the electrical grid;

storing, using each power conversion apparatus, active power relationship information indicating a relationship between an active power control level indicating a level of control on active power output to the electrical grid, and a connection point frequency being a frequency at a connection point to the electrical grid;

repeatedly receiving, using a control apparatus, information indicating a system frequency being a frequency of power measured in the electrical grid;

determining, using the control apparatus, the active power control level based on the system frequency;

transmitting, using the control apparatus, the active power control level to the plurality of power conversion apparatuses;

repeatedly measuring, using each power conversion apparatus, the connection point frequency;

receiving, using each power conversion apparatus, the active power control level from the control apparatus; and

controlling, using each power conversion apparatus, the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information.

12. A power conversion apparatus comprising:

a storage unit configured to store active power relationship information indicating a relationship between an active power control level representing a level of control for active power output to an electrical grid and a connection point frequency being a frequency at a connection point to the electrical grid;

a measurement unit configured to repeatedly measure the connection point frequency;

a communication unit configured to receive the active power control level;

a DC/DC conversion unit coupled to a power source and configured to control the active power based on the measured connection point frequency, the received active power control level, and the active power relationship information; and

a DC/AC conversion unit connected with the electrical grid and configured to convert DC power from the DC/DC conversion unit to AC power and output the AC power to the electrical grid.

* * * * *