



(51) International Patent Classification:

H02P 27/08 (2006.01) H02M 1/12 (2006.01)
H02M 7/5387 (2007.01)

(21) International Application Number:

PCT/JP2015/052599

(22) International Filing Date:

22 January 2015 (22.01.2015)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2014-030932 20 February 2014 (20.02.2014) JP

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

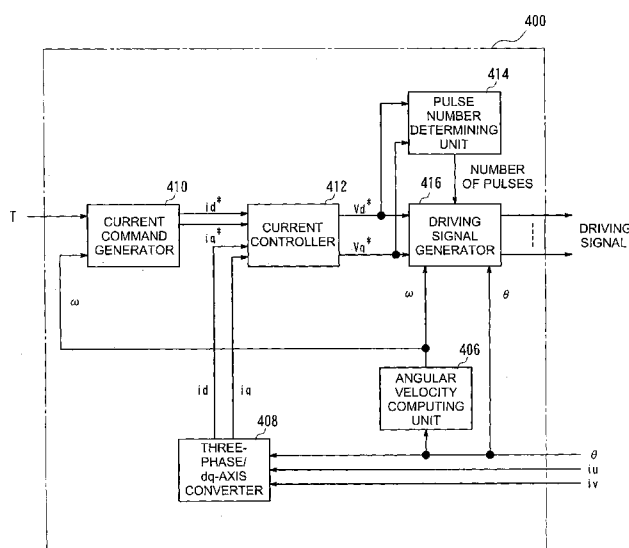
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: POWER CONVERTER CONTROL APPARATUS AND MOTOR SYSTEM HAVING THE SAME

FIG. 2



(57) Abstract: A power converter control apparatus includes a pulse number determining unit 414 configured to determine the number of pulses in one electrical cycle, and a driving signal generator 416 configured to determine a percent modulation and a phase difference of the driving voltage and generate the driving voltage in accordance with the percent modulation and the phase difference. The driving signal generator 416 decreases a pulse ratio, which is a ratio of the number of pulses within a range of electrical angle of 60 degrees to 120 degrees with respect to the number of all pulses in an electrical half cycle, with an increase in the percent modulation.

DESCRIPTION

TITLE OF THE INVENTION

POWER CONVERTER CONTROL APPARATUS

5

AND

MOTOR SYSTEM HAVING THE SAME

TECHNICAL FIELD

The present invention relates to a power converter control apparatus and a motor
10 system including the power converter control apparatus.

BACKGROUND ART

Moving bodies, such as hybrid vehicles, electric cars, and so on, include a motor
(electric machine) installed therein. A motor receives electric power from a power supply
15 source, such as battery, and converts the electric power to mechanical power to generate a
driving force. It is therefore desirable to minimize loss of power of the motor.

Patent Document 1 discloses, as a modulation method with a smaller number of
switching times as compared with PWM (Pulse Width Modulation), technology of
eliminating high-order harmonic components (of the fifth order, the seventh order, the
20 eleventh order, . . .) from specific waveform positions of rectangular waveform voltage to
thereby reduce factors that would cause current distortion.

Patent Document 2 discloses technology of setting switching angles α_1 to α_n such
that a value obtained by dividing normalized harmonic loss by normalized fundamental
wave power is minimal in an n-pulse mode, as the inverter voltage for driving the motor by
25 the inverter, thereby eliminating the low-order harmonics while increasing the output
voltage of the fundamental wave component.

PRIOR ART DOCUMENTS

PATENT LITERATURE

Patent Document 1: JP 2011-35991 A

Patent Document 2: JP 2012-120250 A

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SUMMARY OF INVENTION

TECHNICAL PROBLEMS

The conventional harmonic suppression technology takes into consideration only reduction in the low-order harmonic components of the input voltage by switching of the inverter circuit, and does not take into consideration current distortion or effects on the torque when electric current is applied to the motor. Therefore, the conventional harmonic suppression technology does not take into consideration the iron loss of the motor caused by harmonic components of the current, and only partially considers the loss of the motor system.

Further, according to the conventional technology, processing is executed while evaluating only the harmonic components of the controllable order in selected n pulses even when it is not necessary to completely delete specific low-order harmonics. This results in consideration and removal of only low-order harmonic components, failing to optimize the whole motor system to reduce the loss thereof.

20

SOLUTION TO PROBLEMS

According to one aspect of the invention, there is provided a power converter control apparatus configured to output driving voltage to a switching element of each phase provided in a three-phase full-bridge power converter. The power converter control apparatus includes a pulse number determining unit configured to determine the number of pulses in one electrical cycle; and a driving signal generator configured to determine a percent modulation and a phase difference of the driving voltage and generate the driving voltage in accordance with the percent modulation and the phase difference.

25

The driving signal generator decreases a pulse ratio, which is a ratio of the number of pulses within a range of electrical angle of 60 degrees to 120 degrees with respect to the number of all pulses in an electrical half cycle, with an increase in the percent modulation.

According to another aspect of the present invention, there is provided a motor system including a three-phase motor, and a power converter control apparatus which is configured to output driving voltage to a switching element of each phase provided in a three-phase full-bridge power converter and controls the three-phase motor. The power converter control apparatus includes a pulse number determining unit configured to determine the number of pulses in one electrical cycle, and a driving signal generator configured to determine a percent modulation and a phase difference of the driving voltage and generate the driving voltage in accordance with the percent modulation and the phase difference. The driving signal generator decreases a pulse ratio, which is a ratio of the number of pulses within a range of electrical angle of 60 degrees to 120 degrees with respect to the number of all pulses in an electrical half cycle, with an increase in the percent modulation.

The driving signal generator decreases the pulse ratio from 100% with the increase in the percent modulation.

The driving signal generator sets the number of pulses in one electrical cycle to one pulse or more, and changes the pulse ratio stepwise with respect to the percent modulation.

ADVANTAGEOUS EFFECTS OF INVENTION

According to the present invention, it is possible to provide a power converter control apparatus and a motor system including the power converter control apparatus, which are capable of reducing the loss of the whole motor system.

BRIEF DESCRIPTION OF DRAWINGS

These and other objects of the invention will be explained in the description below, by reference to the accompanying drawings, in which:

FIG. 1 is a view illustrating a structure of a motor system according to an embodiment of the present invention;

5 FIG. 2 is a view illustrating a structure of a control circuit according to the embodiment of the present invention;

FIG. 3 is a view illustrating a structure of a driving signal generator according to the embodiment of the present invention;

10 FIG. 4 is a view illustrating a relationship of a pulse ratio with a range of electrical angles from 60 degrees to 120 degrees with respect to a percent modulation according to the embodiment of the present invention;

FIG. 5 is a view illustrating example driving voltage generated in the embodiment of the present invention;

15 FIG. 6 is a view illustrating example driving voltage generated in the embodiment of the present invention; and

FIG. 7 is a view illustrating an effect of reducing the loss in the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

20 A motor system according to an embodiment of the present invention includes a motor 100, a power source circuit 200, a power converter 300, and a power converter control apparatus 400, as illustrated in FIG. 1. Electric power supplied from the power source circuit 200 is DC-AC converted by the power converter 300 under control of the power converter control apparatus 400 and is supplied to the motor 100.

25 The motor 100 is driven by the power supplied from the power source circuit 200. The motor 100 can be a synchronous machine having a permanent magnet in a rotor. The alternating current power from the power converter 300 is supplied to an armature winding

of a stator of the motor 100, to thereby control rotation of the motor 100. The driving force of the motor 100 can be utilized, for example, as a driving force for movable bodies, such as hybrid vehicles and electric vehicles.

The motor 100 may also be a motor generator which also functions as a power generator. In this case, electric power generated by power generation is AC-DC converted by the power converter 300 for charging the battery of the power source circuit 200.

The motor 100 may also include a resolver 10 attached thereto for detecting the rotation position (rotation angle) θ of the rotor. The resolver 10 detects the rotation position (rotation angle) θ of the rotor of the motor 100. The output from the resolver 10 is input to an angular velocity computing unit of the power converter control apparatus 400, where the rotation position is converted to an angular velocity ω (number of revolutions) of the rotor of the motor 100.

A current sensor 12 is also provided on a power source supply line to the motor 100. A current value i_u , i_v of each phase is detected in real time by the current sensor 12, and is converted from the current values i_u and i_v to a d-axis current value i_d and q-axis current value i_q , respectively, by a three-phase/dq-axis converter of the power converter control apparatus 400.

The power source circuit 200 includes a battery 20 and a smoothing capacitor 22. The electric power is supplied and received between the battery 20 and the motor 100 through the power converter 300. The smoothing capacitor 22 is provided to smooth the output voltage of the battery 20.

The power converter 300 includes an inverter circuit. The power converter 300 can be formed as a three-phase full-bridge circuit including an upper arm and a lower arm having switching elements which are controlled to be opened or closed by a driving signal having a pulse shape output from the power converter control apparatus 400.

Each of the upper arm and the lower arm is composed of an IGBT (Insulated Gate Bipolar Transistor), which is a switching element, and a diode which are connected in

parallel to each other. The upper arms and the lower arms are connected in series with each other to thereby form three upper-lower arm series circuits. The midpoint of each upper-lower arm series circuit is connected to an alternating current power line of the motor 100. The switching elements of the upper arm and the lower arm receive a driving
5 signal from the power converter control apparatus 400. The driving signal controls the open/close operations of the switching element of the inverter circuit, and three-phase dummy sine wave voltage is generated and supplied to the motor 100. When the motor 100 functions as a generator, the three-phase alternating current power output from the motor 100 is converted to direct-current electric power, which is then supplied to the
10 power source circuit 200.

Further, the power converter 300 may further include a voltage converter for boosting or decreasing the direct-current voltage.

The power converter control apparatus 400 includes a control circuit 402 and a driver circuit 404. The control circuit 402 is configured to generate a driving signal to be
15 supplied to the driver circuit 404. The control circuit 402, based on inputs from other control apparatuses and sensors, generates an unamplified driving signal for controlling the switching timing of the power converter 300. The driver circuit 404, in response to the unamplified driving signal generated by the control circuit 402, generates a driving signal by amplifying the unamplified driving signal, for example, for actually driving the
20 switching elements of the power converter 300.

The control circuit 402 can be implemented by a microcomputer configured to perform operation processing of the switching timing of the switching elements of the power converter 300. The control circuit 402 receives input of a target torque value T required for the motor 100, the current values i_u and i_v supplied from the power converter
25 300 to the motor 100, and the rotation angle θ of the rotor of the motor 100. The target torque value T is a command signal output from an accelerator control unit or the like of a vehicle, which is a signal indicative of an output torque required for the motor 100.

The control circuit 402, based on the target torque value T , computes a d-axis

current command value and a q-axis current command value of the motor 100, and, based on a difference between these d-axis current command value and the q-axis current command value and the actual d-axis current value and q-axis current value corresponding to the detected current values i_u and i_v , computes a d-axis voltage command value and a q-axis voltage command value. The control circuit 402 further generates, from the d-axis voltage command value and the q-axis voltage command value, a pulsed modulation wave. This pulsed modulation wave signal is then amplified by the driver circuit 404 and output to the power converter 300.

As illustrated in FIG. 2, the control circuit 402 includes an angular velocity computing unit 406, a three-phase/dq-axis converter 408, a current command generator 410, a current controller 412, a pulse number determining unit 414, and a driving signal generator 416.

The angular velocity computing unit 406 receives a detection signal of the rotation position (rotation angle θ) of the rotor of the motor 100 supplied from the resolver 10 and converts the rotation position (rotation angle θ) to the angular velocity ω (number of revolutions) of the rotor of the motor 100 and outputs the angular velocity ω to the current command generator 410 and the driving signal generator 416. The angular velocity computing unit 406 is mainly composed of a differentiator.

The three-phase/dq-axis converter 408 receives the detected values of the current values i_u and i_v of the current flowing in the motor 100 from the current sensor 12 and a detection signal of the rotation position (rotation angle θ) of the rotor supplied from the resolver 10, and converts the current values i_u and i_v to the d-axis current value i_d and the q-axis current value i_q and outputs these values to the current controller 412.

The current command generator 410, in response to the input target torque value T output from an external accelerator control unit or the like, generates and outputs a d-axis current command signal i_d^* and a q-axis current command signal i_q^* , which are current command values with respect to the motor 100. Specifically, the current command generator 410, based on the relationship between the target torque value T and the angular

velocity ω of the rotor, generates the d-axis current command signal i_d^* and the q-axis current command signal i_q^* . More specifically, a current command value table including the d-axis current command signal i_d^* and the q-axis current command signal i_q^* registered in association with a combination of the target torque value T and the angular velocity ω of the rotor may be registered, so that the d-axis current command signal i_d^* and the q-axis current command signal i_q^* , which are associated with the input target torque value T and the angular velocity ω of the rotor, can be read and output.

The current controller 412, in response to the d-axis current command signal i_d^* and the q-axis current command signal i_q^* from the current command generator 410 and the d-axis current value i_d and the q-axis current value i_q of the current actually flowing in the motor 100, supplied from the three-phase/dq-axis converter 408, computes a d-axis voltage command signal V_d^* and a q-axis voltage command signal V_q^* such that the d-axis current value i_d and the q-axis current value i_q follow the d-axis current command signal i_d^* and the q-axis current command signal i_q^* , respectively. The d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* which are computed are input to the pulse number determining unit 414 and the driving signal generator 416.

The pulse number determining unit 414 determines the number of pulses included in one electrical cycle of the driving signal generated in the driving signal generator 416. Specifically, the pulse number determining unit 414, in response to the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* , which are input, determines the number of pulses in the one electrical cycle, in accordance with the percent modulation (a) calculated from the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* . For example, the number of pulses may preferably vary within a range from 1 pulse to 31 pulses in accordance with the percent modulation (a). The percent modulation (a) can be calculated by the pulse number determining unit 414 in a manner similar to the driving signal generator 416 which will be described below. At this time, it is preferable to set the number of pulses in accordance with the percent modulation (a) such that the loss in the actual motor 100 can be reduced as much as

possible.

The driving signal generator 416 receives the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* , the rotation position (rotation angle θ) of the rotor and the angular velocity ω (number of revolutions), and the number of pulses, and generates and outputs a driving signal which is a pulsed signal for driving the power converter 300. The driving signal generator 416 includes, as illustrated in FIG. 3, a voltage phase difference computing unit 420, a percent modulation computing unit 422, and a pulse generator 424.

The voltage phase difference computing unit 420 receives the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* , and calculates, from these signals, a phase difference between the magnetic pole position and the voltage phase; i.e., a voltage phase difference. The voltage phase difference δ can be calculated based on the following Equation (1).

$$\delta = \arctan (V_d^* / V_q^*) \dots\dots (1)$$

The percent modulation computing unit 422, in response to the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* , calculates a percent modulation by normalizing the magnitude of a vector formed by the d-axis voltage command signal V_d^* and the q-axis voltage command signal V_q^* . The percent modulation (a) can be calculated based on the following Equation (2) wherein V_{dc} is battery voltage.

$$a = (\sqrt{(V_d^*)^2 + (V_q^*)^2}) / V_{dc} \dots\dots (2)$$

The pulse generator 424 receives the percent modulation (a), a voltage phase signal θ_v , the angular velocity ω (number of revolutions) of the rotor, and the number of pulses, and generates, based on these values, a driving signal which is a pulsed signal. Here, the voltage phase signal θ_v is a value obtained by adding the rotation position (rotation angle θ) of the rotor to the voltage phase difference δ . Specifically, the voltage phase signal θ_v can be represented by the following Equation (3), where the rotation angle of the rotor is θ .

$$\theta_v = \delta + \theta \cdots \cdots (3)$$

The pulse generator 424 generates a driving signal such that the pulse ratio, which is a ratio of the number of pulses within the range of electrical angle of 60 degrees or greater and 120 degrees or smaller ($\pi/3$ to $2\pi/3$) with respect to the total number of pulses in an electrical half cycle, decreases with an increase in the percent modulation (a). Specifically, a driving signal is generated such that, when the percent modulation (a) is small, the ratio of the number of pulses within the range of electrical angle of 60 degrees or greater and 120 degrees or smaller in the electrical half cycle is great and the ratio of the number of pulses within the range of electrical angle of 60 degrees or greater and 120 degrees or smaller in the electrical half cycle decreases with an increase in the percent modulation (a).

The pulse generator 424 uses an evaluation function which takes into consideration eddy-current loss in the motor 100 to determine the pulse waveform (switching pattern) of the driving signal. The conventional driving signal determining method, including both low-order harmonic elimination PWM and low-order harmonic amplitude and phase control PWM, eliminates specific harmonics contained in the driving signal or controls the specific harmonics to a target value. In this case, only the harmonics which are equal in number to or smaller than the controllable number in the pulse waveform (switching pattern) of the driving signal are considered, and thus only the low-order harmonic is suppressed in view of improvement in current distortion and controllability to improve the current distortion, thereby attempting to reduce the motor loss. However, under low revolution and light load conditions, the motor loss reduction effect achieved by such suppression of low-order harmonic is small, and also the control of the low-order harmonic results in an increase in high-order harmonics which are not the subject of control, leading to an increase in the motor iron loss. The present embodiment has therefore adopted a method of determining the pulse waveform (switching pattern) of a driving signal, which takes into consideration not only the low-order harmonics but also the high-order harmonics.

In the present embodiment, as in the low-order harmonic amplitude and phase control PWM, the driving signal has half-wave symmetry [$f(\omega t) = -f(\omega t + \pi)$]. The method which adopts such a pulse waveform (switching pattern) of the driving signal can provide an advantage in that, as compared to the driving signal having half-wave symmetry

5 $[f(\omega t) = -f(\omega t + \pi)]$ and odd symmetry [$f(\omega t) = f(\pi - \omega t)$] which is used in the conventional low-order harmonic elimination PWM, the range of choices for the pulse waveform (switching pattern) is wider, and therefore improved controllability can be expected for both amplitude and phase of the frequency components contained in the driving signal.

The pulse waveform of the driving signal can be represented by the following

10 Equation (4) using Fourier series expansion. Here, $n = 1, 5, 7, 11, 13 \dots$ (odd number integer), p denotes the number of pulses, and the number of switching in electrical half cycle is $M = p-1$.

$$f(\theta) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos n\theta + b_n \sin n\theta)$$

$$a_n = \frac{1}{\pi} \int_0^{2\pi} f(\theta) \cos n\theta d\theta = -\frac{2}{n\pi} \sum_{m=1}^M (-1)^m \sin n\theta_m \quad \dots\dots (4)$$

15
$$b_n = \frac{1}{\pi} \int_0^{2\pi} f(\theta) \sin n\theta d\theta = \frac{2}{n\pi} \left\{ \left(\sum_{m=1}^M (-1)^m \cos n\theta_m \right) + 1 \right\}$$

With a coefficient a_n and a coefficient b_n of Equation (4), the amplitude C_n and the phase α_n for each order can be obtained based on the following Equation (5). The amplitude C_n and the phase α_n thus obtained are used to determine the pulse waveform (switching pattern) of the driving signal which realizes a reduced loss.

20
$$C_n = \sqrt{a_n^2 + b_n^2}$$

$$\alpha_n = \tan^{-1} \frac{b_n}{a_n} \quad \dots\dots (5)$$

The motor iron loss W_i can be represented by the following Formula (6) according

to Steinmetz's empirical formula. Here, W_i denotes a motor iron loss, W_h denotes a hysteresis loss, W_e denotes an eddy current loss, K_h denotes a hysteresis loss coefficient, B_m denotes a magnetic flux density, f denotes a rotation magnetic flux frequency, and K_e denotes an eddy current loss coefficient.

5

$$W_i = W_h + W_e = K_h B_m^2 f + K_e B_m^2 f^2 \dots\dots (6)$$

Here, as the ratio of the eddy current loss with respect to the entire iron loss is large, the eddy current loss is determined as an evaluation function. The switching pattern is then determined such that this evaluation function is minimized.

10

This evaluation function is used to determine the pulse waveform (switching pattern) of the driving signal. As a constraint, the amplitude and phase of the fundamental wave contained in the driving signal are given. The fundamental wave amplitude is determined based on the percent modulation (a). As the fundamental wave phase is 0 degree, a_1 in Formula (4) is set to 0. With these constraints described above, the pulse waveform (switching pattern) of the driving signal is determined such that the eddy current loss in the iron loss is the minimum value.

15

FIG. 4 shows an example correspondence of the pulse ratio within the range of the electrical angle of 60 degrees or more and 120 degrees or less with respect to the percent modulation (a).

20

When the total number of pulses is 5, for example, the pulse generator 424 is controlled to generate a driving signal such that, until the percent modulation (a) exceeds about 0.7, the pulse ratio within the range of the electrical angle of 60 degrees or greater and 120 degrees or smaller is 100%, as illustrated in FIG. 5. The pulse generator 424 is further controlled to generate a driving signal such that, when the percent modulation (a) exceeds about 0.72, the pulse ratio within the range of the electrical angle of 60 degrees or greater and 120 degrees or smaller becomes 0.

25

When the total number of pulses is 27, for example, as illustrated in FIG. 6 (a), the pulse generator 424 is controlled to generate a driving signal such that the pulse ratio

within the range of the electrical angle of 60 degrees or greater and 120 degrees or smaller is 100% in the range of the percent modulation (a) from 0 to 0.14, and to generate a driving signal such that the pulse ratio is decreased stepwise as the percent modulation (a) increases and a part of the pulse is included in the range of the electrical angle below 60
5 degrees or exceeding 120 degrees, as shown in FIG. 6 (b). The pulse generator 424 is further controlled to generate a driving signal such that when the percent modulation (a) exceeds about 0.72, the pulse ratio within the range of the electrical angle of 60 degrees or greater and 120 degrees or smaller is minimum.

The unamplified driving signal generated in the pulse generator 424 is amplified
10 and so on by the driver circuit 404, and input to the power converter 300. The driver circuit 404, when driving the lower arm, amplifies a signal having a pulsed modulation wave and applies the signal, as a driving signal, to a gate electrode of the switching element (IGBT) of the lower arm. Further, the driver circuit 404, when driving the upper
15 level of the reference potential of the upper arm and thereafter amplifies the pulsed modulation wave signal, and applies this signal, as a driving signal, to the gate electrode of the switching element (IGBT) of the upper arm. Thus, each switching element (IGBT) of the power converter 300 is to be switched based on the input driving signal. With this
20 switching, the direct-current electric power supplied from the power source circuit 200 is converted to driving voltages V_u , V_v , V_w of U, V, and W phases, respectively, which are shifted from each other by an electrical angle of $2\pi/3$ degrees, and these driving voltages V_u , V_v , V_w of U, V, and W phases are then supplied to the motor 100, which is a three-phase alternating current motor.

In the present embodiment, a driving signal is generated such that the pulses are
25 concentrated in the range of the electrical angle of 60 degrees or greater and 120 degrees or smaller, so that the voltage applied to the motor can include harmonic components of higher order as compared to the conventional art. This allows a behavior as if the number of pulses of switching of the power converter 300 increases, which makes it possible to

suppress the loss, especially the iron loss, in the motor 100.

FIG. 7 shows a result of comparison of the loss ratio in the motor 100 with respect to the number of pulses included in the electrical half cycle, between when generating a driving signal with the conventional triangular wave comparison PWM method and when
5 generating a driving signal with the structure of the present invention. As is obvious from FIG. 7, the structure of the present application allows a reduction in the loss of the motor 100 in all the number pulses.

CLAIMS

1. A power converter control apparatus configured to output driving voltage to a switching element of each phase provided in a three-phase full-bridge power converter, the power converter control apparatus comprising:

a pulse number determining unit configured to determine the number of pulses in electrical one cycle; and

a driving signal generator configured to determine a percent modulation and a phase difference of the driving voltage and generate the driving voltage in accordance with the percent modulation and the phase difference,

the driving signal generator decreasing a pulse ratio with an increase in the percent modulation, the pulse ratio being a ratio of the number of pulses within a range of electrical angle of 60 degrees to 120 degrees with respect to the number of all pulses in an electrical half cycle.

2. The power converter control apparatus according to claim 1, wherein the driving signal generator decreases the pulse ratio from 100% with an increase in the percent modulation.

3. The power converter control apparatus according to claim 1, wherein the driving signal generator sets the number of pulses in one electrical cycle to one pulse or more, and changes the pulse ratio stepwise with respect to the percent modulation.

4. The power converter control apparatus according to claim 2, wherein the driving signal generator sets the number of pulses in one electrical cycle to one pulse or more, and changes the pulse ratio stepwise with respect to the percent modulation.

5. A motor system comprising:

a three-phase motor; and

a power converter control apparatus configured to output driving voltage to a

5 switching element of each phase provided in a three-phase full-bridge power converter, the power converter control apparatus controlling the three-phase motor,

the power converter control apparatus comprising:

a pulse number determining unit configured to determine the number of pulses in one electrical cycle; and

10 a driving signal generator configured to determine a percent modulation and a phase difference of the driving voltage and generate the driving voltage in accordance with the percent modulation and the phase difference,

the driving signal generator decreasing a pulse ratio with an increase in the percent modulation, the pulse ratio being a ratio of the number of pulses within a range of
15 electrical angle of 60 degrees to 120 degrees with respect to the number of all pulses in an electrical half cycle.

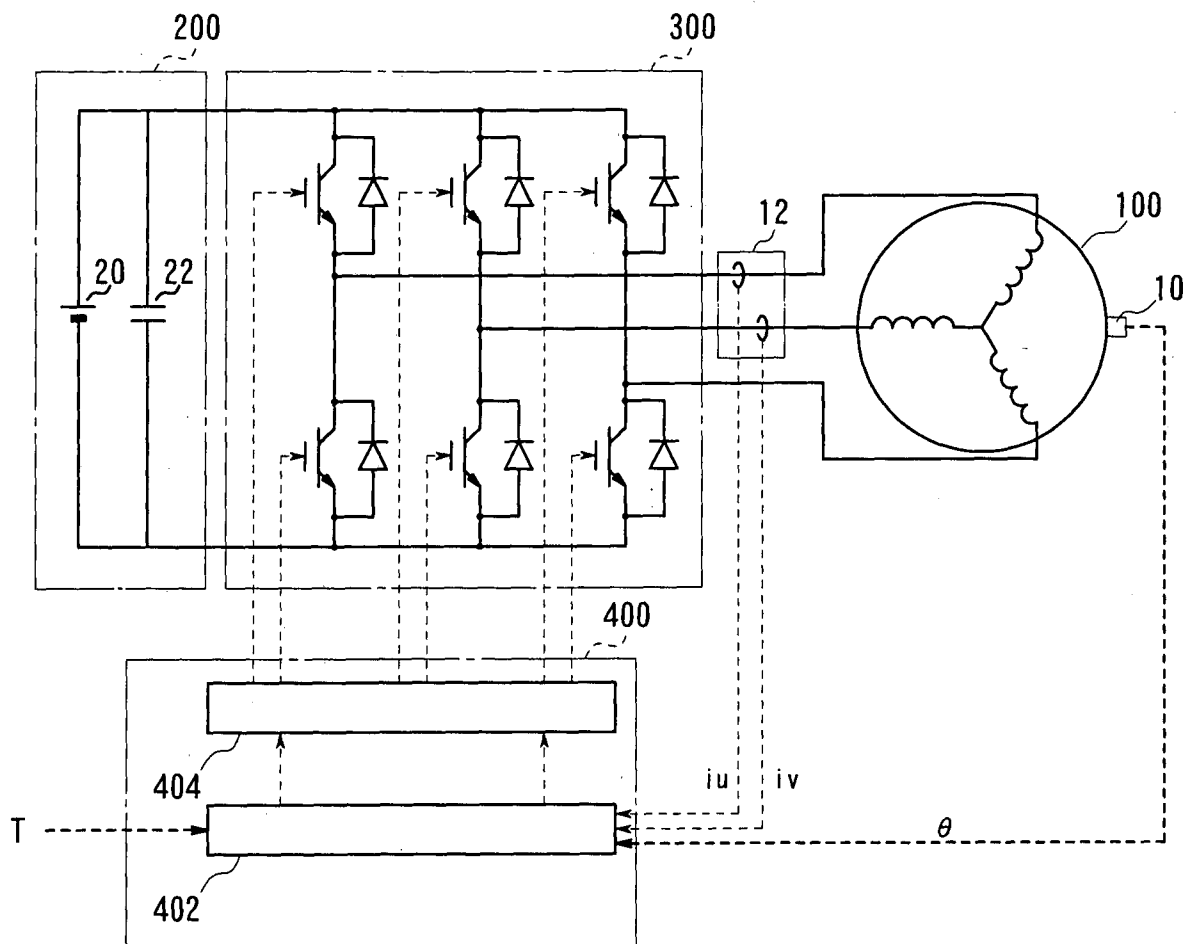


FIG. 1

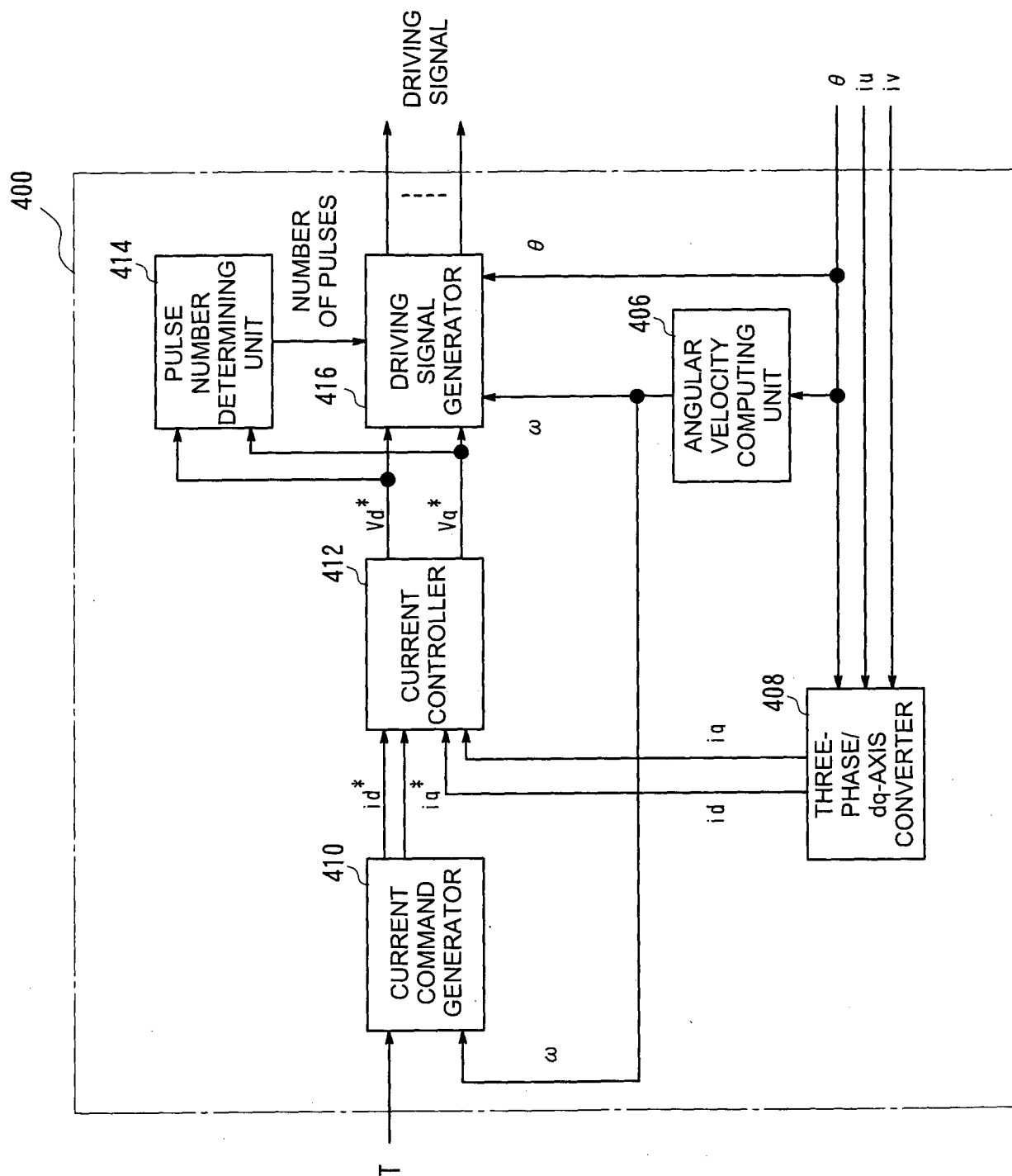


FIG. 2

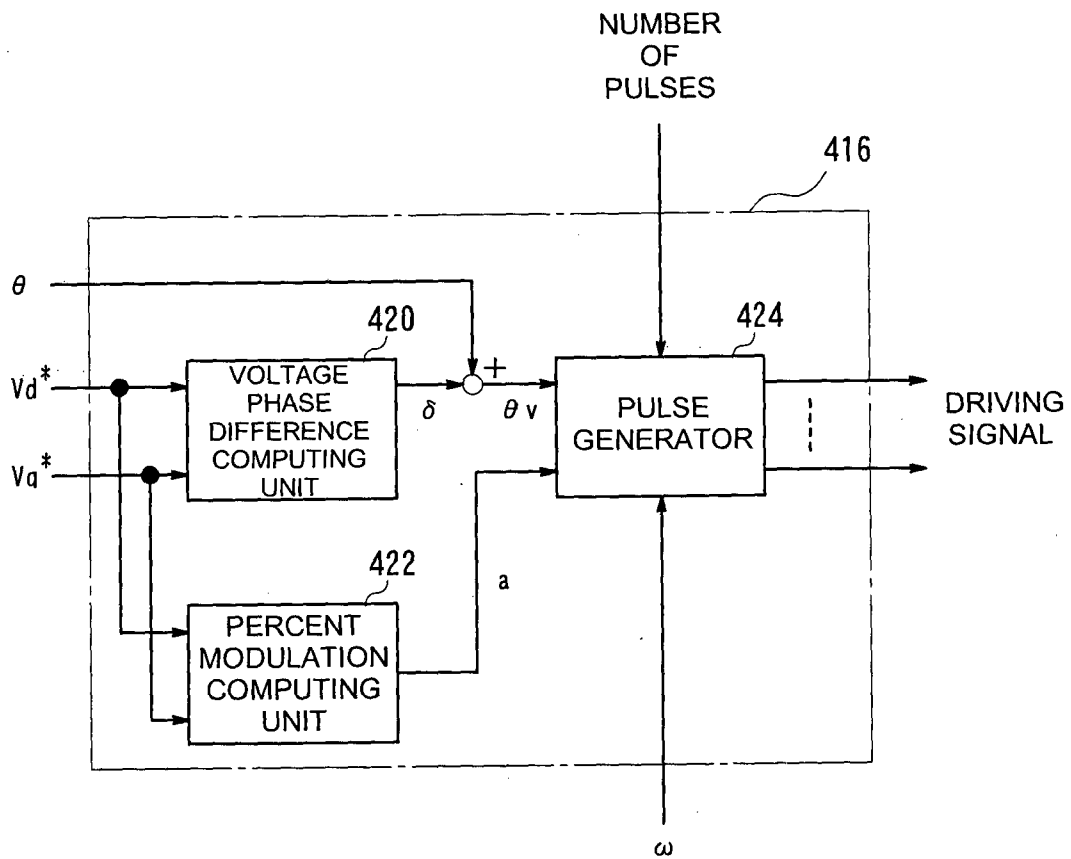


FIG. 3

PULSE RATIO OF
60 TO 120 DEG.
[%]

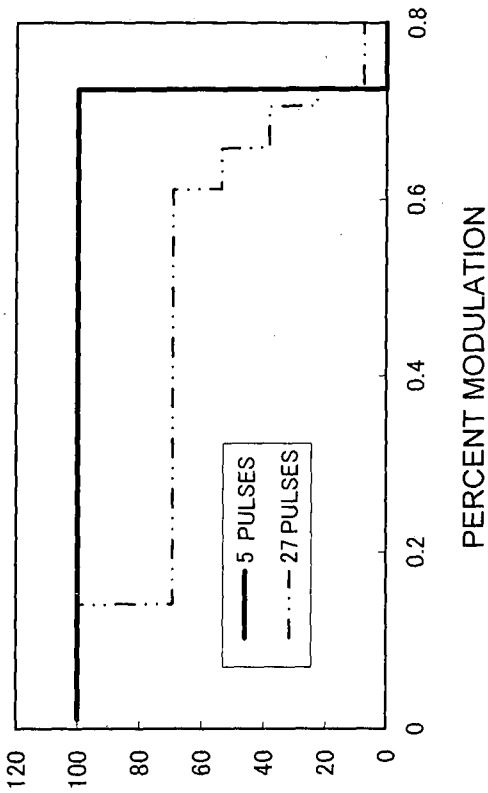


FIG. 4

SWITCHING
PULSE

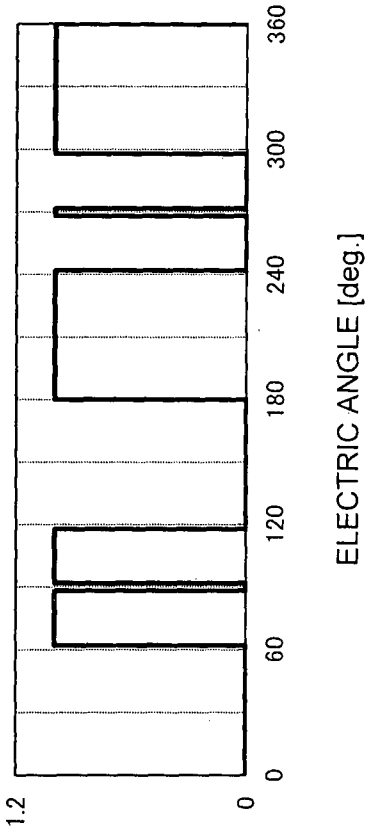


FIG. 5

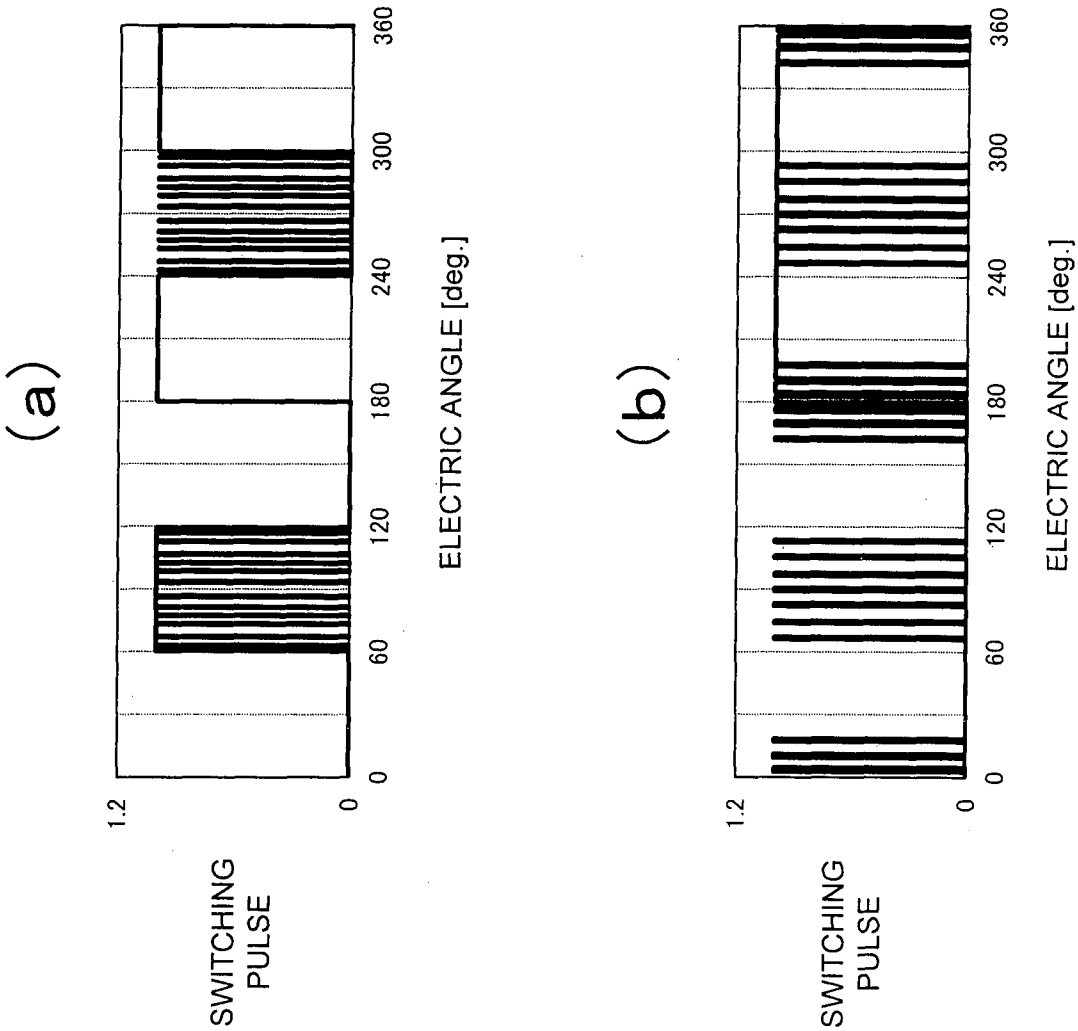


FIG. 6

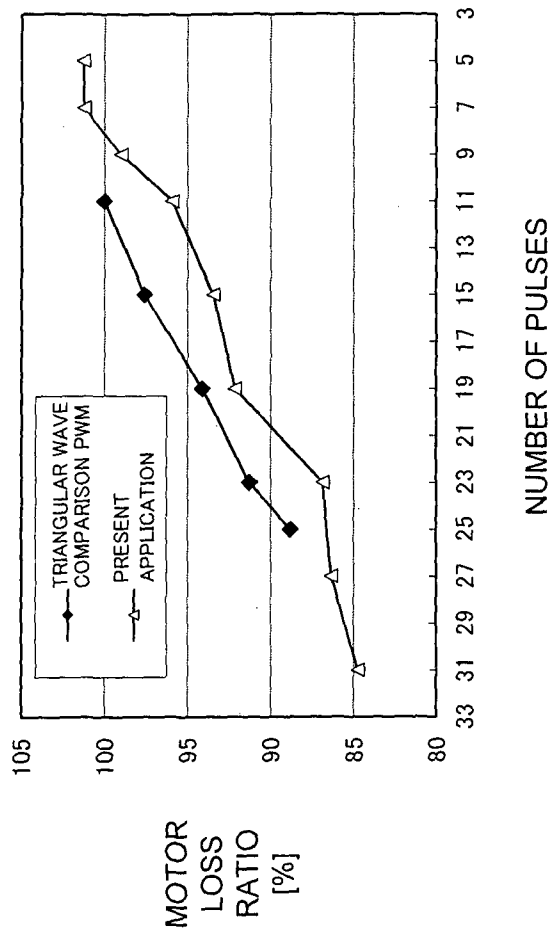


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2015/052599A. CLASSIFICATION OF SUBJECT MATTER
INV. H02P27/08 H02M7/5387
ADD. H02M1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02M H02P H03K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/033205 A1 (FURUKAWA KIMIHISA [JP] ET AL) 7 February 2013 (2013-02-07)	1,3,5
Y	figures 2, 5, 23, 24, 32, 33, 38 paragraph [0208] paragraph [0106] - paragraph [0110]	2,4
X	WO 2008/001524 A1 (TOYOTA MOTOR CO LTD [JP]; OHTANI HIROKI [JP]; NAKAMURA MAKOTO [JP]; YA) 3 January 2008 (2008-01-03)	1,3,5
Y	page 8, line 5 - page 8, line 15 figures 1-4	2,4
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

21 May 2015

Date of mailing of the international search report

02/06/2015

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International application No
PCT/JP2015/052599

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	page 1, line 7 - page 1, line 10 page 8, line 4 - page 8, line 19 page 9, line 2 - page 9, line 5 page 9, line 18 - page 9, line 24 page 10, line 33 - page 12, line 5 figures 3-9 -----	2,4
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