

[DESCRIPTION]

[TITLE OF INVENTION]

CONTROL DEVICE AND CONTROL METHOD

[Technical Field]

5 [0001]

The present disclosure relates to a control device and a control method for controlling an inverter provided in a power supply.

[Background Art]

[0002]

10 In a power system that supplies alternating current (AC) power from a power supply to a load, control is performed such that a voltage and a frequency to be output are maintained regardless of a supply and demand situation. When the amount of AC power introduced from the renewable energy source in the power system increases as compared with the synchronous generator, the supply and demand balance is changeable rapidly, and
15 the stability of the power system tends to decrease. As a countermeasure therefor, a technique called virtual synchronous generator (VSG) control is known (for example, Patent Document 1). The VSG control causes the inverter provided in the power supply to have the inertial force of the synchronous generator in a pseudo manner, thereby stabilizing the power system.

20 [Citation List]

[Patent Document]

[0003]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2016-93103

25 [Summary of Invention]

[Technical Problem]

[0004]

However, in a power supply system including a plurality of distributed power supplies, Q_v control is often performed to suppress reactive power Q circulating between the distributed power supplies. In the Q_v control, the amplitude V_v of the AC voltage output from the inverter is controlled such that the reactive power Q output from the inverter approaches the command value. On the other hand, in the VSG control, the frequency f_v of the AC voltage output from the inverter is controlled such that the active power P output from the inverter approaches the command value. Here, the frequency f_v , the amplitude V_v , and the apparent power S (power corresponding to a square root of a sum obtained by adding a square of the active power P and a square of the reactive power Q) have a close relationship, and when one of the frequency f_v and the amplitude V_v is operated, both the active power P and the reactive power Q are affected. Therefore, the VSG control and the Q_v control interfere with each other, and it may be difficult to appropriately control the inverter.

[0005]

The present disclosure has been made to solve the above problem, and an object thereof is to provide a control device and a control method capable of appropriately controlling an inverter even in a case where both VSG control and Q_v control are performed.

[Solution to Problem]

[0006]

In order to solve the above problem, one aspect of the present disclosure is a control device that controls an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control device

comprising: a virtual synchronous generator (VSG) controller that controls a frequency of the AC voltage so as to have a virtual inertial force; and a Qv controller that controls an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power, wherein the Qv controller determines a control amount of the amplitude of the AC voltage according to a relationship between a frequency band of a Qv control system and a frequency band of a VSG control system, the Qv control system controlling to reduce the difference, and the VSG control system controlled by the VSG controller.

[0007]

In order to solve the above problem, one aspect of the present disclosure is a control method control method that is performed by a control device for controlling an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control method comprising: controlling, by a virtual synchronous generator (VSG) controller, a frequency of the AC voltage so as to have a virtual inertial force, controlling, by a Qv controller, an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power, and determining, by the Qv controller, a control amount of the amplitude of the AC voltage according to a relationship between a frequency band of a Qv control system and a frequency band of a VSG control system, the Qv control system controlling to reduce the difference, and the VSG control system controlled by the VSG controller.

[Advantageous Effects of Invention]

[0008]

According to the present disclosure, the inverter can be appropriately controlled even in a case where both VSG control and Qv control are performed.

[Brief Description of Drawings]

[0009]

FIG. 1 is a diagram illustrating a configuration example of a microgrid according to the first embodiment of the present disclosure.

FIG. 2 is a diagram for explaining control performed by the control device C
5 according to the first embodiment.

FIG. 3 is a diagram for explaining control performed by the control device C according to the first embodiment.

FIG. 4 is a diagram for explaining Qv control according to the first embodiment.

FIG. 5 is a diagram for explaining Qv control according to the first embodiment.

10 FIG. 6 is a diagram for explaining Qv control according to the first embodiment.

FIG. 7 is a diagram for explaining Qv control according to the first embodiment.

FIG. 8 is a diagram illustrating a configuration example of a microgrid according to the second embodiment.

FIG. 9 is a diagram for explaining control performed by the control device C
15 according to the second embodiment.

FIG. 10 is a diagram for explaining control performed by the control device C according to Modification 1 of the second embodiment.

FIG. 11 is a diagram illustrating a configuration example of a microgrid according to Modification 2 of the second embodiment.

20 FIG. 12 is a diagram for explaining the relationship between the control device C and the inverter controller according to the first embodiment.

FIG. 13 is a diagram for explaining the relationship between the control device C and the inverter controller according to the second embodiment.

[Description of Embodiments]

25 [0010]

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings. Note that the scope of the present disclosure is not limited to the following embodiments, and can be arbitrarily changed within the scope of the technical idea of the present disclosure.

5 [0011]

<First Embodiment>

FIG. 1 is a diagram illustrating a configuration example of a microgrid according to the first embodiment. As illustrated in FIG. 1, a microgrid 1 comprises a power generation facility 2, a plurality of power reception and distribution facilities 4, a plurality
10 of storage batteries 5, a power transmission and distribution network 6, and a storage battery control system 10. The components in the microgrid 1 are connected to each other by the power transmission and distribution network 6.

[0012]

The power generation facility 2 is, for example, a wind power plant, a solar cell,
15 a hydraulic power plant, or the like. Other types of power generation facilities 2 may be used. Further, a plurality of types of power generation facilities 2 may be used in combination.

[0013]

The microgrid 1 is configured to charge and discharge the plurality of storage
20 batteries 5 according to the supply and demand situation of power. For example, in a situation with small demand, the plurality of storage batteries 5 are charged using the power generated by the power generation facility 2. Besides, in a situation with large power demand, the power generated by the power generation facility 2 and the power of the plurality of storage batteries 5 are combined and output to the power system.
25 Alternatively, the combined power may be supplied to the load in the microgrid 1. In the

present embodiment, the microgrid 1 constitutes a self-sustaining power system that independently generates and consumes power.

[0014]

The microgrid 1 may be connected to a power system comprising a load via the power transmission and distribution network 6. In this case, a switch (not illustrated) may be provided between the microgrid 1 and the power system. The switch is switchable between a closed state and an open state. When the switch is in the open state, the microgrid 1 and the power system are disconnected, and the microgrid 1 constitutes a self-sustaining power system. When the switch is in the closed state, the microgrid 1 and the power system 3 are connected.

[0015]

Each of the storage batteries 5 may be, for example, a lithium-ion battery, a NAS battery, a redox flow battery, or the like. Other types of storage batteries 5 may be used.

[0016]

The storage battery control system 10 comprises an integrated controller 11 and a plurality of power conditioning systems (PCSs) 12.

[0017]

The integrated controller 11 manages the plurality of PCSs 12. The integrated controller 11 controls the storage battery control system 10. The integrated controller 11 may be configured as any of, for example, a community energy management system (CEMS), an area energy management system (AEMS), a building and energy management system (BEMS), and the like. The integrated controller 11 comprises a calculator unit, a communicator, and the like. The calculator is a CPU or the like, and performs calculation for realizing the function of the integrated controller 11 described above. The communicator performs wireless or wired communication with each PCS 12. For

example, the communicator transmits a command value generated by the calculator, for example, a command value P_{ref} of the active power P and a command value Q_{ref} of the reactive power Q to be described later, to each PCS 12.

[0018]

5 The PCS 12 is configured as a distributed power supply incorporating an inverter INV that controls charging and discharging of the storage battery 5. The PCS 12 comprises a control device C that controls the inverter INV and a communication device T that communicates with the integrated controller 11. In the present embodiment, each PCS 12 performs grid following (GFL) control according to a command value provided from the
10 integrated controller 11, for example, the command value P_{ref} of the active power P and the command value Q_{ref} of the reactive power Q to be described later, and causes the storage battery 5 corresponding to the PCS 12 to function as a voltage source.

[0019]

FIG. 2 is a diagram for explaining control performed by the control device C
15 according to the first embodiment. FIG. 2 schematically illustrates the inverter INV controlled by the control device C, the inverter INV, and a load, another inverter INV, or the like that is a connection target connected via a line impedance L . In the following description, a load, another inverter INV, or the like, which is a connection destination, may be simply referred to as a “connection target”.

20 [0020]

As illustrated in FIG. 2, the relational expression between the output voltage v_1 of the AC power output from the inverter INV, the line impedance L , the current i flowing through the line impedance L , and the output voltage v_2 of the AC power output from the connection target is Formula (1) below.

25 [0021]

[Mathematical Formula 1]

$$L \frac{di}{dt} = V_v e^{j2\pi f_v t} - V_0 e^{j(2\pi f_0 t + \theta_0)} \quad \cdot \cdot \cdot (1)$$

[0022]

Here, f_v is the frequency of the AC voltage output from the inverter INV. f_0 is
 5 the frequency of the AC voltage output from the connection target. θ_0 is a phase difference
 between the active power P and the reactive power Q.

[0023]

In the present embodiment, the output power may mean power flow. That is,
 power received by the inverter INV from a load or another inverter INV as a connection
 10 target or the power transmission network E may be set as negative output power, and may
 be handled unitarily with output power supplied to the load or another inverter INV as a
 connection target or the power transmission network E.

[0024]

In Formula (1), given that a difference between the frequency f_v and the frequency
 15 f_0 is Δf , the relationship of Formula (1) is expressed by Formula (2-1) below. Solving
 Formula (2-1) for the current i , Formulas (2-2) to (2-4) below are obtained.

[0025]

[Mathematical Formula 2]

$$f_0 = f_V - \Delta f \quad \cdot \cdot \cdot (2-1)$$

$$L \frac{di}{dt} = V_V e^{j2\pi f_V t} - V_0 e^{j(2\pi f_V t - 2\pi \Delta f t + \theta_0)} \quad \cdot \cdot \cdot (2-2)$$

$$Li = \frac{V_V}{j2\pi f_V} e^{j2\pi f_V t} - \frac{V_0}{j2\pi(f_V - \Delta f)} e^{j(2\pi f_V t - 2\pi \Delta f t + \theta_0)} \quad \cdot \cdot \cdot (2-3)$$

$$i = \frac{V_V}{j2\pi f_V L} e^{j2\pi f_V t} - \frac{V_0}{j2\pi(f_V - \Delta f)L} e^{j(2\pi f_V t - 2\pi \Delta f t + \theta_0)} \quad \cdot \cdot \cdot (2-4)$$

$$i = -\frac{jV_V}{2\pi f_V L} e^{j2\pi f_V t} + \frac{jV_0 \{ \cos(\theta_0 - 2\pi \Delta f t) + j \sin(\theta_0 - 2\pi \Delta f t) \}}{2\pi(f_V - \Delta f)L} e^{j2\pi f_V t} \quad \cdot \cdot \cdot (2-5)$$

$$i = -\frac{V_0 \sin(\theta_0 - 2\pi \Delta f t)}{2\pi(f_V - \Delta f)L} e^{j2\pi f_V t} - j \frac{V_V}{2\pi f_V L} e^{j2\pi f_V t} + j \frac{V_0 \cos(\theta_0 - 2\pi \Delta f t)}{2\pi(f_V - \Delta f)L} e^{j2\pi f_V t} \quad \cdot \cdot \cdot (2-6)$$

[0026]

Using Formula (2-4), the apparent power S output from the inverter INV is expressed by Formula (3-1) below. Here, P is active power output from the inverter INV.

- 5 Q is reactive power output from the inverter INV. According to Formula (3-1), the active power P can be expressed as Formula (3-2). In addition, according to Formula (3-2), the reactive power Q can be expressed as Formula (3-3).

[0027]

[Mathematical Formula 3]

$$S = P + jQ = \bar{v}i = V_V \frac{V_0 \sin(2\pi \Delta f t - \theta_0)}{2\pi(f_V - \Delta f)L} - jV_V \frac{V_V}{2\pi f_V L} + jV_V \frac{V_0 \cos(2\pi \Delta f t - \theta_0)}{2\pi(\Delta f - f_D)L} \quad \cdot \cdot \cdot (3-1)$$

$$P = V_V \frac{V_0 \sin(2\pi \Delta f t - \theta_0)}{2\pi(f_V - \Delta f)L} \quad \cdot \cdot \cdot (3-2)$$

$$Q = -V_V \frac{V_V}{2\pi f_V L} + V_V \frac{V_0 \cos(2\pi \Delta f t - \theta_0)}{2\pi(f_V - \Delta f)L} \quad \cdot \cdot \cdot (3-3)$$

[0028]

The VSG control causes, by adjusting the frequency f_v of the AC voltage output from the inverter INV, the PCS 12 to have the inertial force of the synchronous generator in a pseudo manner, thereby stabilizing the power system. When the frequency f_v fluctuates by the VSG control, the active power P and the reactive power Q are generated according to the relationship between the amplitude V_o , the frequency f_o , and the phase difference θ_o at the connection target. In addition, when another inverter INV as a connection target is the inverter INV having VSG control, the active power P and the reactive power Q are similarly generated.

[0029]

When the reactive power Q is generated, the output of the reactive power Q can be suppressed by adjusting the amplitude V_v of the AC voltage output from the inverter INV by the Q_v control.

[0030]

However, as shown in Formula (3-2), the active power P comprises both the amplitude V_v and the frequency f_v of the AC voltage output from the inverter INV as parameters. As shown in Formula (3-3), the reactive power Q comprises both the amplitude V_v and the frequency f_v of the AC voltage output from the inverter INV as parameters.

[0031]

Therefore, when the operation of fluctuating the frequency f_v is performed by the VSG control such that the active power P approaches the command value P_{ref} , the reactive power Q fluctuates with the fluctuation of the frequency f_v . On the other hand, when the operation of fluctuating the amplitude V_v is performed by the Q_v control such that the reactive power Q approaches the command value Q_{ref} , the active power P fluctuates with the fluctuation of the amplitude V_v . Consequently, control interference may occur between

the VSG control and the Q_v control.

[0032]

As a countermeasure for avoiding the occurrence of this control interference, it is considered to perform control to reduce the control amount of the amplitude V_v by the Q_v control. In this case, for example, the amount of fluctuation of the amplitude is multiplied by a gain corresponding to a real number larger than 0 (zero) and less than 1, such as a relatively small gain, for example, 0.3, and the fluctuation of the amplitude V_v is controlled to be suppressed. However, the decreased gain of the amplitude V_v by the Q_v control, the effect of suppressing the reactive power Q is reduced. When the effect of suppressing the reactive power Q is small, in particular, in the storage battery control system comprising a plurality of inverters INV that perform VSG control, the reactive power Q is circulated between the inverters INV, thereby occurring wasteful power loss.

[0033]

In order to solve such a problem, the present embodiment focuses on the fact that the VSG control suppresses a rapid change in the output power due to a fluctuation in the power generation amount and a load fluctuation to take measures. Specifically, in the present embodiment provides the fluctuation of the amplitude V_v by the Q_v control hardly in a relatively high frequency band that is a control target in the VSG control.

[0034]

More specifically, in the present embodiment, in the Q_v control, two types of gains are provided: a high-band gain applied to a high frequency band that is interfered with the VSG control; and a low-band gain applied to a low frequency band that is less interfered with the VSG control. For example, the high-band gain is set to a smaller value than the low-band gain.

[0035]

As a result, in the Q_v control, the fluctuation of the amplitude V_v may be suppressible by applying the high-band gain in a high frequency band that is interfered with the VSG control. On the other hand, in the Q_v control, the reactive power Q may be suppressible by applying the low-band gain in a low frequency band that is less interfered with the VSG control. Therefore, both avoidance of control interference and suppression of wasteful power generation due to circulation of the reactive power Q may be achieved.

[0036]

FIG. 3 is a diagram for explaining control performed by the control device C according to the first embodiment. The “control target” illustrated in FIG. 3 corresponds to a connection target in FIG. 2, and is an inverter controller that controls the inverter INV, the inverter INV, an inverter output filter, and a power system connected via the inverter INV. The inverter controller here is a device that sets, to the inverter INV, the amplitude and frequency of the AC voltage output from the inverter INV. In addition, the power system connected via the inverter INV is, for example, another PCS 12 as a connection target, wiring and a load to the other PCS 12, and the like. According to the relationship with the power system connected via the inverter INV, the control device C controls the amplitude V_v and the frequency f_v of the AC voltage output from the inverter INV.

[0037]

As illustrated in FIG. 3, the control device C comprises, for example, control blocks B11, B12, and B13, a zero-order hold ZOH, an adder, and a subtractor.

[0038]

The command value P_{ref} and the command value Q_{ref} , which are respectively command values of the active power P and the reactive power Q provided from the integrated controller 11, are input to the control device C. In addition, a measured value $P_{measure}$ and a measured value $Q_{measure}$, which are respectively the measured values of

the active power P and the reactive power Q from the inverter INV, are input to the control device C. The measured value Q_{measure} and the measured value P_{measure} are measured by, for example, a measuring instrument attached to a power line to which power is supplied.

5 [0039]

The control device C calculates a deviation dQ of the reactive power Q by the subtractor. The deviation dQ is a difference between the command value Q_{ref} and the measured value Q_{measure} . The control device C outputs a difference value obtained in the subtractor by subtracting, from the command value Q_{ref} , a signal value obtained by the zero-order hold ZOH on the measured value Q_{measure} , as the deviation dQ , to the control block B11.

[0040]

The control block B11 performs Q_v control. The control block B11 is an example of a “ Q_v controller”. In the example of this drawing, the control block B11 is described as “two-stage gain”. In addition, a closed-loop system control system that can be expressed by a transfer function of output/input from the control block B11 corresponding to the “ Q_v controller” to the control target may be referred to as a “ Q_v control system”.

[0041]

The control block B11 calculates the amplitude deviation such that the deviation dQ approaches 0. The control block B calculates an amplitude deviation in which the deviation dQ approaches zero by performing feedback control such as PI control, for example. The amplitude deviation here is a difference between the amplitude V_v of the AC voltage output from the inverter INV to the control target and the rated voltage V_m .

25 [0042]

Here, the gain applied to the amplitude deviation, when the control block B11 performs the Qv control, will be described with reference to FIGS. 4 to 7. FIGS. 4 to 7 are diagrams for explaining Qv control according to the first embodiment.

[0043]

5 FIG. 4 schematically illustrates frequency characteristics L1 to L3 of the gain applied to the Qv control. In FIG. 4, the horizontal axis represents the frequency F, and the vertical axis represents the gain Gain. The frequency characteristic L1 is an example of the frequency characteristic of the gain applied to the amplitude deviation in the conventional Qv control. The frequency characteristic L2 is the frequency characteristic of the gain
10 applied to the amplitude deviation in the present embodiment. The frequency characteristic L3 is another example of the frequency characteristic of the gain applied to the amplitude deviation in the conventional Qv control.

[0044]

 The frequency characteristic L1 is a uniform value independent of the frequency
15 band as a gain applied to the amplitude deviation in the Qv control, and indicates a characteristic in a case of operation that a relatively large gain is set and the reactive power Q is suppressed. In this case, in a high frequency band, the control by the Qv control and the VSG control interfere with each other, and it makes difficult to appropriately control the inverter INV.

20 [0045]

 The frequency characteristic L3 is a uniform value independent of the frequency
band as a gain applied to the amplitude deviation in the Qv control, and indicates a characteristic in a case of operation that a relatively small gain is set and the reactive power Q is hardly suppressed. In this case, the interference between the control by the Qv
25 control and the VSG control may be suppressed, whereas the reactive power Q may not be

suppressed, thus consuming unnecessary power.

[0046]

On the other hand, in the frequency characteristic L2, a high-band gain, that is a relatively small gain, is applied in a high frequency band that is interfered with the VSG control. This may suppress fluctuation of the amplitude V_v . Besides, in a low frequency band that is interfered with the VSG control, a low-band gain, that is a relatively large gain, is applied. This may suppress the reactive power Q . Therefore, both avoidance of control interference and suppression of wasteful power generation may be achieved.

[0047]

FIG. 5 is a block diagram illustrating an example of a configuration of the control block B11. As illustrated in FIG. 5, in the control block B11, for example, a numerator and a denominator can be expressed by a function of an N-order system, where N is an arbitrary natural number. The example of this drawing exemplifies a case where the control block B11 is configured by a function of a first-order system.

[0048]

The control block B11 comprises, for example, a multiplier, a first frequency characteristic adjuster, and a second frequency characteristic adjuster. The multiplier is a multiplier that multiplies K . Here, K is a gain of the amplitude deviation. The first frequency characteristic adjuster is a frequency characteristic adjuster that applies a transfer function $\{1/(1+sT_a)\}$. The second frequency characteristic adjuster is a frequency characteristic adjuster that causes the transfer function $(1+sT_b)$ to act. T_a and T_b are time constants. s is a Laplace operator.

[0049]

The control block B11 outputs, as an amplitude deviation, a value obtained by applying the transfer function $\{1/(1+sT_a)\}$ and the transfer function $(1+sT_b)$ to a

multiplication value obtained by multiplying the deviation dQ by the gain K of the amplitude deviation. Therefore, the control block B11 can output a value obtained by applying the transfer function $\{K \cdot (1+sT_b)/(1+sT_a)\}$ to the deviation dQ as an amplitude deviation.

5 [0050]

Here, in a case of the low-band gain larger than the high-band gain, the time constant T_b needs to be made smaller than the time constant T_a .

[0051]

In addition, the time constants T_a and T_b are desirably set to be large enough not
10 to affect the control system characteristics other than the Q_v control system, that is, the VSG control and the governor (speed governor) control by the control block B13.

[0052]

For example, as a method of determining the time constants T_a and T_b and the gain K of the amplitude deviation, which are the control parameters for performing the Q_v
15 control of the present embodiment, it is considered to determine the control parameters through three stages in the order of the first stage to the third stage. In the first stage, the time constant T_b is determined. In the second stage, a low-band gain corresponding to the gain K of the amplitude deviation related to the convergence value when the gain is converged in the low frequency band is determined. In the third stage, $(K \cdot T_b/T_a)$
20 corresponding to the high-band gain related to stability in the high frequency band is determined. The time constant T_a is indirectly determined in the third stage.

[0053]

FIG. 6 illustrates a gain characteristic that is a frequency characteristic of a gain applied to the amplitude deviation in the Q_v control of the present embodiment. In FIG. 6,
25 the horizontal axis represents the angular frequency ω , and the vertical axis represents the

gain G. In FIG. 6, a solid line indicates frequency characteristics of the Qv control (two-stage gain) of the present embodiment. A broken line indicates the frequency characteristic of the gain K of the amplitude deviation. An alternate long and short dash line indicates the frequency characteristic of the transfer function $\{1/(1+sT_a)\}$ corresponding to the first frequency characteristic adjuster. An alternate long and two short dashes line indicates the frequency characteristic of the transfer function $(1+sT_b)$ corresponding to the second frequency characteristic adjuster.

[0054]

In the example of FIG. 6, the gain K of the amplitude deviation as the control parameter is “2”. This means an amplification of about 6 [dB]. The time constant T_a is 0.1 [sec]. This is a time constant corresponding to the cutoff frequency at which the gain G attenuates by about 3 [dB] in the frequency characteristic of the transfer function $\{1/(1+sT_a)\}$. The time constant T_b is 0.01 [sec]. This is a time constant corresponding to the frequency at which the gain G increases by about 3 [dB] in the frequency characteristic of the transfer function $(1+sT_b)$.

[0055]

The relationship between the transfer function and the frequency characteristic can be obtained by replacing the Laplace operator s in the transfer function with the complex number $j\omega$ corresponding to the sine wave. Specifically, as shown in Formula (4-1), in the transfer function $\{K \cdot (1+j\omega T_b)/(1+j\omega T_a)\}$ obtained by replacing the Laplace operator s in the transfer function $\{K \cdot (1+sT_b)/(1+sT_a)\}$ with the complex number $j\omega$, the limiting value in a case where the angular frequency ω is brought close to 0 as shown in Formula (4-2) corresponds to the low-band gain. In the example of this drawing, the low-band gain is the gain K of the amplitude deviation. In addition, as shown in Formula (4-3), in the transfer function $\{K \cdot (1+j\omega T_b)/(1+j\omega T_a)\}$, the limit value, in a case where the

angular frequency ω is brought close to infinity ∞ , corresponds to the high-band gain. In the example of this drawing, the high-band gain is $(K \cdot Tb/Ta)$. That is, the gain characteristics in the example of this drawing show the gain K of an amplitude deviation which is a low-band gain in a low frequency band, and a high-band gain $(K \cdot Tb/Ta)$ in a high frequency band. In the example of this drawing, the gain difference between the low-band gain and the high-band gain is about 20 [dB].

[0056]

[Mathematical Formula 4]

$$K \frac{1 + sTb}{1 + sTa} \quad \cdot \cdot \cdot (4 - 1)$$

$$\lim_{\omega \rightarrow 0} K \frac{1 + j\omega Tb}{1 + j\omega Ta} = K \quad \cdot \cdot \cdot (4 - 2)$$

$$\lim_{\omega \rightarrow \infty} K \frac{1 + j\omega Tb}{1 + j\omega Ta} = K \frac{Tb}{Ta} \quad \cdot \cdot \cdot (4 - 3)$$

10 [0057]

FIG. 7 illustrates a phase characteristic of the gain applied to the amplitude deviation in the Qv control of the present embodiment. FIG. 7 illustrates phase characteristics of the transfer function having the gain characteristics illustrated in FIG. 6. In FIG. 7, the horizontal axis represents the angular frequency ω , and the vertical axis represents the phase $\angle G$. In FIG. 7, a solid line indicates the phase characteristic of the Qv control (two-stage gain) of the present embodiment. A broken line indicates the phase characteristic of the gain K of the amplitude deviation. An alternate long and short dash line indicates the phase characteristic of the transfer function $\{1/(1+sTa)\}$ corresponding to the first integrator. An alternate long and two short dashes line indicates the phase characteristic of the transfer function $(1+sTb)$ corresponding to the second integrator. In the example of FIG. 7, in the Qv control (two-stage gain) of the present embodiment, a

delay of about 50 [deg.] at the maximum occurs. As described above, in addition to the control block B11, the control parameter needs to be set such that the Qv control system expressed by the zero-order hold ZOH and the transfer function of the control target is not unstable. As a method for determining the stability of the Qv control system, a general
 5 control theory such as a Nyquist stability determination method may be used.

[0058]

Back to the description of FIG. 3, in the control device C, the zero-order hold ZOH is performed on the amplitude deviation calculated by the control block B11, the rated voltage V_m is added to the amplitude deviation obtained by the zero-order hold ZOH,
 10 and the sum is output as the amplitude V_v .

[0059]

As illustrated in the lower part of FIG. 3, the control device C controls the frequency f_v based on the active power P . The control device C calculates a subtractor output difference value obtained by subtracting the speed governor output value from the
 15 command value P_{ref} of the active power P by the subtractor, and outputs the calculated subtractor output difference value to the control block B12. The speed governor output value here is an output value from the control block B13. The control block B13 is a functional block that performs control simulating a governor (speed governor) for keeping the rotation speed of the synchronous generator constant.

20 [0060]

The control block B12 performs VSG control. The control block B12 is an example of a “VSG controller”. In addition, a closed-loop control system that can be expressed by a transfer function of output/input from the control block B12 corresponding to the “VSG controller” to the control target may be referred to as a “VSG control system”.
 25 The control block B12 calculates a deviation dP of the active power P . The deviation dP

is a difference between the subtractor output difference value and the measured value P_{measure} . The control block B12 sets, as the deviation dP , a difference value obtained by subtracting, by a subtractor, a signal value obtained by performing zero-order hold ZOH on the measured value P_{measure} from the subtractor output difference value.

5 [0061]

The control block B12 calculates the frequency deviation df based on the deviation dP . For calculating the deviation df , the control block B12 applies a transfer function corresponding to the braking parameter D and the inertia parameter M in order to impart the inertia force of the synchronous generator in a pseudo manner. Specifically,
 10 the control block B12 divides the deviation dP by the braking parameter D , and outputs a value obtained by applying the transfer function $\{1/(1+sM/D)\}$ to the division value as the frequency deviation df . The control block B12 outputs, as the frequency f_v , a sum obtained by adding the rated frequency f_n to the signal value obtained by performing the zero-order hold ZOH on the frequency deviation df . In addition, the control block B12 outputs the
 15 frequency deviation df to the control block B13.

[0062]

The control block B13 performs a behavior like a governor (speed governor) in a pseudo manner. The control block B13 calculates a speed governor output value by applying a transfer function $\{K/(1+sT)\}$ to the frequency deviation df . T represents a speed
 20 governor time constant. The speed governor time constant T is a time constant corresponding to the integration time. Here, K represents the gain of the speed governor. The control block B13 feeds back the calculated speed governor output value.

[0063]

As described above, the control device C according to the first embodiment is a
 25 control device that controls the inverter INV that converts the DC voltage from the storage

battery 5 into the AC voltage. The control device C comprises the control block B12 (VSG controller) and the control block B11 (Qv controller). The control block B12 (VSG controller) controls the frequency of the AC voltage so as to have a virtual inertial force. The control block B11 (Qv controller) controls the amplitude of the AC voltage to reduce the difference between the command value Q_{ref} and the measured value $Q_{measure}$ in the reactive power Q . The control block B11 (Qv controller) determines the control amount of the amplitude of the AC voltage, for example, a gain value to be multiplied by the amplitude deviation, according to the relationship between the frequency band of the Qv control system to control the reactive power so as to reduce the difference between the command value and the measured value and the frequency band of the VSG control system controlled by the VSG controller. Consequently, the control device C according to the first embodiment may change the amount of fluctuation may fluctuate the amplitude V_v by the Qv control between the frequency band controlled by the VSG control and the uncontrolled frequency band. For example, the control interference can be avoided by reducing the amount of fluctuation for fluctuating the amplitude V_v in the frequency band controlled in the VSG control system, and the generation of the reactive power Q can be suppressed by increasing the amount of fluctuation for fluctuating the amplitude V_v in the frequency band not controlled in the VSG control system. Therefore, the inverter can be appropriately controlled even in a case where both VSG control and Qv control are performed.

[0064]

In the control device C according to the first embodiment, the control block B11 (Qv controller) comprises a high-band gain (first gain) and a low-band gain (second gain). The high-band gain (first gain) is a gain intended for interference reduction between the Qv control system and the VSG control system. The low-band gain (second gain) is a gain

intended for steady-state deviation reduction of the difference. The difference is a difference between the command value Q_{ref} and the measured value $Q_{measure}$ in the reactive power Q . The high-band gain (first gain) is a value smaller than the low-band gain (second gain). As a result, the control device C according to the first embodiment can

5 realize the adjustment of the gain according to the frequency band, that is, the two-stage gain. In a frequency band (relatively high frequency band) that is a control target in the VSG control, it is possible to perform control so as not to interfere with the VSG control by fluctuating the amplitude V_v by the Q_v control less likely to occur. In addition, in a frequency band (relatively low frequency band) that is not a control target in the VSG

10 control, it is possible to perform control so as to suppress wasteful power generation due to the circulation of the reactive power Q by fluctuating the amplitude V_v by the Q_v control.

[0065]

In the control device C according to the first embodiment, the control block B11 (Q_v controller) calculates the amplitude deviation amount such that the difference between

15 the command value Q_{ref} and the measured value $Q_{measure}$ in the reactive power Q becomes small. The control block B11 (Q_v controller) applies the transfer function $\{K \cdot (1+sT_b)/(1+sT_a)\}$ to the calculated amplitude deviation amount, thereby calculating a control amount obtained by multiplying the amplitude deviation amount by a high-band gain (first gain) or a low-band gain (second gain), which is a gain corresponding to the

20 frequency band of the Q_v control system, as the amount of fluctuation for fluctuating the amplitude V_v . The transfer function $\{K \cdot (1+sT_b)/(1+sT_a)\}$ is a function in which the time constants T_a and T_b are set so as to reduce the amplification amount in the frequency band of the VSG controller system. Consequently, in the control device C according to the first embodiment, the two-stage gain can be realized by passing the signal corresponding to the

25 amplitude deviation amount through the filter that blocks the signal of the frequency band

that is a control target in the VSG control, enabling control hardly to suppress the circulation of the reactive power Q in the frequency band (relatively low frequency band) that is not a control target in the VSG control so as not to interfere with the VSG control in the frequency band (relatively high frequency band) that is a control target in the VSG control.

[0066]

<Second Embodiment>

Here, the second embodiment will be described. The present embodiment is different from the above-described embodiment in that the command value Q_{ref} of the reactive power Q is not provided from the integrated controller 11.

[0067]

For example, it is assumed that the command value of Q_{ref} is fixed to 0 (zero), and the power amount of the reactive power Q required by the power system, that is a control target, with another PCS 12, wiring, and load, etc. is Q_a (actual measured value $Q_{measure}$). In this case, the amplitude V_v calculated by the Q_v control always has an amplitude value larger than the rated voltage V_m .

[0068]

Here, in the storage battery control system 10, when the PCS 12 performing the Q_v control similar to the above is present, each of the plurality of PCs 12 is controlled to output the amplitude V_v larger than the rated voltage V_m . Consequently, the amplitude V_v of the AC voltage output from each PCS 12 changes, the measured value $Q_{measure}$ of the reactive power Q measured by each PCS 12 changes each time the amplitude V_v changes, and the amplitude V_v calculated by another PCS 12 changes in conjunction with each change in the measured value $Q_{measure}$. Depending on such a chain of changes, there is a high possibility that the storage battery control system 10 is not appropriately

controlled, and thus, it is better to avoid such a chain of changes. In order to avoid the chain of changes, for example, it is considered to take measures such as reducing the gain and reducing the amount of fluctuation of the amplitude V_v by the Q_v control. However, in this case, the load end voltage varies to a large extent.

5 [0069]

In order to solve such a problem, in the present embodiment, the control device C calculates the command value Q_{ref} of the reactive power Q . The control device C sets the reactive power Q_a (measured value $Q_{measure}$) requested from the power system that is a control target to the command value Q_{ref} in advance, and calculates the amplitude V_v .

10 [0070]

In the storage battery control system 10, when the PCS 12 performing the Q_v control is present similarly to the above, each of the plurality of PCSs 12 is controlled to output the amplitude V_v as approximate to the rated voltage V_m as possible. Consequently, the amount of fluctuation of the amplitude V_v in the AC power output from each PCS 12 is suppressed, and the chain of changes is suppressed. For example, even in a case where the gain is reduced and the amount of fluctuation of the amplitude V_v is reduced by the Q_v control, the variation in the load end voltage can be improved.

[0071]

In the present embodiment, measures are taken focusing on the fact that the VSG control is performed in each PCS 12, and the difference Δf in frequency of the AC voltage output from each PCS 12 gradually converges to an ideal state approaching 0 (zero). Specifically, in the present embodiment, assuming that the frequency difference Δf of the AC voltage output from each PCS 12 is 0 (zero), the command value Q_{ref} is calculated so as to suppress the reactive power Q . This calculation of the command value Q_{ref} may prepare the reactive power Q to be suppressed in advance when each PCS 12 is in an ideal

20

25

state in which the control by the VSG control is converged.

[0072]

Hereinafter, a configuration for calculating the command value Q_{ref} for the microgrid 1 of the present embodiment will be described with reference to FIGS. 8 to 9.

5 Hereinafter, configurations different from those of the above-described embodiment will be mainly described, and configurations similar to those of the above-described embodiment will be denoted by the same references, and description thereof will be omitted.

[0073]

10 FIG. 8 is a diagram illustrating a configuration example of a microgrid according to the second embodiment. As illustrated in FIG. 8, the microgrid 1 comprises an integrated controller 11a. The integrated controller 11a notifies each PCS 12 of the command value P_{ref} of the active power P but not of the command value Q_{ref} of the reactive power Q .

[0074]

15 FIG. 9 is a diagram illustrating a configuration example of a microgrid according to the second embodiment. As illustrated in FIG. 9, the control device C comprises a control block B14 (reactive power command setter). The control block B14 (reactive power command setter) calculates the command value Q_{ref} of the reactive power Q based on the measured value $P_{measure}$ and the measured value $Q_{measure}$ that are respectively
20 the measured values of the active power P and the reactive power Q . Hereinafter, a method in which the control block B14 (reactive power command setter) calculates the command value Q_{ref} of the reactive power Q will be described.

[0075]

First, assuming that the difference Δf between the frequency f_v and the frequency
25 f_o is 0 (zero) as shown in Formula (5-1), the control block B14 calculates the active power

P as shown in Formula (5-2) and calculates the reactive power Q as shown in Formula (5-3). Formula (5-2) can be calculated by substituting 0 (zero) for the difference Δf in Formula (3-2). Formula (5-3) can be calculated by substituting 0 (zero) for the difference Δf in Formula (3-3).

5 [0076]

[Mathematical Formula 5]

$$\Delta f = 0 \quad \cdot \cdot \cdot (5 - 1)$$

$$P = -V_V \frac{V_0 \sin \theta_0}{2\pi f_V L} \quad \cdot \cdot \cdot (5 - 2)$$

$$Q = \frac{V_V}{2\pi f_V L} (V_0 \cos \theta_0 - V_V) \quad \cdot \cdot \cdot (5 - 3)$$

[0077]

Next, the control block B14 estimates the phase difference θ_0 between the active
 10 power and the reactive power using Formulas (5-2) and (5-3). For example, the control
 block B14 uses Formulas (5-2) and (5-3) to express the apparent power S as a vector
 expression using a complex number as shown in Formula (5-4). By solving Formula (5-4)
 for the amplitude V_0 , a vector expression of the amplitude V_0 as shown in Formulas (5-5)
 and (5-6) is calculated. Then, using Formula (5-6), the scalar value of the amplitude V_0
 15 can be obtained as Formula (5-7). In addition, the scalar value of the phase difference θ_0
 can be obtained as in Formula (5-8) using Formula (5-6).

[0078]

[Mathematical Formula 6]

$$P + jQ = -V_V \frac{V_0 \sin \theta_0}{2\pi f_V L} + j(V_0 \cos \theta_0 - V_V) \frac{V_0 \sin \theta_0}{2\pi f_V L} \quad \cdot \cdot \cdot (5-4)$$

$$V_0 \cos \theta_0 + jV_0 \sin \theta_0 = V_V + \frac{Q}{\left(\frac{V_V}{2\pi f_V L}\right)} - j \frac{P}{\left(\frac{V_V}{2\pi f_V L}\right)} \quad \cdot \cdot \cdot (5-5)$$

$$V_0 e^{j\theta_0} = V_V + \frac{Q}{\left(\frac{V_V}{2\pi f_V L}\right)} - \frac{jP}{\left(\frac{V_V}{2\pi f_V L}\right)} \quad \cdot \cdot \cdot (5-6)$$

$$V_0 = \sqrt{\left\{V_V + \frac{Q}{\left(\frac{V_V}{2\pi f_V L}\right)}\right\}^2 + \left\{\frac{P}{\left(\frac{V_V}{2\pi f_V L}\right)}\right\}^2} \quad \cdot \cdot \cdot (5-7)$$

$$\theta_0 = \tan^{-1} \frac{-\frac{P}{\left(\frac{V_V}{2\pi f_V L}\right)}}{V_V + \frac{Q}{\left(\frac{V_V}{2\pi f_V L}\right)}} = \tan^{-1} \frac{-P}{V_V \left(\frac{V_V}{2\pi f_V L}\right) + Q} \quad \cdot \cdot \cdot (5-8)$$

[0079]

When the amplitude V_0 can be measured using a measuring instrument or the like, the control block B14 estimates the line impedance L based on the measured value of the amplitude V_0 . In addition, the rated voltage V_m may be adjusted such that the amplitude V_0 is within a prescribed range. The control block B14 calculates the command value Q_{ref} to suppress the reactive power Q such that the difference Δf approaches 0 (zero) on the basis of a value obtained by substituting the line impedance L for the phase difference θ_0 shown in Formula (5-7).

10 [0080]

When the amplitude V_0 cannot be measured, the control block B14 sets the line impedance L using a preset value or a representative value. The control block B14 calculates a command value Q_{ref} of the reactive power Q based on a value obtained by substituting the line impedance L for the phase difference θ_0 shown in Formula (5-7).

[0081]

The control block B14 may calculate the command value Q_{ref} of the reactive power Q as the phase difference θ_0 by applying a low-pass filter to the estimated value of the phase difference θ_0 to remove a frequency change component corresponding to noise.

5 [0082]

As described above, the control device C according to the second embodiment further comprises the control block B14 (reactive power command setter). The control block B14 (reactive power command setter) calculates the command value Q_{ref} of the reactive power Q using the measured value $P_{measure}$ and the measured value $Q_{measure}$.

10 The control block B14 (reactive power command setter) calculates the command value Q_{ref} on the assumption that the frequency difference Δf is zero from a power system serving as a connection target, e.g. another PCS 12, and a power system serving as a connection target such as wiring and a load to the other PCS 12, e.g. another PCS 12, wiring, or a load. Consequently, the control device C according to the second
15 embodiment can calculate the command value Q_{ref} to suppress the reactive power Q as the frequency difference Δf of the AC voltage output from each PCS 12 gradually approaches the ideal state approaching 0 (zero), and output the amplitude V_v based on the calculated command value Q_{ref} . Therefore, the amplitude can be controlled so as to suppress the reactive power Q .

20 [0083]

In the second embodiment, the control block B14 (reactive power command setter) calculates the line impedance L up to the coupling point based on the amplitude V_0 at the coupling point with the power system as the connection target, calculates the phase difference θ_0 based on the calculated line impedance L , and calculates the command value
25 Q_{ref} based on the phase difference θ_0 . As a result, the control device C according to the

second embodiment achieves effects similar to those described above.

[0084]

<Modification 1 of Second Embodiment>

Here, Modification 1 of the second embodiment will be described. In the present
5 modification, the gain setting according to the frequency band is not performed in the Qv
control, and the uniform gain regardless of the frequency band is set as in the related art.

[0085]

FIG. 10 is a diagram for explaining control performed by the control device C
according to the second embodiment. As illustrated in FIG. 10, in the present modification,
10 the control block B11 performs conventional Qv control. The control block B11 of the
present modification calculates the amplitude deviation such that the deviation dQ, which
is the difference between the command value Q_{ref} and the measured value $Q_{measure}$ in
the reactive power Q, approaches 0 (zero), and outputs a value obtained by multiplying the
calculated amplitude deviation by the uniform gain G regardless of whether the frequency
15 corresponding to the time-series change in the amplitude deviation is high or low.

[0086]

In the present modification, the command value Q_{ref} close to the measured value
 $Q_{measure}$ calculated in the control block B14 in the preceding stage is input to the control
block B11. Therefore, the deviation dQ becomes a value close to 0 (zero), and the
20 amplitude deviation does not become a large value. Therefore, even if conventional Qv
control, that is, Qv control for amplification with the uniform gain G regardless of the
frequency band, is performed, control interference with VSG control may be suppressed.
In addition, the command value Q_{ref} is calculated to suppress the reactive power Q in the
ideal state in which the difference Δf approaches to 0 (zero) by the VSG control.
25 Therefore, the reactive power Q is suppressed in the ideal state in which the VSG control

is converged, and it is possible to suppress the reactive power Q as well as wasteful power consumption while suppressing control interference with the VSG control.

[0087]

As described above, the control device C according to Modification 1 of the second embodiment comprises the control block B12 (VSG controller), the control block B11 (Q_v controller), and the control block B14 (reactive power command setter). The control block B12 (VSG controller) controls the frequency of the AC voltage so as to have a virtual inertial force. The control block B11 (Q_v controller) controls the amplitude of the AC voltage to suppress the difference between the command value Q_{ref} and the measured value $Q_{measure}$ in the reactive power Q . The control block B14 (reactive power command setter) calculates the command value Q_{ref} of the reactive power Q . The control block B14 (reactive power command setter) uses the measured value $P_{measure}$ of the active power P and the measured value $Q_{measure}$ of the reactive power Q to calculate the command value Q_{ref} of the reactive power Q on an assumption that Δf is 0 (zero) at the coupling point with the power system of the connection target connected via the inverter INV. Here, Δf is a difference between the frequency f_v of the AC voltage output from the inverter INV and the frequency f_o of the AC voltage at the connection point. That is, the command value Q_{ref} is calculated assuming that the frequency f_v of the AC voltage output from the inverter INV and the frequency f_o of the AC voltage at the coupling point are the same and the frequency is in a stable ideal state in the storage battery control system 10. Thus, in the control device C according to Modification 1 of the second embodiment, assuming that the frequency is controlled by VSG control into a stable ideal state in the storage battery control system 10, the Q_v control is performed to suppress the reactive power Q in the ideal state. As a result, it is possible to suppress the reactive power Q as well as wasteful power consumption while suppressing control interference with the VSG

control.

[0088]

<Modification 2 of Second Embodiment>

Here, Modification 2 of the second embodiment will be described. The present
5 modification is different from the above-described embodiment in that the integrated
controller 11 is not provided.

[0089]

FIG. 11 is a diagram illustrating a configuration example of a microgrid according
to Modification 2 of the second embodiment. As illustrated in FIG. 11, the storage battery
10 control system 10 comprises one PCS 12 and a storage battery 5. The control device C
performs the VSG control by the control block B12 (VSG controller) based on the
command value Pref corresponding to the active power P predetermined according to the
power supply capacity of the storage battery control system 10 comprising the storage
battery 5. Similarly to the second embodiment, the control device C calculates the
15 command value Qref of the reactive power Q by the control block B14 (reactive power
command setter), and performs Qv control by the control block B11 (Qv controller) based
on the calculated command value Qref.

[0090]

In the Qv control by the control block B11 (Qv controller), Qv control using a
20 two-stage gain may be performed, or a uniform gain is set regardless of a frequency band
as in the related art. Here, the Qv control using a two-stage gain is Qv control in which a
high-band gain is applied in a high frequency band and a low-band gain is applied in a low
frequency band according to the frequency band.

[0091]

25 <Variations of Embodiments>

In the above-described embodiments, the configuration in which the storage battery control system 10 comprises the plurality of PCSs 12 has been described as an example. Among the plurality of PCSs 12 constituted in the storage battery control system 10, at least one PCS 12 may be provided with a control device C that performs VSG control and Qv control using a two-stage gain. Among the plurality of PCSs 12 constituted in the storage battery control system 10, the other PCSs 12 may or may not perform the VSG control. In the other PCS 12, the Qv control may be performed or may not be performed. In a case where the Qv control is performed, the Qv control using a two-stage gain may be performed, or a uniform gain regardless of the frequency band may be set as in the related art.

[0092]

<Relationship between control device C and inverter controller>

In the above description, the configuration in which the control device C outputs the amplitude and frequency of the AC voltage output from the inverter INV to the inverter INV controller as a control target has been described as an example, but the present disclosure is not limited thereto. A part or all of the control device C may be an inverter INV controller. The relationship between the control device C and the inverter controller will be described with reference to FIGS. 12 and 13. FIGS. 12 and 13 are diagrams for explaining the relationship between the control device C and the inverter controller.

[0093]

FIG. 12 illustrates the relationship between the control device C and the inverter controller according to the first embodiment. In FIG. 12, ranges of configurations that can be taken as an inverter controller in the control device C and the control target of FIG. 3 are indicated by references INVC1 to INVC3.

[0094]

When the inverter controller is a device comprising components in the range indicated by reference INVC1, the inverter controller has the function of the control device C according to the first embodiment and the function of setting, to the inverter INV, the amplitude and frequency of the AC voltage output from the inverter INV.

5 [0095]

In a case where the inverter controller is a device comprising components in the range indicated by reference INVC2, the control device C is a device that outputs a signal value obtained by performing the zero-order hold ZOH on the amplitude deviation calculated by the control block B11 for Q_v control, and outputs a signal value obtained by performing the zero-order hold ZOH on the frequency deviation df calculated by the control block B12 for VSG control. The inverter controller acquires the amplitude deviation subjected to the zero-order hold ZOH from the control device C, and sets, to the inverter INV, a sum obtained by adding the rated voltage V_m to the acquired amplitude deviation as the amplitude V_v of the AC voltage output from the inverter INV. Further, the inverter controller acquires the frequency deviation df subjected to the zero-order hold ZOH from the control device C, and sets, to the inverter INV, a sum obtained by adding the rated frequency f_n to the acquired frequency deviation df as the frequency f_v of the AC voltage output from the inverter INV.

[0096]

20 When the inverter controller is a device comprising components in the range indicated by reference INVC3, the control device C has the function of the control device C according to the first embodiment, and outputs a signal value indicating the frequency f_v with the amplitude V_v of the AC voltage output from the inverter INV to the inverter controller. The inverter controller acquires a signal value indicating the frequency f_v with the amplitude V_v from the control device C, and sets, to the inverter INV, the acquired

25

signal value as the frequency f_v of the AC voltage output from the inverter INV.

[0097]

FIG. 13 illustrates the relationship between the control device C and the inverter controller according to the second embodiment. In FIG. 13, ranges of configurations that can be taken as an inverter controller in the control device C and the control target of FIG. 9 are indicated by references INVC4 to INVC7.

[0098]

When the inverter controller is a device comprising components in the range indicated by reference INVC4, the inverter controller has the function of the control device C according to the second embodiment and the function of setting, to the inverter INV, the amplitude and frequency of the AC voltage output from the inverter INV.

[0099]

In FIG. 13, the input of the command value Pref of the active power P is constituted in the range surrounded by the reference INVC4, but this does not indicate that the inverter controller has a function of generating or inputting the command value Pref. In a case where the inverter controller is a device comprising components in the range indicated by reference INVC4, it is assumed that the command value Pref is input from the outside of the inverter controller. For example, the command value Pref is input from the integrated controller 11 to the inverter controller.

[0100]

In a case where the inverter controller is a device comprising components in the range indicated by reference INVC5, the inverter controller is obtained by excluding the function of the control block B14 from the control device C according to the second embodiment, that is, comprises the function of the control device C according to the first embodiment. This is similar to the case of a device comprising components in the range

indicated by reference INVC1 in FIG. 12, and thus the description thereof will be omitted.

[0101]

In a case where the inverter controller is a device comprising components in the range indicated by reference INVC6, the inverter controller is similar to a case where the inverter controller is a device comprising components in the range indicated by reference INVC2 in FIG. 12, and thus the description thereof will be omitted.

[0102]

In a case where the inverter controller is a device comprising components in the range indicated by reference INVC7, the inverter controller is similar to a case where the inverter controller is a device comprising components in the range indicated by reference INVC3 in FIG. 12, and thus the description thereof will be omitted.

[0103]

Note that the control device C described above comprises a computer system therein. Then, the procedure of the above-described processing is stored in a computer-readable recording medium in the form of a program, and the processing is performed by the computer reading and executing the program. Here, the computer-readable recording medium refers to a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like. Furthermore, the computer program may be distributed to a computer via a communication line, and the computer that has received the distribution may execute the program.

[Reference Signs List]

[0104]

1 Microgrid

2 Power generation facility

4 Power reception and distribution facility

5 Storage battery

10 Storage battery control system

11 Integrated controller

12 PCS

5 C Control device

INV Inverter

B11 Control block (Qv controller)

B12 Control block (VSG controller)

B14 Control block (reactive power command setter)

10

[CLAIMS]

[Claim 1]

A control device that controls an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control device
5 comprising:

a virtual synchronous generator (VSG) controller that controls a frequency of the AC voltage so as to have a virtual inertial force; and

a Qv controller that controls an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power, wherein

10 the Qv controller determines a control amount of the amplitude of the AC voltage according to a relationship between a frequency band of a Qv control system and a frequency band of a VSG control system, the Qv control system controlling to reduce the difference, and the VSG control system controlled by the VSG controller.

[Claim 2]

15 The control device according to claim 1, wherein

the Qv controller comprises a first gain being a high-band gain for interference reduction between the Qv control system and the VSG control system, and a second gain being a low-band gain for steady-state deviation reduction of the difference, and

the first gain being a value smaller than the second gain.

20 [Claim 3]

The control device according to claim 2, wherein

the Qv controller calculates an amplitude deviation amount to reduce the difference, and calculates the control amount by multiplying the amplitude deviation amount by a gain corresponding to the frequency band of the Qv control system by
25 applying a transfer function to the amplitude deviation amount,

the transfer function is a function with a time constant to reduce an amplification amount in the frequency band of the VSG control system.

[Claim 4]

The control device according to claim 1, further comprising:

- 5 a reactive power command setter that calculates a command value of reactive power on an assumption that a frequency of the AC voltage output from the inverter equals a frequency of the AC voltage at a coupling point with a power system, the power system being a connection target connected via the inverter, by using a measured value of active power and a measured value of reactive power.

10 [Claim 5]

The control device according to claim 4, wherein

- the reactive power command setter calculates a line impedance to the coupling point based on the amplitude at the coupling point, calculates a phase difference between the active power and the reactive power based on the calculated line impedance, and
15 calculates a command value of the reactive power based on the calculated phase difference.

[Claim 6]

A control device that controls an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control device comprising:

- 20 a virtual synchronous generator (VSG) controller that controls a frequency of the AC voltage so as to have a virtual inertial force;

a Qv controller that controls an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power; and

- a reactive power command setter that calculates a command value of reactive
25 power on an assumption that a frequency of the AC voltage output from the inverter equals

a frequency of the AC voltage at a coupling point with a power system, the power system being a connection target via the inverter, by using a measured value of active power and a measured value of reactive power.

[Claim 7]

5 A control method that is performed by a control device for controlling an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control method comprising:

controlling, by a virtual synchronous generator (VSG) controller, a frequency of the AC voltage so as to have a virtual inertial force,

10 controlling, by a Qv controller, an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power, and

determining, by the Qv controller, a control amount of the amplitude of the AC voltage according to a relationship between a frequency band of a Qv control system and a frequency band of a VSG control system, the Qv control system controlling to reduce the
15 difference, and the VSG control system controlled by the VSG controller.

[Claim 8]

A control method that is performed by a control device for controlling an inverter that converts a direct current (DC) voltage from a storage battery into an alternating current (AC) voltage, the control method comprising:

20 controlling, by a virtual synchronous generator (VSG) controller, a frequency of the AC voltage so as to have a virtual inertial force,

controlling, by a Qv controller, an amplitude of the AC voltage to reduce a difference between a command value and a measured value in reactive power, and

calculating, by a reactive power command setter, a command value of reactive
25 power on an assumption that a frequency of the AC voltage output from the inverter equals

a frequency of the AC voltage at a coupling point with a power system, the power system being a connection target via the inverter, by using a measured value of active power and a measured value of reactive power.