SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] A power converter which does not use any electrolytic capacitors and which is designed such that a DC voltage output from a rectifier has pulsations corresponding to a power supply frequency is also known. Such a power converter does not need any electrolytic capacitors or reactors of a relatively large size, and therefore, may have a reduced size. In such a power converter, however, no electrolytic capacitors functioning as energy storage elements are used, and only capacitors with a relatively small capacitance are used. Thus, pulsations are generated in the DC voltage and active power. Particularly when the power converter drives a concentrated winding motor, the current supplied from an AC power supply will include a lot of harmonics resulting from the rotation of the motor.

[0006] The power supply harmonic suppressor of Patent Document 1 may compensate for harmonics, of which one period corresponds to that of the power supply frequency, and thereby reduce the harmonics of the power supply current. However, the frequency of harmonics caused by a motor rotating at various velocities does not agree with the power supply frequency. Thus, the power supply harmonic suppressor of Patent Document 1 is unable to compensate for such harmonics.

[0007] Embodiments of the present invention reduce the harmonics of a power supply current resulting from the rotation of a motor.

SOLUTION TO THE PROBLEM

[0008] A power converter device according to an aspect includes: a power converter; and a current compensator. The power converter includes: a rectifier configured to rectify alternating current supplied from an AC power supply and output pulsating direct current; an inverter configured to convert the direct current into alternating current to drive a

motor; and a small-capacitance capacitor connected between input nodes of the inverter. The current compensator includes: a current compensating capacitor; a compensation current generator having an input connected to the AC power supply and an output connected to the current compensating capacitor, and performing a switching operation in accordance with a drive signal, thereby controlling compensation currents flowing between itself and the AC power supply; a compensation controller configured to obtain output voltage instruction values such that the compensation currents cancel a harmonic component included in load currents flowing from the AC power supply into the rectifier and resulting from rotation of the motor and a harmonic component included in the load currents and dependent on a period of a voltage of the AC power supply; and a drive signal generator configured to generate the drive signal based on the output voltage instruction values.

[0009] According to this aspect, the compensation controller obtains output voltage instruction values such that the reactive component of the compensation currents cancels a harmonic component resulting from rotation of the motor and a harmonic component dependent on a period of a voltage of the AC power supply. Thus, the harmonics to be caused in a power supply current by rotating the motor may be reduced. The harmonics of the power supply current may be reduced particularly significantly in a power converter device which uses only a capacitor with a relatively small capacitance and which is configured such that a DC voltage output from a rectifier has pulsation corresponding to the power supply frequency.

[0010] A power converter device according to an embodiment further includes a reactor connected between an output node of the rectifier

and one of the input nodes of the inverter. An inductance of the reactor and a capacitance of the small-capacitance capacitor are set such that a filter formed by the reactor and the small-capacitance capacitor attenuates a current component having the same frequency as a carrier used for generating a control signal for the inverter.

[0011] According to this embodiment, a current component having the same frequency as a carrier used for generating a control signal for the inverter may be prevented from flowing out into the AC power supply.

[0012] In an embodiment, the output voltage instruction values include an active voltage instruction value and a reactive voltage instruction value. The compensation controller obtains the active voltage instruction value such that an active component of the compensation currents cancels a harmonic component in the load currents flowing from the AC power supply into the rectifier and resulting from the rotation of the motor, and obtains the reactive voltage instruction value such that a reactive component of the compensation currents cancels a harmonic component in the load currents and dependent on the period of the voltage of the AC power supply.

[0013] According to this embodiment, the harmonic component resulting from the rotation of the motor may be suppressed with the active voltage instruction value and the harmonic component dependent on a period of the voltage of the AC power supply may be suppressed with the reactive voltage instruction value.

[0014] In an embodiment, the compensation controller includes: a high-pass filter configured to extract and output a high-frequency component from the active component of the load currents; an adder configured to

output a result of addition by adding a voltage correction value, obtained based on a result of subtraction that has been calculated by subtracting a voltage of the current compensating capacitor from its instruction value, to an output of the high-pass filter; an active current controller configured to obtain the active voltage instruction value such that the active component of the compensation currents cancels the result of addition; and a reactive current controller configured to obtain the reactive voltage instruction value such that the reactive component of the compensation currents cancels a reactive component of the load currents.

[0015] According to this embodiment, the active current controller obtains the active voltage instruction value such that the active component of the compensation currents cancels the result of addition, and the reactive current controller obtains the reactive voltage instruction value such that the reactive component of the compensation currents cancels a reactive component of the load currents. Thus, the harmonic components in the power supply current may be reduced.

[0016] In an embodiment, the active current controller includes a first lead compensator configured to delay the result of addition for a period of time corresponding to one period of rotation of the motor, thereby adding an apparent phase lead to the result of addition, and obtains the active voltage instruction value based on a result of addition that has been delayed by the first lead compensator. The reactive current controller includes a second lead compensator configured to delay the reactive component of the load currents for a period of time corresponding to one period of the voltage of the AC power supply, thereby adding an apparent phase lead to the reactive component of the load currents, and obtains the reactive voltage instruction value based on a reactive component of the load currents that has been

delayed by the second lead compensator.

[0017] According to this embodiment, the active current controller delays the result of addition for a period of time corresponding to one period of rotation of the motor, thereby adding an apparent phase lead to the result of addition of which the waveform is a repetition of similar waveform patterns in a steady state. Also, the reactive current controller delays the reactive component of the load currents for a period of time corresponding to one period of the voltage of the AC power supply, thereby adding an apparent phase lead to the reactive component of the load current of which the waveform is a repetition of similar waveform patterns in a steady state. Thus, the influence of the delay caused by the current compensator may be reduced.

[0018] In an embodiment, the active current controller further includes: a first subtractor configured to calculate the difference between the result of addition delayed by the first lead compensator and the active component of the compensation currents; and a first calculator configured to calculate, as the active voltage instruction value, at least a value proportional to the difference obtained by the first subtractor. The reactive current controller further includes: a second subtractor configured to calculate the difference between the reactive component of the load currents delayed by the second lead compensator and the reactive component of the compensation currents; and a second calculator configured to calculate, as the reactive voltage instruction value, at least a value proportional to the difference obtained by the second subtractor.

[0019] According to this embodiment, the first subtractor calculates the deviation of the active component of the compensation currents with respect to the result of addition delayed by the first lead compensator, and the second subtractor calculates the deviation of the

reactive component of the compensation currents with respect to the reactive component of the load currents delayed by the second lead compensator. Thus, the active voltage instruction value and the reactive voltage instruction value may be obtained appropriately.

[0020] In an embodiment, the active current controller further includes: a first subtractor configured to calculate the difference between the result of addition delayed by the first lead compensator and the active component of the compensation currents; a first calculator configured to calculate at least a value proportional to the difference obtained by the first subtractor; a first feed forward controller configured to calculate a value based on the result of addition delayed by the first lead compensator; and a first adder configured to calculate, as the active voltage instruction value, the sum of the value obtained by the first calculator and the value obtained by the first feed forward controller. The reactive current controller further includes: a second subtractor configured to calculate the difference between the reactive component of the load currents delayed by the second lead compensator and the reactive component of the compensation currents; a second calculator configured to calculate at least a value proportional to the difference obtained by the second subtractor; a second feed forward controller configured to calculate a value based on the reactive component of the load currents delayed by the second lead compensator; and a second adder configured to calculate, as the reactive voltage instruction value, the sum of the value obtained by the second calculator and the value obtained by the second feed forward controller.

[0021] According to this embodiment, the first and second feed forward controllers are provided, and not only feedback control but also feed forward control are performed as well.

Thus, the harmonics resulting from the rotation of the motor may be compensated for with good stability.

[0022] In an embodiment, the current compensator further includes a reactor between the AC power supply and the compensation current generator. The active current controller further includes: a first subtractor configured to calculate the difference between the result of addition delayed by the first lead compensator and the active component of the compensation currents; a first voltage calculator configured to calculate a voltage of the reactor corresponding to the difference obtained by the first subtractor; a first storage section configured to store an input value and output the input value after having delayed the input value for one sample period; a second subtractor configured to calculate, and store in the first storage section, the difference between the voltage of the reactor corresponding to the difference obtained by the first subtractor and an output of the first storage section; and a first adder configured to calculate, as the active voltage instruction value, the sum of the difference obtained by the second subtractor and the voltage of the AC power supply. The reactive current controller further includes: a third subtractor configured to calculate the difference between the reactive component of the load currents delayed by the second lead compensator and the reactive component of the compensation currents; a second voltage calculator configured to calculate a voltage of the reactor corresponding to the difference obtained by the third subtractor; a second storage section configured to store an input value and output the input value after having delayed the input value for one sample period; a fourth subtractor configured to calculate, and store in the second storage section, the difference between the voltage of the reactor corresponding to the difference obtained by the third subtractor and an output of

the second storage section; and a second adder configured to calculate, as the reactive voltage instruction value, the sum of the difference obtained by the fourth subtractor and the voltage of the AC power supply.

[0023] According to this embodiment, a phase lag of the high-frequency component may be compensated for, and the influence of a detection delay of a current transformer and a waveform distortion caused by the high-pass filter may be reduced.

[0024] In an embodiment, the active current controller includes: a first subtractor configured to calculate the difference between the result of addition and the active component of the compensation currents; a first calculator configured to calculate, as a control value, at least a value proportional to the difference obtained by the first subtractor; a first cyclic controller configured to calculate a result of accumulation by accumulating over multiple periods, with respect to each of multiple sample points, a corresponding one of a plurality of control values obtained by the first calculator in one period of rotation of the motor; and a first adder configured to calculate, as the active voltage instruction value, the sum of the control value obtained by the first calculator and the result of accumulation obtained by the first cyclic controller. The reactive current controller includes: a second subtractor configured to calculate the difference between the reactive component of the load currents and the reactive component of the compensation currents; a second calculatorconfigured to calculate, as a control value, at least a value proportional to the difference obtained by the second subtractor; a second cyclic controller configured to calculate a result of accumulation by accumulating over multiple periods, with respect to each of multiple sample points, a corresponding one of a plurality of control values obtained by the second calculator in one period of the voltage of the AC power supply; and a

second adder configured to calculate, as the reactive voltage instruction value, the sum of the control value obtained by the second calculator and the result of accumulation obtained by the second cyclic controller.

[0025] According to this embodiment, a plurality of the control values obtained by the first calculator at multiple sample points are respectively accumulated over multiple periods of rotation of the motor, and a plurality of the control values obtained by the second calculator at multiple sample points are respectively accumulated over multiple periods of the voltage of the AC power supply. Thus, the harmonic component of the load current, of which the waveform is a repetition of similar waveform patterns in a steady state, may be reduced.

[0026] In an embodiment, the compensation controller includes: a high-pass filter configured to extract and output a high-frequency component from the active component of the load currents; a delay controller configured to obtain a delay-compensated high-frequency component by compensating for a delay of the high-frequency component output from the high-pass filter; an active current controller configured to calculate a value to obtain the active voltage instruction value such that the active component of the compensation currents cancels the voltage correction value obtained based on a result of subtraction that has been calculated by subtracting the voltage of the current compensating capacitor from its instruction value; an adder configured to obtain, as the active voltage instruction value, a result of addition by adding the delay-compensated high-frequency component to the value obtained by the active current controller; and a reactive current controller configured to obtain the reactive voltage instruction value such that the reactive component of the compensation currents cancels the reactive component of the

load currents.

[0027] According to this embodiment, the high-frequency component of the active component of the load currents is feed-forwarded. This thus improves the responsivity of the control.

ADVANTAGES OF THE INVENTION

[0028] With the power converter device according to embodiments of the present invention, the harmonics to be caused in the power supply current by rotating the motor may be reduced. As a result, the harmonics in the power supply current may also be reduced even in a power converter device in which only a capacitor with a relatively small capacitance is used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] [FIG. 1] FIG. 1 is a block diagram illustrating an exemplary configuration for a power converter device according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a circuit diagram illustrating an exemplary configuration for the power converter shown in FIG. 1.

[FIG. 3] FIG. 3 is a circuit diagram illustrating an exemplary configuration for the compensation current generator shown in FIG. 1.

[FIG. 4] FIG. 4 is a block diagram illustrating a specific example of the active current controller and reactive current controller shown in FIG. 1.

[FIG. 5] FIG. 5 is a graph showing exemplary current waveforms in the power converter device shown in FIG. 1.

[FIG. 6] FIG. 6 is a graph showing exemplary current waveforms in a conventional power converter device.

[FIG. 7] FIG. 7 is a block diagram illustrating another example of the active current

CLAIMS:

1. A power converter device comprising:

a power converter (20); and

a current compensator (40),

wherein

the power converter (20) includes:

a rectifier (22) configured to rectify alternating current supplied from an AC power supply (12) and output pulsating direct current;

an inverter (28) configured to convert the direct current into alternating currents to drive a motor (16); and

a small-capacitance capacitor (26) connected between input nodes of the inverter (28), and

the current compensator (40) includes:

a current compensating capacitor (54);

a compensation current generator (52) having an input connected to the AC power supply (12) and an output connected to the current compensating capacitor (54), and performing a switching operation in accordance with a drive signal (Scd), thereby controlling compensation currents (Icr, Ics, Ict) flowing between itself (52) and the AC power supply (12);

a compensation controller (60) configured to obtain output voltage instruction values (Vid, Viq) such that the compensation currents (Icr, Ics, Ict) cancel a harmonic component in load currents (Ir, Is, It) flowing from the AC power supply (12) into the rectifier (22) and resulting from rotation of the motor (16) and a harmonic component in the load currents (Ir, Is, It) and dependent on a period (Ts) of a voltage of the AC power supply (12); and

a drive signal generator (56) configured to generate the drive signal (Scd) based on the output voltage instruction values (Vid, Viq),

wherein

the output voltage instruction values (Vid, Viq) include an active voltage instruction value (Vid) and a reactive voltage instruction value (Viq), and

the compensation controller (60) obtains the active voltage instruction value (Vid) such that an active component of the compensation currents (Icr, Ics, Ict) cancels a harmonic component in the load currents (Ir, Is, It) flowing from the AC power supply (12) into the rectifier (22) and resulting from the rotation of the motor (16), and obtains the reactive voltage instruction value (Viq) such that a reactive component of the compensation currents (Icr, Ics, Ict) cancels a harmonic component in the load currents (Ir, Is, It) and dependent on the period (Ts) of the voltage of the AC power supply (12), and

wherein

the compensation controller (60) includes:

a high-pass filter (71) configured to extract and output a high-frequency component (imot) from the active component of the load currents;

an adder (72) configured to output a result of addition (id*) by adding a voltage correction value (Vcn), obtained based on a result of subtraction that has been calculated by subtracting a voltage (Vdc) of the current compensating capacitor (54) from its instruction value (Vdc*), to an output of the high-pass filter (71);

an active current controller (76; 276; 376; 476) configured to obtain the active voltage instruction value (Vid) such that the active component (id) of the compensation currents cancels the result of addition (id*); and

a reactive current controller (78; 278; 378; 478) configured to obtain the reactive voltage instruction value (Viq) such that the reactive component (iq) of the compensation currents cancels a reactive component (iq*) of the load currents.

2. The power converter device of claim 1, further comprising

a reactor (24) connected between an output node of the rectifier (22) and one of the input nodes of the inverter (28), wherein

an inductance of the reactor (24) and a capacitance of the small-capacitance capacitor (26) are set such that a filter formed by the reactor (24) and the small-capacitance capacitor (26) attenuates a current component having the same frequency as a carrier used for generating a control signal for the inverter (28).

3. The power converter device of claim 1, wherein

the active current controller (76; 376; 476) includes a first lead compensator (82) configured to delay the result of addition (id*) for a period of time corresponding to one period of rotation (Tm) of the motor (16), thereby adding an apparent phase lead to the result of addition (id*), and obtains the active voltage instruction value (Vid) based on a result of addition (id2*) that has been delayed by the first lead compensator (82), and

the reactive current controller (78; 378; 478) includes a second lead compensator (92) configured to delay the reactive component (iq*) of the load currents for a period of time corresponding to one period (Ts) of the voltage of the AC power supply (12), thereby adding an apparent phase lead to the reactive component (iq*) of the load currents, and obtains the reactive voltage instruction value (Viq) based on a reactive component (iq2*) of the load currents that has been delayed by the second lead compensator (92).

4. The power converter device of claim 3, wherein

the active current controller (76) further includes:

a first subtractor (83) configured to calculate the difference between the result of addition (id2*) delayed by the first lead compensator (82) and the active component (id) of the

compensation currents; and

a first calculator (84) configured to calculate, as the active voltage instruction value (Vid), at least a value proportional to the difference obtained by the first subtractor (83), and

the reactive current controller (78) further includes:

a second subtractor (93) configured to calculate the difference between the reactive component (iq2*) of the load currents delayed by the second lead compensator (92) and the reactive component (iq) of the compensation currents; and

a second calculator (94) configured to calculate, as the reactive voltage instruction value (Viq), at least a value proportional to the difference obtained by the second subtractor (93).

5. The power converter device of claim 3, wherein

the active current controller (376) further includes:

a first subtractor (83) configured to calculate the difference between the result of addition (id2*) delayed by the first lead compensator (82) and the active component (id) of the compensation currents;

a first calculator (84) configured to calculate at least a value proportional to the difference obtained by the first subtractor (83);

a first feed forward controller (88) configured to calculate a value based on the result of addition (id2*) delayed by the first lead compensator (82); and

a first adder (85) configured to calculate, as the active voltage instruction value (Vid), the sum of the value obtained by the first calculator (84) and the value obtained by the first feed forward controller (88), and

the reactive current controller (378) further includes:

a second subtractor (93) configured to calculate the difference between the reactive component (iq2*) of the load currents delayed by the second lead compensator (92) and the

reactive component (iq) of the compensation currents;

a second calculator (94) configured to calculate at least a value proportional to the difference obtained by the second subtractor (93);

a second feed forward controller (98) configured to calculate a value based on the reactive component (iq2*) of the load currents delayed by the second lead compensator (92); and

a second adder (95) configured to calculate, as the reactive voltage instruction value (Viq), the sum of the value obtained by the second calculator (94) and the value obtained by the second feed forward controller (98).

6. The power converter device of claim 3, wherein

the current compensator (40) further includes a reactor (48) between the AC power supply (12) and the compensation current generator (52), and

the active current controller (476) further includes:

a first subtractor (83) configured to calculate the difference between the result of addition (id2*) delayed by the first lead compensator (82) and the active component (id) of the compensation currents;

a first voltage calculator (81) configured to calculate a voltage (vLd) of the reactor (48) corresponding to the difference obtained by the first subtractor (83);

a first storage section (89) configured to store an input value and output the input value after having delayed the input value for one sample period;

a second subtractor (87) configured to calculate, and store in the first storage section (89), the difference between the voltage (vLd) of the reactor (48) corresponding to the difference obtained by the first subtractor (83) and an output of the first storage section (89); and

a first adder (85) configured to calculate, as the active voltage instruction value (Vid), the sum of the difference obtained by the second subtractor (87) and the voltage of the AC power

supply (12), and

the reactive current controller (478) further includes:

a third subtractor (93) configured to calculate the difference between the reactive component (iq2*) of the load currents delayed by the second lead compensator (92) and the reactive component (iq) of the compensation currents;

a second voltage calculator (91) configured to calculate a voltage (vLq) of the reactor (48) corresponding to the difference obtained by the third subtractor (93);

a second storage section (99) configured to store an input value and output the input value after having delayed the input value for one sample period;

a fourth subtractor (97) configured to calculate, and store in the second storage section (99), the difference between the voltage (vLq) of the reactor (48) corresponding to the difference obtained by the third subtractor (93) and an output of the second storage section (99); and

a second adder (95) configured to calculate, as the reactive voltage instruction value (Viq), the sum of the difference obtained by the fourth subtractor (97) and the voltage of the AC power supply (12).

7. The power converter device of claim 1, wherein

the active current controller (276) includes:

a first subtractor (83) configured to calculate the difference between the result of addition (id*) and the active component (id) of the compensation currents;

a first calculator (84) configured to calculate, as a control value (id_out), at least a value proportional to the difference obtained by the first subtractor (83);

a first cyclic controller (86) configured to calculate a result of accumulation (id_rpt) by accumulating over multiple periods, with respect to each of multiple sample points in one period of rotation (Tm) of the motor (16), a corresponding one of a plurality of control values (id_out)

obtained by the first calculator (84); and

a first adder (85) configured to calculate, as the active voltage instruction value (Vid), the sum of the control value (id_out) obtained by the first calculator (84) and the result of accumulation (id_rpt) obtained by the first cyclic controller (86), and

the reactive current controller (278) includes:

a second subtractor (93) configured to calculate the difference between the reactive component (iq*) of the load currents and the reactive component (iq) of the compensation currents;

a second calculator (94) configured to calculate, as a control value (iq_out), at least a value proportional to the difference obtained by the second subtractor (93);

a second cyclic controller (96) configured to calculate a result of accumulation (iq_rpt) by accumulating over multiple periods, with respect to each of multiple sample points in one period (Ts) of the voltage of the AC power supply (12), a corresponding one of a plurality of control values (iq_out) obtained by the second calculator (94); and

a second adder (95) configured to calculate, as the reactive voltage instruction value (Viq), the sum of the control value (iq_out) obtained by the second calculator (94) and the result of accumulation (iq_rpt) obtained by the second cyclic controller (96).

8. A power converter device comprising:

a power converter (20); and

a current compensator (40),

wherein

the power converter (20) includes:

a rectifier (22) configured to rectify alternating current supplied from an AC power supply (12) and output pulsating direct current;

an inverter (28) configured to convert the direct current into alternating currents to drive a motor (16); and

a small-capacitance capacitor (26) connected between input nodes of the inverter (28), and

the current compensator (40) includes:

a current compensating capacitor (54);

a compensation current generator (52) having an input connected to the AC power supply (12) and an output connected to the current compensating capacitor (54), and performing a switching operation in accordance with a drive signal (Scd), thereby controlling compensation currents (Icr, Ics, Ict) flowing between itself (52) and the AC power supply (12);

a compensation controller (260) configured to obtain output voltage instruction values (Vid, Viq) such that the compensation currents (Icr, Ics, Ict) cancel a harmonic component in load currents (Ir, Is, It) flowing from the AC power supply (12) into the rectifier (22) and resulting from rotation of the motor (16) and a harmonic component in the load currents (Ir, Is, It) and dependent on a period (Ts) of a voltage of the AC power supply (12); and

a drive signal generator (56) configured to generate the drive signal (Scd) based on the output voltage instruction values (Vid, Viq),

wherein

the output voltage instruction values (Vid, Viq) include an active voltage instruction value (Vid) and a reactive voltage instruction value (Viq), and

the compensation controller (260) obtains the active voltage instruction value (Vid) such that an active component of the compensation currents (Icr, Ics, Ict) cancels a harmonic component in the load currents (Ir, Is, It) flowing from the AC power supply (12) into the rectifier (22) and resulting from the rotation of the motor (16), and obtains the reactive voltage instruction value (Viq) such that a reactive component of the compensation currents (Icr, Ics, Ict)

cancels a harmonic component in the load currents (Ir, Is, It) and dependent on the period (Ts) of the voltage of the AC power supply (12), and

wherein

the compensation controller (260) includes:

a high-pass filter (71) configured to extract and output a high-frequency component (imot) from the active component of the load currents;

a delay controller (75) configured to obtain a delay-compensated high-frequency component (Vmot) by compensating for a delay of the high-frequency component (imot) output from the high-pass filter (71);

an active current controller (576) configured to calculate a value to obtain the active voltage instruction value (Vid) such that the active component (id) of the compensation currents cancels the voltage correction value (id*) obtained based on a result of subtraction that has been calculated by subtracting the voltage (Vdc) of the current compensating capacitor (54) from its instruction value (Vdc*);

an adder (77) configured to obtain, as the active voltage instruction value (Vid), a result of addition by adding the delay-compensated high-frequency component (Vmot) to the value obtained by the active current controller (76); and

a reactive current controller (78) configured to obtain the reactive voltage instruction value (Viq) such that the reactive component (iq) of the compensation currents cancels the reactive component (iq*) of the load currents.