

DESCRIPTION

CEILING FAN

5 TECHNICAL FIELD

[0001]

The present invention relates to a ceiling fan equipped with a brushless DC motor for driving the fan.

10 BACKGROUND ART

[0002]

Recently, a ceiling fan needs to be equipped with a DC motor for reducing power consumption. Among others, a ceiling fan that reduces power consumption while maintaining maximum air blowing performance without
15 being affected by an installation state has been demanded.

[0003]

Conventionally, the one disclosed in Patent Literature 1 has been known as a ceiling fan of this type.

[0004]

20 This ceiling fan will be described below with reference to FIG. 12.

[0005]

As illustrated in FIG. 12, brushless DC motor 100 includes stator windings 114 (U, V, W), rotor 107 having eight permanent magnets provided on the surface of rotor such that N poles and S poles are alternately arranged,
25 and three position detection elements 102a, 102b, 102c. These position detection elements 102a, 102b, 102c are Hall sensors, for example, and mounted on electric circuit board 101.

[0006]

Position detection elements 102a, 102b, 102c converts a change in magnetic poles upon the transition from N pole to S pole or from S pole to N pole of the permanent magnets on rotor 107 into an electric signal of H or L, and inputs this signal into rotating speed detector 109 as a position detection signal.

[0007]

Rotating speed detector 109 detects the rotating speed of brushless DC motor 100 from the position detection signal which has been input. The position detection signal is input to time interval measurement unit 103 in rotating speed detector 109. Time interval measurement unit 103 measures a time interval from when one of position detection signals is changed till other one of position detection signals is changed, and stores twelve time intervals, that is, the time interval corresponding to 360-degree rotation of the mechanical angle of rotor 107.

[0008]

Time interval average unit 104 in rotating speed detector 109 obtains an average of twelve time intervals stored in time interval measurement unit 103.

[0009]

Rotating speed feedback unit 110 compares a target rotating speed, which has been determined in advance, with the rotating speed detected by rotating speed detector 109, and outputs a signal for changing a DC voltage to be applied to the stator winding to DC voltage changing unit 112 according to the difference between the rotating speeds.

[0010]

DC voltage changing unit 112 performs PWM (pulse width modulation)

to a signal based on the signal which is output from rotating speed feedback unit 110 for changing the DC voltage to be applied to the stator winding, and outputs the resultant signal to drive signal generator 105.

[0011]

5 Drive signal generator 105 senses a change in position detection signals from three position detection elements 102a, 102b, 102c, and sequentially energizes stator windings U, V, W in a predetermined direction in a predetermined order according to the states of the position detection signals at that time. Simultaneously, drive signal generator 105 outputs a signal for
10 changing a DC voltage to be applied to stator windings U, V, W to drive unit 106 on the basis of the PWM-modulated signal output from DC voltage changing unit 112.

[0012]

Rotating speed detector 109, rotating speed feedback unit 110, DC
15 voltage changing unit 112, and drive signal generator 105 are incorporated in microcomputer 108.

[0013]

Drive unit 106 converts the signal output from drive signal generator 105 incorporated in microcomputer 108 into a signal for turning on or off a
20 switching element in switching unit 113.

[0014]

Switching unit 113 is connected to DC power supply 111, and includes six switching elements Q1, Q2, Q3, Q4, Q5, Q6, and six free wheeling diodes D1, D2, D3, D4, D5, D6. With this configuration, switching unit 113
25 sequentially energizes stator windings U, V, W at predetermined timings, as well as changes the DC voltage from DC power supply 111 and applies the changed DC voltage to stator windings U, V, W to rotate brushless DC motor

100.

[0015]

Rotating speed feedback unit 110 compares target rotating speed N_m determined in advance with rotating speed N_T detected by time interval
5 average unit 104 in rotating speed detector 109, and obtains rotating speed difference N_d from the following equation.

$$N_d = N_T - N_m$$

[0016]

When a ratio for changing a voltage corresponding to rotating speed
10 difference N_d , which has been determined in advance, is defined as gain A , and DC voltage applied to stator windings is defined as V , voltage V_d for changing the DC voltage with respect to rotating speed difference N_d is obtained from the following equation.

$$V_d = N_d \times A$$

15 [0017]

When rotating speed N_T becomes lower than target rotating speed N_m to cause large rotating speed difference N_d , the DC voltage applied to stator windings U , V , W is increased by voltage V_d for changing the DC voltage. Thus, the rotating speed is controlled to be close to target rotating speed N_m .

20 In addition, when rotating speed N_T becomes higher than target rotating speed N_m to cause large rotating speed difference N_d , the DC voltage applied to stator windings U , V , W is decreased by voltage V_d for changing the DC voltage. Thus, the rotating speed is controlled to be close to target rotating speed N_m . In this way, control is performed so that constant rotation at the
25 target rotating speed is implemented.

Citation List

Patent Literature

[0018]

PTL 1: Japanese Patent No. 4649934

SUMMARY OF THE INVENTION

5 [0019]

A ceiling fan according to one aspect of the present invention includes a brushless DC motor, an inverter circuit, a drive logic controller, a duty instruction unit, and a motor current detector. The brushless DC motor has a drive coil. The inverter circuit includes an upper stage and a lower stage,
10 each of which forms a bridge connection by a plurality of switching elements. The drive logic controller performs PWM control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil. The duty instruction unit instructs an ON/OFF duty in the PWM control. The motor current detector detects current flowing through the drive
15 coil. Then, the duty instruction unit determines a duty instruction value based on a detection value of the motor current detector. Thus, the original object can be achieved.

[0020]

The ceiling fan according to one aspect of the present invention can
20 make motor torque constant, thereby providing an effect of exerting maximum performance of the ceiling fan without being affected by the distance between blades and the ceiling due to an installation state.

BRIEF DESCRIPTION OF DRAWINGS

25 [0021]

FIG. 1 is a view illustrating an outer appearance of a ceiling fan according to the present invention.

FIG. 2 is a perspective view illustrating the configuration of the ceiling fan according to the present invention.

FIG. 3 is a block diagram illustrating a configuration of a ceiling fan according to a first exemplary embodiment of the present invention.

5 FIG. 4 is a graph illustrating rotating-speed/torque characteristic of a brushless DC motor according to the first exemplary embodiment of the present invention.

FIG. 5 is a block diagram illustrating a configuration of a ceiling fan according to a second exemplary embodiment of the present invention.

10 FIG. 6 is a graph illustrating rotating-speed/torque characteristic of a brushless DC motor according to the second exemplary embodiment of the present invention.

FIG. 7 is a block diagram illustrating a configuration of a ceiling fan according to a third exemplary embodiment of the present invention.

15 FIG. 8 is a block diagram illustrating a configuration of a ceiling fan according to a fourth exemplary embodiment of the present invention.

FIG. 9 is a graph illustrating rotating-speed/torque characteristic of a brushless DC motor according to the fourth exemplary embodiment of the present invention.

20 FIG. 10 is a block diagram illustrating a configuration of a ceiling fan according to a fifth exemplary embodiment of the present invention.

FIG. 11 is a graph illustrating rotating-speed/torque characteristic of a brushless DC motor according to the fifth exemplary embodiment of the present invention.

25 FIG. 12 is a block diagram illustrating a configuration of a conventional ceiling fan.

FIG. 13 is a graph illustrating rotating-speed/torque characteristic of a

brushless DC motor mounted on the conventional ceiling fan.

DESCRIPTION OF EMBODIMENTS

[0022]

5 Exemplary embodiments of the present invention will be described below with reference to the drawings. Note that the exemplary embodiments described below are one example for embodying the present invention, and do not restrict the technical scope of the present invention. Throughout all drawings, the same components are identified by the same reference marks
10 and the description therefor will be omitted. In each drawing, the detailed description of components which do not directly relate to the present invention will be omitted.

[0023]

FIRST EXEMPLARY EMBODIMENT

15 As illustrated in FIG. 1, ceiling fan 1 according to the present exemplary embodiment is installed on a ceiling, which is not illustrated, and includes a plurality of blades 3 around a body. As illustrated in FIG. 2, ceiling fan 1 is equipped with brushless DC motor 10 inside the body, and rotates blades 3 by brushless DC motor 10 to blow air toward the lower side in the
20 drawing, i.e., downward in the vertical direction.

[0024]

Hereinafter, drive control of ceiling fan 1 will be described in detail.

[0025]

As illustrated in FIG. 3, ceiling fan 1 includes blades 3, brushless DC
25 motor 10, rectifier diode 12, smoothing capacitor 13, inverter circuit 4, Hall IC 9 (9u, 9v, 9w), drive logic controller 5, and duty instruction unit 6.

[0026]

Brushless DC motor 10 has drive coil 2 (2u, 2v, 2w). The drive of brushless DC motor 10 is controlled by sequentially energizing drive coil 2 by drive logic controller 5 through three-phase inverter circuit 4.

[0027]

5 Specifically, an AC voltage supplied from AC power supply 11 is rectified by rectifier diode 12, smoothed into a DC voltage by smoothing capacitor 13, and applied to inverter circuit 4.

[0028]

Inverter circuit 4 includes three switching elements 7 (7u, 7v, 7w) constituting an upper stage and three switching elements 8 (8u, 8v, 8w) constituting a lower stage, and each of switching elements 7 and 8 forms a bridge connection.

[0029]

Drive logic controller 5 sequentially full-wave energizes drive coils 2u, 2v, 2w in a predetermined direction and in a predetermined order based on the signals from three Hall ICs 9u, 9v, 9w that detect the rotation position of brushless DC motor 10. In this case, drive logic controller 5 performs PWM control to the DC voltage applied to inverter circuit 4 by switching element 7 in the upper stage or switching element 8 in the lower stage, thereby controlling current to be supplied to brushless DC motor 10. A sequence of control procedures by drive logic controller 5 for rotating to drive brushless DC motor 10 is defined as a drive logic.

[0030]

Duty instruction unit 6 instructs ON/OFF duty when drive logic controller 5 makes PWM control for switching elements 7, 8.

[0031]

Meanwhile, brushless DC motor 10 in the present exemplary

embodiment further includes motor current detector 14, and duty instruction unit 6 controls motor torque to be constant by performing control described below.

[0032]

5 Specifically, motor current detector 14 detects a value of three-phase current flowing through respective drive coils 2u, 2v, 2w, and transmits the detected value to duty instruction unit 6.

[0033]

 Duty instruction unit 6 changes a duty ratio based on the motor
10 current value detected by motor current detector 14 and a predetermined current value stored in the memory. Specifically, when the motor current value is lower than the predetermined current value, duty instruction unit 6 increases the duty ratio. On the other hand, when the motor current value is higher than the predetermined current value, duty instruction unit 6
15 decreases the duty ratio. Thus, the motor current can be maintained at the predetermined current value. Since the motor torque is proportional to the value of current flowing through the motor, the motor torque can consequently be made constant.

[0034]

20 When ceiling fan 1 described above is installed on a ceiling, easiness to flow air is different, and loads imposed on blades 3 are different, depending on the distance between blades 3 and the ceiling.

[0035]

 Curved lines in FIG. 4 indicate load characteristics of blades 3 based
25 on the difference between blades and the ceiling. In FIG. 4, bold line 41 indicates the relationship between torque and the rotating speed in the case in which the distance between the ceiling and blades is long. On the other hand,

thin line 42 indicates the relationship between torque and the rotating speed in the case in which the distance between the ceiling and blades is short.

[0036]

As illustrated in FIG. 13, the conventional ceiling fan illustrated in
5 FIG. 12 is controlled such that the rotating speed of the motor becomes constant at a predetermined rotating speed, that is, a control state is aligned on axis 43 having constant rotating speed. Therefore, in the installation state which makes it difficult to efficiently blow air, that is, in the state in which the distance between blades 103 and the ceiling is short, the motor rotates on
10 point a on axis 43 having constant rotating speed. On the other hand, in the installation state which makes it easy to efficiently blow air, that is, in the state in which the distance between blades 103 and the ceiling is long, the motor rotates on point b on axis 43 having constant rotating speed. If the load torque on point a is the rated maximum output of the ceiling fan from the
15 viewpoint of the strength of blades and motor temperature rise, the maximum output cannot be output on point b on which the motor runs at the same rotating speed.

[0037]

On the other hand, according to the present invention, motor current
20 can be controlled to be constant, that is, motor torque can be controlled to be constant. That is, it is controlled such that the control state is aligned on axis 44 having constant current. Therefore, in the installation state which makes it difficult to efficiently blow air, that is, in the state in which the distance between blades 3 and the ceiling is short, the motor rotates on point a on axis
25 44 having constant current. On the other hand, in the installation state which makes it easy to efficiently blow air, that is, in the state in which the distance between blades 3 and the ceiling is long, the motor rotates on point c

on axis 44 having constant current.

[0038]

Ceiling fan 1 described above according to the present exemplary embodiment can blow air by rotating blades at constant torque without being
5 affected by a change in the distance between blades 3 and the ceiling due to the installation state of ceiling fan 1. In addition, the maximum performance is set based on a current value, which can implement an operation up to an upper limit determined by the strength of the blades and motor temperature rise. Thus, the performance of ceiling fan 1 can sufficiently be exerted.

10 [0039]

SECOND EXEMPLARY EMBODIMENT

A second exemplary embodiment will be described with reference to FIGS. 5 and 6.

[0040]

15 In ceiling fan 1b in the second exemplary embodiment, current flowing through inverter circuit 4 is detected by power supply current detector 15 as illustrated in FIG. 5.

[0041]

Based on a power supply current value from power supply current
20 detector 15, duty instruction unit 6 increases a duty when the power supply current value is lower than a predetermined current value stored in a memory in advance, and decreases the duty when the power supply current value is higher than the predetermined current value. Thus, duty instruction unit 6 controls the power supply current to be the predetermined current.

25 [0042]

According to this configuration, current supplied to inverter circuit 4 can be detected on only one location.

[0043]

Notably, in brushless DC motor 10, the relationship between torque and rotating speed is changed as indicated by five thin lines 45 in FIG. 6 by an ON/OFF duty output from duty instruction unit 6.

5 [0044]

Specifically, when the duty is 100%, the straight line connecting a point on which the rotating speed is 0 min^{-1} and torque is $4.0 \text{ N}\cdot\text{m}$ and a point on which torque is $0 \text{ N}\cdot\text{m}$ and the rotating speed is 400 min^{-1} indicates the relationship between torque and rotating speed.

10 [0045]

When the duty is 80%, the straight line connecting a point on which the rotating speed is 0 min^{-1} and torque is $3.2 \text{ N}\cdot\text{m}$ which is 80% of $4.0 \text{ N}\cdot\text{m}$ and a point on which torque is $0 \text{ N}\cdot\text{m}$ and the rotating speed is 320 min^{-1} which is 80% of 400 min^{-1} indicates the relationship between torque and

15 rotating speed.

[0046]

When the duty is 60%, the straight line connecting a point on which the rotating speed is 0 min^{-1} and torque is $2.4 \text{ N}\cdot\text{m}$ which is 60% of $4.0 \text{ N}\cdot\text{m}$ and a point on which torque is $0 \text{ N}\cdot\text{m}$ and the rotating speed is 240 min^{-1}

20 which is 60% of 400 min^{-1} indicates the relationship between torque and rotating speed.

[0047]

In the case in which the duty is 40% and in the case in which the duty is 20%, torque and rotating speed are indicated by a straight line according to

25 the similar calculation.

[0048]

In addition, duty D , motor current I_m , and power supply current I_s

have the following relationship.

$$I_s = D \times I_m$$

Torque constant k_t , motor current I_m , and torque T have the following relationship.

5 $T = k_t \times I_m$

[0049]

When torque constant k_t is set as 10 N·m/A, and power supply current I_s is controlled to be 0.1 A, rotating speed N assumes values described below in the characteristics in FIG. 6.

10 $D = 100\%, I_m = 0.10 \text{ A}, T = 1.0 \text{ N}\cdot\text{m}, N = 300 \text{ min}^{-1}$

$$D = 80\%, I_m = 0.13 \text{ A}, T = 1.3 \text{ N}\cdot\text{m}, N = 195 \text{ min}^{-1}$$

$$D = 60\%, I_m = 0.17 \text{ A}, T = 1.7 \text{ N}\cdot\text{m}, N = 73 \text{ min}^{-1}$$

When the points of rotating speeds N and points of torques T are connected, bold line 46 in FIG. 6 is obtained.

15 [0050]

In this way, even if the power supply current is controlled to be constant, motor torque can be controlled to be almost constant.

[0051]

In addition, under this control, different from the first exemplary
20 embodiment, motor current detector 14 that detects three-phase motor current is unnecessary, whereby motor torque can be controlled to be almost constant by a simple configuration.

[0052]

THIRD EXEMPLARY EMBODIMENT

25 A third exemplary embodiment will be described with reference to FIG. 7.

[0053]

In ceiling fan 1c in the third exemplary embodiment, current flowing through inverter circuit 4 is detected by power supply current detector 15 as illustrated in FIG. 7. In addition, rotating speed detector 19 detects the rotating speed of brushless DC motor 10 from cycles of square wave signals HU, HV, HW which are output signals from Hall ICs 9u, 9v, 9w.

[0054]

When current I_s is detected by power supply current detector 15 is smaller than predetermined value I_p stored in a memory in advance, for example, duty instruction unit 6 determines a duty instruction value based on rotating speed N_s detected by rotating speed detector 19. That is, duty instruction unit 6 increases or decreases the duty instruction value so that rotating speed N_s detected by rotating speed detector 19 approaches predetermined rotating speed N_t stored in the memory in advance.

[0055]

Specifically, when the rotating speed difference between predetermined rotating speed N_t and detected rotating speed N_s is defined as N_d , the equation of:

$$N_d = N_t - N_s$$

is established, and when a proportional constant is defined as α , duty increase/decrease value D_d proportional to rotating speed difference N_d is obtained from the following equation.

$$D_d = \alpha \times N_d$$

[0056]

When the current duty instruction value is defined as D_n , and the next duty instruction value is defined as D_{n+1} , the following equation is established.

$$D_{n+1} = D_n + D_d$$

[0057]

When detected rotating speed N_s is smaller than predetermined rotating speed N_t , rotating speed difference N_d assumes a positive value, and
5 duty increase/decrease value D_d proportional to rotating speed difference N_d also assumes a positive value. Therefore, next duty instruction value D_{n+1} becomes larger than current duty instruction value D_n .

[0058]

When the above-mentioned process is repeated, the duty instruction
10 value is gradually increased, whereby the rotating speed of brushless DC motor 10 is raised, resulting in that predetermined rotating speed N_t and detected rotating speed N_s become the same.

[0059]

On the contrary, when detected rotating speed N_s is larger than
15 predetermined rotating speed N_t , rotating speed difference N_d assumes a negative value, and duty increase/decrease value D_d proportional to rotating speed difference N_d also assumes a negative value. Therefore, next duty instruction value D_{n+1} becomes smaller than current duty instruction value D_n .

[0060]

When the above-mentioned process is repeated, the duty instruction
20 value is gradually decreased, whereby the rotating speed of brushless DC motor 10 is lowered, resulting in that predetermined rotating speed N_t and detected rotating speed N_s become the same.

[0061]

25 That is, the rotating speed of brushless DC motor 10 can be controlled to be constant at predetermined rotating speed N_t .

[0062]

On the other hand, when current I_s detected by power supply current detector 15 is larger than predetermined value I_p , the power supply current is controlled to be constant to control the motor torque to be almost constant, as in the second exemplary embodiment.

5 [0063]

As described above, control is switched based on whether or not current I_s detected by power supply current detector 15 is larger than predetermined value I_p .

[0064]

10 Specifically,

when $I_s < I_p$, the rotating speed is controlled to be constant, and

when $I_s \geq I_p$, the motor torque is controlled to be almost constant.

[0065]

In the case in which power supply current I_s is smaller than
15 predetermined value I_p and a load on brushless DC motor 10 is small in the state in which ceiling fan 1c is installed to have a long distance between blades 3 and the ceiling and to easily blow air, there is some leeway in a motor output. Therefore, under this control, blades 3 are constantly rotated by controlling the rotating speed of brushless DC motor 10 to be constant, by which a constant
20 amount of air can be generated.

[0066]

On the other hand, in the case in which power supply current I_s is larger than predetermined value I_p and a load on brushless DC motor 10 is large in the state in which ceiling fan 1c is installed to have a short distance
25 between blades 3 and the ceiling and not to easily blow air, there is no leeway in a motor output. Therefore, the motor torque is controlled to be almost constant, and the motor output is controlled to be almost constant at

maximum output.

[0067]

As described above, the ceiling fan which blows a constant amount of air by controlling the rotating speed to be constant as a basic operation is
5 controlled such that, when the load on the motor is high due to unsatisfactory installation state, the motor output is controlled to be constant at maximum output. Therefore, an overload state of the motor can be prevented, and safety can be ensured while in use.

[0068]

10 In addition, it is unnecessary to manufacture an individual product according to an installation state, which leads to reduction in manufacturing cost.

[0069]

FOURTH EXEMPLARY EMBODIMENT

15 A fourth exemplary embodiment will be described with reference to FIGS. 8 and 9.

[0070]

In ceiling fan 1d in the fourth exemplary embodiment, current flowing through inverter circuit 4 is detected by power supply current detector 15 as
20 illustrated in FIG. 8. In addition, motor current calculator 16 calculates motor current from a duty instruction value output from duty instruction unit 6 and the power supply current detection value detected by power supply current detector 15.

[0071]

25 As described in the third exemplary embodiment, duty D, motor current I_m , and power supply current I_s have the following relationship.

$$I_s = D \times I_m$$

[0072]

Based on a motor current value from motor current calculator 16, duty instruction unit 6 performs control to increase the duty when the motor current value is lower than a predetermined current value. On the other hand, when the motor current value is higher than the predetermined current value, duty instruction unit 6 performs control to decrease the duty. In this way, the motor current is controlled to be predetermined current by the configuration in which duty instruction unit 6 controls the duty. Since the motor torque is proportional to the motor current, the motor torque can be controlled to be constant.

[0073]

Although this configuration does not need motor current detector 14 that detects three-phase motor current, it enables calculation of motor current, whereby motor torque can be precisely controlled to be constant by a simple configuration.

[0074]

However, while the motor torque can be controlled to be almost constant, the constant value of the torque may be changed when the power supply voltage is changed, in the fourth exemplary embodiment.

[0075]

That is, in the fourth exemplary embodiment, the motor characteristic having a power supply voltage of 240 V and duty of 100% is indicated by thin solid line 47, while the motor characteristic having a power supply voltage of 200 V and duty of 100% is indicated by thin chain line 48 as illustrated in FIG. 9. When torque constant k_t is set as 10 N·m/A, and power supply current I_s is controlled to be 0.1 A, rotating speed N assumes values described below in the characteristics having a power supply voltage of 240 V in FIG. 9.

D = 100%, Im = 0.10 A, T = 1.0 N·m, N = 300 min⁻¹

D = 80%, Im = 0.13 A, T = 1.3 N·m, N = 195 min⁻¹

D = 60%, Im = 0.17 A, T = 1.7 N·m, N = 73 min⁻¹

[0076]

5 When the points of rotating speeds N and points of torques T are connected, bold solid line 49 in FIG. 9 is obtained.

[0077]

 In the characteristics having a power supply voltage of 200 V in FIG. 9, rotating speed N assumes values described below.

10 D = 100%, Im = 0.10 A, T = 1.0 N·m, N = 233 min⁻¹

D = 80%, Im = 0.13 A, T = 1.3 N·m, N = 142 min⁻¹

D = 60%, Im = 0.17 A, T = 1.7 N·m, N = 33 min⁻¹

 When the points of rotating speeds N and points of torques T are connected, bold chain line 50 in FIG. 9 is obtained. In summary, torque differs according
15 to the power supply voltage.

[0078]

FIFTH EXEMPLARY EMBODIMENT

 In view of this, a fifth exemplary embodiment will be described with reference to FIGS. 10 and 11.

20 [0079]

 In ceiling fan 1e in the fifth exemplary embodiment, current flowing through inverter circuit 4 is detected by power supply current detector 15, and voltage applied to inverter circuit 4 is detected by power supply voltage detector 17, as illustrated in FIG. 10. Then, the product of the power supply
25 current value and the power supply voltage value is calculated by power calculator 18.

[0080]

Based on the power value from power calculator 18, duty instruction unit 6 increases the duty when the power value is lower than a predetermined power value, and decreases the duty when the power value is higher than the predetermined power value. Thus, duty instruction unit 6 controls power to
5 be predetermined power.
[0081]

As illustrated in FIG. 11, bold solid line 51 indicates the state in which the power supply voltage is 240 V and power supply current I_s is controlled to be 0.1 A, and this indicates that power is controlled to be 24 W. When the
10 power supply voltage is 200 V, controlling power to be 24 W is the same as the state in which power supply current I_s is controlled to be 0.12 A. When power supply current I_s is controlled to be 0.12 A, rotating speed N assumes values described below in the characteristics having a power supply voltage of 200 V in FIG. 11.

15 $D = 100\%$, $I_m = 0.12\text{ A}$, $T = 1.2\text{ N}\cdot\text{m}$, $N = 213\text{ min}^{-1}$

$D = 80\%$, $I_m = 0.15\text{ A}$, $T = 1.5\text{ N}\cdot\text{m}$, $N = 117\text{ min}^{-1}$

$D = 60\%$, $I_m = 0.20\text{ A}$, $T = 2.0\text{ N}\cdot\text{m}$, $N = 0\text{ min}^{-1}$

When the points of rotating speeds N and points of torques T are connected, bold chain line 52 in FIG. 11 is obtained. That is, the line same as bold solid
20 line 51 in the case of power supply voltage of 240 V is obtained, which means that brushless DC motor 10 can be controlled to have the same torque, even if the power supply voltage is changed.
[0082]

In the present exemplary embodiment, motor current detector 14 that
25 detects three-phase motor current is unnecessary, whereby motor torque can be controlled to be almost constant without being affected by the power supply voltage by a simple configuration.

[0083]

Note that, while Hall ICs 9u, 9v, 9w are provided to detect the rotation position of brushless DC motor 10 in each exemplary embodiment, a sensorless drive system without having a position sensor may be employed.

5 [0084]

OUTLINE OF EXEMPLARY EMBODIMENTS

A ceiling fan according to one aspect of the present invention includes a brushless DC motor, an inverter circuit, a drive logic controller, a duty instruction unit, and a motor current detector. The brushless DC motor has a
10 drive coil. The inverter circuit includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements. The drive logic controller performs PWM control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil. The duty instruction unit instructs an ON/OFF duty in the PWM
15 control. The motor current detector detects current flowing through the drive coil. Then, the duty instruction unit determines a duty instruction value based on a detection value of the motor current detector.

[0085]

According to this configuration, the motor current can be controlled to
20 be constant, and motor torque proportional to the motor current becomes also constant, whereby load torque applied to the ceiling fan becomes constant. Therefore, the ceiling fan provides an effect of exerting the maximum performance without being affected by the distance between the blades and the ceiling due to an installation state.

25 [0086]

In addition, a ceiling fan according to another aspect of the present invention includes a brushless DC motor, an inverter circuit, a drive logic

controller, a duty instruction unit, and a power supply current detector. The brushless DC motor has a drive coil. The inverter circuit includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements. The drive logic controller performs PWM control to a
5 DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil. The duty instruction unit instructs an ON/OFF duty in the PWM control. The power supply current detector detects current supplied to the inverter circuit. Then, the duty instruction unit determines a duty instruction value based on a detection value of the power
10 supply current detector.

[0087]

This configuration does not need a motor current detector that detects three-phase motor current, thereby providing an effect of being capable of controlling motor torque to be almost constant by a simple configuration.

15 [0088]

In addition, according to a specific aspect of the ceiling fan having the above-mentioned configuration, the ceiling fan further includes a rotating speed detector that detects a rotating speed of the brushless DC motor. When a detection value of current detected by the power supply current detector is
20 smaller than a predetermined value, the duty instruction unit determines a duty instruction value based on a detection value of a rotating speed detected by the rotating speed detector. When a detection value of current detected by the power supply current detector is larger than a predetermined value, the duty instruction unit determines a duty instruction value based on the
25 detection value of current detected by the power supply current detector.

[0089]

In addition, a ceiling fan according to still another aspect of the present

invention includes a brushless DC motor, an inverter circuit, a drive logic controller, a duty instruction unit, a power supply current detector, a duty detector, and a motor current calculator. The brushless DC motor has a drive coil. The inverter circuit includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements. The drive logic controller performs PWM control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil. The duty instruction unit instructs an ON/OFF duty in the PWM control. The power supply current detector detects current supplied to the inverter circuit. The duty detector detects a duty instruction value output from the duty instruction unit. The motor current calculator calculates motor current from a detection value of the power supply current detector and a detection value of the duty detector. Then, the duty instruction unit determines a duty instruction value based on a calculation value of the motor current calculator.

[0090]

This configuration does not need a motor current detector that detects three-phase motor current, and enables calculation of motor current, thereby providing an effect such that motor torque can be precisely controlled to be constant by a simple configuration.

[0091]

In addition, a ceiling fan according to still another aspect of the present invention includes a brushless DC motor, an inverter circuit, a drive logic controller, a duty instruction unit, a power supply current detector, a power supply voltage detector, and a power supply power calculator. The brushless DC motor has a drive coil. The inverter circuit includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of

switching elements. The drive logic controller performs PWM control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil. The duty instruction unit instructs an ON/OFF duty in the PWM control. The power supply current detector detects
5 current supplied to the inverter circuit. The power supply voltage detector detects voltage supplied to the inverter circuit. The power supply power calculator calculates power supply power from a detection value of the power supply current detector and a detection value of the power supply voltage detector. Then, the duty instruction unit determines a duty instruction value
10 based on a calculation value of the power supply power calculator.

[0092]

This configuration does not need a motor current detector that detects three-phase motor current, thereby providing an effect such that motor torque can be controlled to be almost constant without being affected by a power
15 supply voltage by a simple configuration.

INDUSTRIAL APPLICABILITY

[0093]

The ceiling fan according to the present invention can blow air by
20 rotating blades at constant maximum torque without being affected by a change in the distance between the blades and a ceiling, and thus, useful for a ceiling fan for driving a fan.

REFERENCE MARKS IN THE DRAWINGS

25 [0094]

1, 1b, 1c, 1d, 1e: ceiling fan

2, 2u, 2v, 2w: drive coil

	3: blade
	4: inverter circuit
	5: drive logic controller
	6: duty instruction unit
5	7, 7u, 7v, 7w: switching element in upper stage
	8, 8u, 8v, 8w: switching element in lower stage
	9, 9u, 9v, 9w: Hall IC
	10: brushless DC motor
	11: AC power supply
10	12: rectifier diode
	13: smoothing capacitor
	14: motor current detector
	15: power supply current detector
	16: motor current calculator
15	17: power supply voltage detector
	18: power calculator

CLAIMS

1. A ceiling fan comprising:
 - a brushless direct-current (DC) motor equipped with a drive coil;
 - 5 an inverter circuit that includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements;
 - a drive logic controller that performs pulse width modulation (PWM) control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil;
 - 10 a duty instruction unit that instructs an ON/OFF duty in the PWM control; and
 - a motor current detector that detects current flowing through the drive coil,
 - wherein
 - 15 the duty instruction unit determines a duty instruction value, based on a detection value of the motor current detector.

2. A ceiling fan comprising:
 - a brushless direct-current (DC) motor equipped with a drive coil;
 - 20 an inverter circuit that includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements;
 - a drive logic controller that performs pulse width modulation (PWM) control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil;
 - 25 a duty instruction unit that instructs an ON/OFF duty in the PWM control; and
 - a power supply current detector that detects current supplied to the

inverter circuit,

wherein

the duty instruction unit determines a duty instruction value, based on a detection value of the power supply current detector.

5

3. The ceiling fan according to claim 2, further comprising

a rotating speed detector that detects a rotating speed of the brushless DC motor,

wherein

10 the duty instruction unit determines the duty instruction value, based on a detection value of a rotating speed detected by the rotating speed detector, when a detection value of current detected by the power supply current detector is smaller than a predetermined value, and

the duty instruction unit determines the duty instruction value, based
15 on the detection value of current detected by the power supply current detector, when the detection value of current detected by the power supply current detector is larger than the predetermined value.

4. A ceiling fan comprising:

20 a brushless direct-current (DC) motor equipped with a drive coil;

an inverter circuit that includes an upper stage and a lower stage, each of which forms a bridge connection by a plurality of switching elements;

a drive logic controller that performs pulse width modulation (PWM) control to a DC voltage to be applied to the inverter circuit, and controls a
25 drive logic for sequentially energizing the drive coil;

a duty instruction unit that instructs an ON/OFF duty in the PWM control;

a power supply current detector that detects current supplied to the inverter circuit;

a duty detector that detects a duty instruction value output from the duty instruction unit; and

5 a motor current calculator that calculates motor current from a detection value of the power supply current detector and a detection value of the duty detector,

wherein

the duty instruction unit determines the duty instruction value, based
10 on a calculation value of the motor current calculator.

5. A ceiling fan comprising:

a brushless direct-current (DC) motor equipped with a drive coil;

an inverter circuit that includes an upper stage and a lower stage, each
15 of which forms a bridge connection by a plurality of switching elements;

a drive logic controller that performs pulse width modulation (PWM) control to a DC voltage to be applied to the inverter circuit, and controls a drive logic for sequentially energizing the drive coil;

a duty instruction unit that instructs an ON/OFF duty in the PWM
20 control;

a power supply current detector that detects current supplied to the inverter circuit;

a power supply voltage detector that detects a voltage supplied to the inverter circuit; and

25 a power supply power calculator that calculates power supply power from a detection value of the power supply current detector and a detection value of the power supply voltage detector,

wherein

the duty instruction unit determines the duty instruction value, based on a calculation value of the power supply power calculator.