

TITLE OF THE INVENTION

CONTROL DEVICE FOR CONTROLLING AC MOTOR SUCH AS
THAT IN ELEVATOR WITH HIGH DRIVING EFFICIENCY

5 BACKGROUND OF THE INVENTION

Present invention relates to an improvement of a control device of an AC motor, especially to a control device which is suitable to drive an elevator.

In order to improve efficiency in a drive system
10 for an elevator, Japanese Patent Laid-open No. 59-149283 (1984) discloses that a slip angular frequency is fixed in a predetermined value, when a deviation between a speed reference and a real speed of an elevator is kept within a predetermined range.

15 Further, relating to a synchronous motor in which a torque is controlled highly precisely, Japanese Patent Laid-open No. 2-84093 (1990) discloses a torque control system which estimates a torque of the motor estimated from a detected motor current and makes correspond with
20 a torque reference.

Generally, in an elevator, as number of passenger in a car changes continuously, load to be added to a drive motor always changes. As a result, the torque which should be generated to the motor changes according to the
25 load, too, and at the same time, the torque is needed to be generated so that the motor speed follows the

speed reference. In the first prior art stated above, the efficiency isn't able to be maintained highly depended on any load to be added to the motor.

On the other hand, in the second prior art stated
5 above, high improvement of the efficiency is not cared so much.

SUMMARY OF THE INVENTION

An object of the present invention is in providing
10 a control device of the AC motor and a control device of the elevator maintaining a high efficiency thereof in spite of any change of the load added to the motor, that is to say, in an over load of the motor too.

The present invention is characterized by
15 providing a means for controlling an electric power converter based on a torque reference so that a torque current component and an exciting current component of an AC motor electric current are kept in a predetermined relation.

20 In a desirable embodiment, an operational amount of the torque reference is divided into the torque current reference and the exciting current reference so as to make the driving efficiency of the motor for driving an elevator car, maximum, and each electric
25 current corresponding to these two references controls the induction motor so as to be flown to the motor even

in the over load.

Furthermore, in the elevator comprising a converter for converting three phase alternating source voltage into a direct current voltage, a PWM inverter for
5 converting an output voltage of this converter into a variable frequency variable voltage, a smoothing capacitor connected to a direct-current circuit (smoothing circuit) between the converter and the inverter, an induction motor supplied the alternating
10 voltage from the PWM inverter, a car driven to go up and down by the induction motor, a means for generating a speed reference for the elevator, and a speed control means for generating a torque reference so that an angle of rotation speed of the induction motor follows the
15 speed reference, the present invention is characterized by further comprising a means for detecting an electric current of the induction motor and a means for controlling said electric power converter based on a torque reference so that a torque current component and
20 an exciting current component of an AC motor electric current are kept in a predetermined relation.

A ratio of the exciting current to torque current ratio which keeps a driving efficiency of the motor the maximum is decided as an operational amount of torque
25 reference according to a torque needed at present then an torque current reference and an exciting current

reference are obtained.

In this case, the ratio of the exciting current reference to the torque current reference is decided to become a minimum energy (the input electric power of the motor) needed to obtain a desired torque in a secondary magnetic flux generated at present. A combination of the exciting current component and the torque current component decided in this way is obtained corresponding to the speed reference and the torque reference which continuously change.

Accordingly number of the passengers getting in a car, that is, even if how much or less a load torque which is added to the motor changes, the torque which is necessary to obtain a speed corresponding to the speed reference, desirably, a combination of the exciting current component and the torque current component that may give at the minimum energy is decided in a case including over load, and primary currents corresponding to the two electric currents flow in the primary winding of the motor.

As stated above in the present invention, an operational amount of the torque reference is decided as a ratio of exciting current to torque current according to the motor torque needed at present, thereby a torque current reference and an exciting current reference are obtained. In this case, the ratio of the exciting current

reference to the torque current reference is decided so as to be the minimum energy (the input electric power of the motor) necessary for a desired torque in a secondary magnetic flux generated currently. A combination of the
5 exciting current component and the torque electric current component decided in this way will be obtained corresponding to the speed reference and the torque reference which change continuously.

Accordingly, even if how the number of passenger
10 in the car, that is, the load torque added to the motor changes, the motor torque necessary to obtain the speed corresponding to the speed reference is determined as a combination of the exciting current component and the torque electric current component desirably with a
15 minimum energy, and electric currents corresponding to the two electric current components are flown in the primary winding of the motor.

Furthermore, torque vibration components which is contained in the load torque added to the motor is
20 estimated from a deviation between the load torque estimating value obtained from the motor speed detected value and the load torque, and the motor generating torque estimating value.

In the present invention, the estimate value of
25 the torque vibration component turns over a phase thereof so as to cancel vibration and is added to the torque

reference value so as to compensate the up and down vibration to be decreased, desirably to be the minimum, thereby the comfortableness to ride in is highly improved.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a block diagram of an embodiment of the present invention.

Fig. 2 shows a relation of the exciting current (or magnetic flux) to the torque current which gives the maximum efficiency even any state.

Fig. 3 shows a relation of the exciting current (or magnetic flux) to the torque current which gives the maximum efficiency when the speed of the motor is changeable.

Fig. 4 shows a block diagram for obtaining a ratio of the exciting current to the torque current which gives the maximum efficiency when the various parameters of the motor are changed.

Fig. 5 is a block diagram for obtaining a vibration suppressing signal in the present invention.

Fig. 6 shows an explanatory view for explaining a state of the up and down vibration of the elevator car before and after the vibration suppressing signal is added when regular load torque vibration occurs in a certain condition.

Fig. 7 shows an another embodiment in which a

pattern for providing the maximum efficiency is obtained from the secondary magnetic flux reference and the torque current reference by the constitution shown in Fig. 1, furthermore a torque control is performed.

5 Fig. 8 shows an another embodiment of the present invention in which a direct d-q axis voltage control system is constituted so as to perform the torque control in stead of obtaining the modulated wave of the PWM control from the electric current control system of Fig.
10 1.

 Fig. 9 is a block diagram for showing an another embodiment of then present invention in which the elevator may be driven with the maximum efficiency in spite of the changing of the incoming power source
15 voltage.

 In drive system of the elevator having a battery for service interruption of the power supply, Fig. 10 shows a block diagram for showing an another embodiment of the present invention in which the torque control is
20 performed with the maximum efficiency in spite of the variations in power source voltage supplied in the drive system of the elevator.

 Fig. 11 is a block diagram for showing an other embodiment of the present invention having an other
25 vibration suppressing means.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 shows an embodiment of the present invention.

An alternating power source voltage 10 is
5 converted into a direct current voltage by a converter 20,
this direct current voltage is smoothed by a smoothing
capacitor 30, and the smoothed direct current voltage is
converted into an alternating voltage with a variable
voltage variable frequency by a PWM inverter 40
10 furthermore. The alternating voltage is supplied to an
induction motor (IM) 60, and drives the motor 60 in a
variable speed. The torque generated in the motor 60 is
transmitted to a sheave 70 through a gear (not shown in
the figure) connected directly to the rotor of the motor,
15 and actuates a rope connecting counter weight 80 to the
car 90 by turning of the sheave so as to drive the car 90
up and down.

Accordingly, a weight difference between the
counter weight and the car, is added to the motor as a
20 load torque (weight). The load torque changes
continuously according to number of the passenger which
is changeable in the elevator and becomes less than half
of the motor output power in the majority of the driving.
Furthermore, when the elevator stops, the supply of the
25 electric power is usually stopped. On this account in

order to plan for saving the electric power in the elevator drive system, it is desirable that the drive efficiency of the motor is high by driving the elevator in a state that the load is light on driving (over load).

5 Comfortableness to ride in the elevator, is an important factor, and an acceleration pattern (reference) is decided by considering this factor. This pattern is generated by an acceleration pattern generating means 110. An acceleration pattern generated from the acceleration
10 pattern generating means 110 is input into a speed reference generating means 120. In this means 120, the acceleration pattern is integrated to be converted into the speed reference.

 A speed reference ωR is added to an addition
15 terminal of an addition and subtraction device 130, a rotational angular speed ωM of a rotor of the induction motor operated by a speed operation means 121 based on rotation pulses generated from a speed detection device
100 mounted on the rotor of the induction motor, is
20 introduced into a subtraction terminal of the addition and subtraction device 130, and a difference between said speed reference ωR and said rotational angular speed ωM is generated as a speed deviation.

 Said speed deviation is input into a speed control
25 means 140. A torque reference τR for deciding the torque generated in the induction motor 60 is made by the speed

control means 140, so that the speed deviation becomes zero.

The torque reference τ_R is input into a plus terminal of an addition and subtraction device 131, on the other hand, an instantaneous torque τ_M occurring at present inside of the motor obtained from a generated torque estimating means 152 by using an equation (1) is input on a minus terminal of an addition and subtraction device 131.

$$10 \quad \tau_M = m \cdot p \cdot \{M / (M + l_2)\} \cdot \phi_2 \cdot I_t \quad \dots (1)$$

Here, m: number of phases,

p : number of pole pairs of the induction motor,

M : exciting inductance,

l_2 : leak inductance,

15 I_t : detected torque current,

ϕ_2 : secondary magnetic flux,

The second magnetic flux ϕ_2 is an instantaneous magnetic flux which contributes to generate the torque generated in the induction motor at a time when it is estimated by operating using a secondary magnetic flux operating means 151 on the basis of equation (2).

$$20 \quad \phi_2 = \{M \cdot I_m\} / (1 + T_2 \cdot s) \quad \dots (2)$$

Here, T_2 : a secondary time constant

s : Laplace operator

25 The code I_m in the equation (2) means an exciting current component and is an exciting current which is

necessary to generate the secondary magnetic flux ϕ , detected from a detecting means 150 for detecting a ratio of an exciting current component to a torque current component. Here, The exciting current component I_m and the torque current component I_t are respectively obtained by performing an operation of an equation (3) with the means 150 on the basis of the three phase primary currents i_u , i_v , i_w in respective three phases detected by current sensors 50, 51, 52.

$$\begin{aligned}
 I_m &= (\sqrt{2}/\sqrt{3}) \cdot \{i_u \cdot \cos \theta_1^* + i_v \cdot \cos(\theta_1^* - 2\pi/3) + i_w \cdot \cos(\theta_1^* + 2\pi/3)\} \\
 I_t &= -(\sqrt{2}/\sqrt{3}) \cdot \{i_u \cdot \sin \theta_1^* + i_v \cdot \sin(\theta_1^* - 2\pi/3) + i_w \cdot \sin(\theta_1^* + 2\pi/3)\} \quad \dots (3)
 \end{aligned}$$

Where, codes $\theta_1^* = \int \omega_1 dt$ and ω_1 are angular frequencies of the inverter as shown in an equation (4) and is obtained by summing the rotation angular speed ω_M and a slip angular frequency ω_s mentioned later.

$$\omega_1 = \omega_M + \omega_s \quad \dots (4)$$

The difference (the torque deviation) between the torque reference τ_R obtained through the speed control means 140 and the generated torque τ_m provided with the generated torque estimating means 152 is input into the torque control means 160. Said torque control means 160 decides an operational value (a compensation) τ^* of the torque reference τ_R for controlling the torque deviation to be zero. Said torque control means 160 consists of PI

(proportion + integral calculus) element usually.

Said operational value τ^* is input into the torque current reference operating means 170. In said torque current reference operating means 170, the torque current reference I_t^* is obtained by a calculation of a equation (5).

$$I_t^* = \{\tau^* / \phi_2\} \cdot \{(M + l_2) / M\} \cdot \{1 / (m \cdot p)\} \quad \dots (5)$$

The exciting current reference I_mR corresponding to said torque current reference I_t^* is derived from an exciting current and a torque current ratio decision means 180 based on a technique described as follows.

The relation of the ratio is decided so as to make a loss L in the induction motor minimum.

$$L = A \cdot I_m^2 + B \cdot I_t^2 \quad \dots (6)$$

Here, $A = (R_s + R_m)$, $B = R_s + R_r \cdot (M / L_r) \cdot (M / L_r)$

$$\doteq R_s + R_r \quad \dots (7)$$

$$L_r = M + l_2 ,$$

R_s : primary resistance,

R_m : core loss resistance, and

R_r : secondary resistance

A value of M / L_r is close to 1 usually, that is, a secondary leak inductance l_2 is very small compared with an exciting inductance M , and B is obtained through calculation of the second terms of the equation (7).

Here, when a combination of the exciting current

I_m and the torque current I_t which are necessary in order to generate a predetermined torque τ is defined as (I_t , I_m), the torque τ is in proportion to a product of I_t and I_m . Accordingly, a combination satisfying the
 5 equation (8) mentioned above exists innumerably.

$$\tau = k \cdot I_t \cdot I_m (k: \text{torque proportional constant})$$

... (8)

Here, the ratio $\alpha_{\min}$ ($=I_m/I_t$) of the exciting current I_m and the torque electric current is given by an
 10 equation (9) in the case that a loss L in the motor given with a equation (6) becomes minimum in order to occur a certain torque τ .

$$(\alpha_{\min})^2 = \{R_s + R_r \cdot (M / L_r)^2\} / (R_s + R_m)$$

... (9)

15 Accordingly, the ratio $\alpha_{\min}$ of the exciting current I_m and the torque current I_t for making the loss minimum is given by a function of the primary resistance R_s , secondary resistance R_r , exciting inductance M , and core loss resistance R_m . Here, as the primary resistance
 20 R_s and the second resistance R_r are changed by a temperature in the motor, the exciting inductance M is changed by the exciting current I_m , and the core loss resistance R_m is changed by a speed of the motor (inverter angular frequency), therefore, said ratio $\alpha_{\min}$
 25 should be varied according to the speed change of the motor as shown in Fig. 3.

In an embodiment shown in Fig. 1, an example in which the ratio $\alpha_{\min}$ mentioned above is amended according to the speed of the motor 60 is shown. In figure 2, an exciting current-torque current line provided by a combination of the exciting current and the torque current for giving the maximum efficiency in a case that the generated torque is changed is shown, a parameter given with the equation (9) is already provided and it show a case as that any change does not arise. Figure 4 shows the exciting current-torque current line in the case that the speed is changed and a characteristic which gives the maximum efficiency changes with the speed. In order to compensate this change, a correction coefficient $K(\omega_M)$ is to be obtained according to the speed based on a rating speed ω_{M10} .

$$\alpha_{\min} = K(\omega_M) \cdot (\omega_M / \omega_{M10}) \quad \dots (10)$$

Here, a function table of the correction coefficient $K(\omega_M)$ according to variables of the speed ω_M is prepared beforehand. This compensator is prepared to compensate variation of $\alpha_{\min}$ due to the dependence of core loss resistance R_m on the speed mainly. In a fact, as it is changed by the temperature of the motor in the equation (9) (the temperature of the primary and secondary sides), the motor speed and the exciting current, it is needed to be obtained by a method shown by Fig. 4.

Figure 4 shows a block diagram for showing a method in which the ratio α min which gives the maximum efficiency is operated based on input signals (information) such as the temperature of the motor, the
 5 exciting current, the speed of the motor in the case an each parameter in the equation (9) is changed.

In block 181, the primary resistance R_s and secondary resistance R_r are obtained as a function of the motor temperature (because the temperature detection in
 10 the secondary side is difficult usually, the temperature converted into the primary side is used) beforehand, a table for it is prepared. When the motor temperature (frame temperature) (omitted in the embodiment shown in Fig. 1) is detected, R_s , R_r corresponding to the
 15 temperature is obtained from the table.

In a block 182, the function table of the exciting inductance M corresponding to the exciting current is prepared, and when the detected exciting current is input, the exciting inductance M corresponding to the exciting
 20 current are provided. In this way, the reason why the compensation of the exciting inductance is needed is that although the exciting inductance M is almost constant in the range where the exciting current is small, the magnetic flux is saturated and the exciting inductance M
 25 is decrease suddenly in the domain where the exciting current becomes large. Further, a motor is recently

improved to be small and light, a core of the motor generating the magnetic flux becomes small with miniaturization of the motor progressively, the magnetic circuit apt to be saturated in a domain where the
5 exciting current becomes large, thereby the exciting inductance decreases.

In a block 183, the second term of a numerator of the equation (9) is obtained from the exciting inductance M compensated as above, and the secondary resistance R_r ,
10 the α min giving the maximum efficiency is operated by using the primary resistance R_s obtained from this and the block 181 and the core loss R_m which is determined based on the motor speed detected from the block 184, and said α min is multiplied with the torque current
15 reference I_t^* , thereby the exciting current reference I_{mR} is decided.

The electric current control is performed so that the torque current I_t and the exciting current reference I_m corresponding to a combination of the torque current
20 reference I_t^* and the exciting current reference I_{mR} obtained as above may flow inside of the induction motor 60.

First of all, the exciting current control means
190 operates so that the exciting current I_m corresponding to the exciting current reference I_{mR} flows.
25 Here, a deviation between the exciting current reference

ImR and the exciting minute electric current Im detected from the exciting current to torque current ratio detecting means 150 is provided from the addition and subtraction device 132, and in the above exciting current control means 190, an operational value Im* of a new exciting current occurs so that the deviation becomes zero. Said exciting current control means 190 is set so as to be operated earlier than the torque control means 160. The responsibility of the exciting current is improved, thereby the secondary magnetic flux is obtained corresponding to the demand torque early and the torque is stabilized.

An equation (11) is obtained based on the torque current reference It* provided by a process mentioned above and the operational value Im* of the exciting current reference, and an electric current reference operation means 200 generates three phase AC primary current references iu* , iv* , iw* based on the equation (11).

$$\begin{aligned}
 iu^* &= I_1 \cdot \cos(\theta_1 + \delta) \\
 iv^* &= I_1 \cdot \cos(\theta_1 + \delta - 2\pi/3) \\
 iw^* &= I_1 \cdot \cos(\theta_1 + \delta + 2\pi/3) \quad \dots(11)
 \end{aligned}$$

Here, $\theta_1 = \int \omega_1 dt$

$$\omega_1 = \omega_M + \omega_s$$

$$\omega_s = (M \cdot Im^*) / (T_2 \cdot \phi_2) ,$$

$$T_2 = (M + I_2) / r_2$$

$$\delta = \arctan(I_t^*/I_m^*)$$

$$(I_l)^2 = (I_t^*)^2 + (I_m^*)^2$$

Three phase modulating waves V_u^* , V_v^* , V_w^* (omitted in Fig. 1) are generated from the current
 5 control means 220, so that the AC current references i_u^* ,
 i_v^* , i_w^* may correspond to the three phase AC current
 i_u , i_v , i_w detected from the current sensors 50,51,52.

Said modulated wave is input into a PWM signal
 generating means 230, and is compared with a carrier wave
 10 (a triangular wave, not shown) to generate PWM signal,
 and said PWM signal is applied to a gate of electric
 power element constituting said PWM inverter 40.

As a result, an a terminal of said PWM inverter 40,
 the terminal voltage generating a torque corresponding to
 15 the torque reference occurs, and in the motor inside, a
 combination of the torque current and the exciting
 current which gives maximum efficiency flows. As such
 relation as above is to be maintained regardless of a
 state of the load, a motor is always driven in the
 20 maximum efficiency including a transient state and saving
 energy may be obtained. Therefore, the saving energy
 effect is especially big for an elevator drive system as
 that the number of the passenger in the elevator car
 always changes and the load torque added to the driving
 25 motor changes. Particularly, because an average
 (statistical) load to be added to a motor while the

elevator is driving is usually lied in a light load state less than half of the rating torque of the motor, the saving energy effect is driving is big.

Generally, an acceleration pattern (reference) of
5 the elevator is usually decided so as to be the most comfortable to ride in and is integrated to generate speed reference. In this embodiment, the instantaneous torque of the motor is generated for the speed of the motor to follow the speed reference regardless of the
10 load state and the level of being comfortable to ride in is improved further.

In addition to above in this embodiment, torque control means 160 for feeding back an output of the generated torque estimating means 152 is provided, and the
15 torque control means isn't always necessary, the output of the speed control means 140 may be directly input into the torque current reference operation means 170.

A machanical proper vibration frequency of the elevator is generally in the domain that is easy to
20 resonate with a drive frequency of the motor, and is arisen by a torque ripple of the motor so as to deteriorate the comfortableness to ride in the elevator. There happens a mode superposing the vibration on the motor speed. On this account, if the load torque
25 vibration is estimated by using the detected speed of the motor, and a phase of said estimated value is turned over

and is added to the torque reference, the vibration may be restrained and a good comfortableness to ride in may be secured.

An example of a block diagram of a vibration suppressing means 500 for forming vibration suppressing signal is shown in Fig. 5. A method for forming said vibration suppressing signal is as follows.

First of all, relating to a generating torque τ_M of the motor, a disturbance torque τ_d appearing on an axis of the motor, and the load torque τ added to a motor, a following relation depends.

$$\tau_M + \tau_d = \tau \quad \dots(12)$$

Further, when all the inertia moments of a machine system around the axis of the motor is defined as J , a following relation depends.

$$\tau / (J \cdot s) = \omega_M \quad \dots(13)$$

Usually, because J is already obtained at a machine system design stage, an estimate value $\hat{\tau}$ of τ is may be obtained by the load torque estimating means 300.

$$\hat{\tau} = J \cdot \omega_M \cdot s \quad \dots(14)$$

On the other hand, τ_M is obtained as an estimated value $\hat{\tau}_M$ of a generated torque by generated torque estimating means 152.

Accordingly, τ_d is obtained as an estimated value τ_d from the equation (12) and the equation (14) based

on an equation (15).

$$\begin{aligned}\hat{\tau}_d &= \hat{\tau} - \hat{\tau}_M \\ &= J \cdot \omega_M \cdot s - \hat{\tau}_M\end{aligned}\quad \dots(15)$$

Said (τ_d) obtained in this way is removed noise
5 components thereof by a low pass filter in a signal
adjustment means 301, and is adjusted up and down
vibrations of the car so as to be decreased, and
vibration suppressing signal τ_{sup} is output.

Then, the torque reference to restrain the
10 vibration is formed by adding the τ_{sup} in the torque
reference.

As stated above in the present invention, a
vibration suppressing means shown in Fig. 1 with a dotted
line having the load torque estimating means 300 and the
15 signal adjustment means 301 is provided, thereby the
vibration of the elevator is effectively restrained.

In Fig. 6, when a load torque vibration regularly
occurs, a state of the up and down vibration of the car
is shown before and after adding the vibration
20 suppressing signal.

By the way, an acceleration pattern (reference) of
the elevator is generally decided to obtain the best
comfortableness to ride in, and the speed reference is
generated by integrating this pattern. In this embodiment,
25 as an instantaneous torque of the motor is generated so
that the speed of the motor follows the speed reference

regardless of the load state. In either of speed up and down and constant speed, the comfortableness to ride in is improved further, and The effect that the vibration by an impact disturbance of shocks caused by disorder of an activation compensation in a starting of the motor may
5 be restrained quickly, is obtained too.

In addition to the above, in this embodiment, a torque control means 160 to feed back the output of the generated torque estimating means 152, however, the
10 torque control means isn't always necessary, and the output of the speed control means 140 may be directly input into the torque current reference operation means 170. Furthermore, a low pass filter is provided for a signal adjustment means 301, however, there may be
15 unnecessary if ωM in speed operation a means and noise component are removed from τ in the generated torque estimating means 152, and a band-pass filter may be provided when a routine error does not arise in the vibration suppressing signal .

20 Furthermore, when a phase difference arises between the estimated load torque and the estimated generated torque, said phase difference may be cancelled by providing a phase adjustment device to the output side of the load torque estimating means 300.

25 In the next, other embodiment is shown in Fig. 7. Only a part differing from the embodiment shown in Fig. 1

will be explained.

First of all, in Fig. 1, the exciting current reference I_{mR} is obtained corresponding to the torque current reference I_t^* provided from the torque current reference operation means 170. However, in this embodiment, the second magnetic flux reference $\phi 2^*$ is once obtained from the exciting current reference I_m^* by a following equation and said secondary magnetic flux reference $\phi 2^*$ follows the second magnetic flux $\phi 2$ generated inside of the motor 60.

$$\phi 2^* = (I_{mR} \cdot M) / (1 + T_2 \cdot s) \quad \dots(16)$$

A combination of the torque current reference I_t^* and the exciting current reference I_{mR} is utilized in the same way as in Fig. 1. Said secondary magnetic flux reference $\phi 2^*$ and the second magnetic flux $\phi 2$ operated by the second magnetic flux operation means 151 based on the equation (2) are introduced into the addition and subtraction device 132 and the magnetic flux deviation $\Delta \phi 2$ is generated. The secondary magnetic flux control means 186 decides the operational value I_m^* of the exciting current so that said magnetic flux deviation $\Delta \phi 2$ converges into zero. Thereafter, the three phase primary current references i_u^* , i_v^* , i_w^* are generated from the current reference generating means 200 using the operational value I_m^* of the exciting current and the torque current reference I_t^* , and the modulated wave

generating means 220 generates a modulated wave so that the primary current to be flown in the primary winding of the motor follows said electric current reference and the PWM signal is generated based on said modulated wave.

5 These operation is already explained in the embodiment shown in Fig. 1 and the detail explanations are omitted.

In this embodiment, a method to control the torque current and the second magnetic flux with the maximum efficiency is a basis of the torque control, and as a
10 result, the efficiency may be maintained at maximum, at the same time, the torque control precision is improved furthermore.

Furthermore, the vibration suppressing means 500 is provided in the same way as Fig. 1, the
15 comfortableness to ride in is improved too with the high driving efficiency of the elevator.

In Fig. 6, without providing an current control means 210 for the alternating current to flow into the primary coil of the motor 70 with a combination of the
20 torque current reference and the exciting current reference which gives the maximum efficiency provided in the embodiments stated above, it is constituted to directly generate the modulated wave. Only a constitutional difference of this embodiment from that of
25 the embodiment mentioned above will be explained.

Process in which the torque current reference I_{tR}

(described as I_t^* in the above embodiment) is provided by the torque current reference operation means 170 may be explained in the same way in this embodiment and is omitted.

5 The torque current deviation between the torque current reference I_{tR} and the torque current I_t detected from the exciting current to torque current ratio detecting means 150 is generated from the addition and subtraction device 133, thereby q axis voltage V_q' is
10 obtain by a q axis voltage decision means 171 on the basis of said torque current deviation, and the exciting current deviation between the exciting current reference I_{mR} (here, I_{mR} is obtained by the above-mentioned method from the exciting current to torque current ratio
15 decision means 180 on the basis of I_{tR}) and the exciting current I_m which is provided from the exciting current to torque current detecting means 150 is generated from the addition and subtraction device 132, and a d axis voltage V_d' is obtained by a d axis voltage decision means 172 ,
20 and such are differences in these point. If the voltages V_q' and V_d' are used as they are, interference happens mutually between a d axis and a q axes.

 Therefore, the mutual interference occurring between the d axis and the q axis is restrained by
25 correcting the voltage V_q' and V_d' based on equation (17) with a non-interference means 201.

$$\begin{aligned}
 V_d^* &= r_1 \cdot I_m^* - \omega_1 \cdot \sigma \cdot L_s \cdot I_t^* + V_d' \\
 V_q^* &= r_1 \cdot I_t^* + \omega_1 \{ \sigma \cdot L_s \cdot I_m^* + (M/L_r) \cdot \phi_2 \} + V_q' \\
 \sigma &= 1 - (M/L_s) \cdot (M/L_r), \quad L_s = M + L_1, \quad r = M + L_2, \\
 &\dots(17)
 \end{aligned}$$

5 Two phase voltages of the d axis voltage V_d^* and
 the q axis voltage V_q^* is converted into three phase
 voltage references V_u^* , V_v^* , V_w^* with two phase to three
 phase conversion means 202 (corresponding to a reverse
 conversion of three phase to two phase conversion by the
 10 exciting current to torque current detecting means 150),
 the PWM signals are generated from the PWM signal
 generating means 230 by using the three phase voltage
 reference as the modulated wave, and the induction motor
 60 is driven by controlling the PWM inverter 40 with said
 15 PWM signals.

In the embodiment mentioned above, the AC current
 control system with high speed calculation process is
 needed in comparison with the AC current control system,
 and in only the voltage control system processed with a
 20 DC value on the other hand, there is no need to be
 processed in high speed in comparison with AC current
 control system and the response gain becomes high,
 therefore, it may be driven in stable until a high-speed
 regions and with a high efficiency in a wide load level.

25 Furthermore, the vibration suppressing means 500
 is provided in the same way as Fig. 1, the

comfortableness to ride in is improved too with the high driving efficiency of the elevator.

When an acceleration pattern decision means is added and the voltage of the power supply 10 changes, the embodiment shown in Fig. 9 is able to be driven in stable and with a high efficiency. Only a different point from the above embodiment will be explained. Providing a voltage detecting device 31 to detect the voltage from the smoothing capacitor 30 added to the output side of the converter 20, a state of the power supply 10 is detected. The output voltage of said smoothing capacitor is detected by the voltage detecting device 31, and it is introduced into a voltage level decision means 32. When the said voltage is within a predetermined constant level, any signal isn't sent from said voltage level judgment means 32 into a dynamic braking unit consisting of the transistor 33, the resistor 43 and an acceleration pattern decision means 111, the state thereof is just maintained. That is to say, the transistor 33 doesn't operate, and as any signal is generated from the acceleration pattern decision means 111, the acceleration pattern decided at first is generated from the acceleration pattern generating means 111.

When the voltage detected from the voltage detecting device 31 decreases than a predetermined value, a degree of inclination of the acceleration pattern

generated from the acceleration pattern generating means 111 is corrected to decrease. This means that the torque current increase as an extent that the power supply voltage decreases than the predetermined value, and the control system operates so as to secure a necessary torque. As a result, an excessive torque current flows when accelerated, and a copper loss increases, and efficiency is deteriorated.

A judgment for decreasing a degree of inclination of said acceleration pattern is operated as follows. At first, it is judged when the capacitor voltage 30 does decrease than being fixed and the torque current reference becomes maximum. Here, when it is judged only by the above judgment standard, even if the capacitor voltage 30 decreases, the load may be light, and the torque reference does not always becomes the maximum, the high efficiency control is not obtained until the torque current reference becomes the maximum. Naturally, when the capacitor voltage 30 is within the predetermined value, the torque current reference needn't to be corrected in the case the acceleration pattern is the greatest. This is because it is designed to be operated in the maximum load in a system design. Keeping the driving efficiency high even if the power supply in the system deteriorates, the elevator is driven in stable.

The embodiment in Fig. 10 shows an example

installing a battery for interruption of the power supply,
and a method for solving the case when the power supply
voltage falls and the capacitor voltage 30 decreases to a
predetermined value. Only a different point from the
5 above embodiment will be explained.

When the output voltage of the capacitor 30 falls,
a signal is generated from the voltage level judgment a
means 32, a battery 231 is connected between terminals
of said capacitor 30 through a switch element 232, and
10 supplies a power to the PWM inverter 40 as a direct
current power supply. In this case, the degree of
inclination α in the acceleration pattern, the maximum
value β , the degree of inclination δ of the
acceleration pattern in a descent, the maximum value ϵ
15 are revised by the acceleration pattern correction means
112.

That is to say, in the acceleration, α mentioned
above and the maximum value β is corrected in an adapted
value in the output power (capacity) of the battery 231.
20 As the battery 231 is used as a power supply for an
emergency, the battery 231 having a low voltage compared
with a voltage output from the power source 10 (the
voltage of capacitor 30) is usually installed. In this
case, the value α mentioned above and the maximum value
25 β is decreased according to the decreasing of the
voltage of the battery installed for the voltage output

from the power source 10 when setting these values. So that the maximum speed of the elevator is suppressed low by decreasing it in this way, power input into the induction motor 60 decreases. By this operation, the
5 elevator work may be driven with a little power to balance with the volume of the battery 231. That is to say, ability of the battery 231 is utilized in the maximum and operates with a high efficiency, without shutting the passenger in a elevator car, even if the in
10 the interruption of the power supply is occurred, other effect as that reliability of an elevator improves, is obtained too.

Further, there is an effect too that the life of battery itself improves too, as the over-discharge of the
15 battery is prevented.

When the elevator moves down against the weight of the counter weight 80, power to accelerate is necessary. In this case, a similar effect is provided in the same way as above by decreasing the degree of inclination δ
20 of the acceleration pattern and the best value ε .

In an embodiment shown in Fig. 11, instead of the vibration suppressing means 500, an other vibration suppressing means 501 is provided.

The difference of this embodiment from that shown
25 in Fig. 1 are in some constructions to adjust the load torque estimating means 300 according to ΔJ mentioned

above by arranging a load torque detection device 400 to detect a load torque on the car and a load change component operation means 401 to obtain a load torque change component ΔJ in an inertia moment J from the output of the load torque detection device 400, to obtain the moment J from the torque reference τ^* and a rotation angular speed ωM of the motor by an initial inertia value operation means 402, to maintain said J , and to renew the J used in said load torque estimating means 300 by arranging a data storage means 403.

As for the elevator, the moment J always changes by number of the passenger in the car, the load change minute ΔJ is obtained by the load torque change component operation means 401, the load torque may be estimated more precisely by increasing or decreasing the moment J which is used for estimating the load torque according to ΔJ whenever the passenger number changes.

The initial inertia value operation a means 402 may operate J based on a following equation, for example, by obtaining the rotation angular speed $\omega M1$ of the motor when a constant torque reference value $\tau 1^*$ is given during a predetermined period $t1$.

$$\omega M1 = \tau 1^* \cdot t1 / J \quad \dots(18)$$

As stated above, the moment J is operated just after the elevator is installed and regularly after driving the elevator, and a gap of the moment J from a

design value caused by an aged deterioration is automatically compensated by renewing the moment J used in the load torque estimating means 300.

Thereby, as the load torque is estimated always
5 accurately, not only the activation compensation disorder by the aged deterioration and car vibration are suppressed to increase, but activation compensation adjustment just after installing the elevator and adjustment items in maintenance inspection may be
10 decreased. In this embodiment, the moment J is adjusted by two means of the load torque change component operation means 401 and the initial inertia value operation means 402, however, even either one of them may accurately estimate the load torque and a sufficient
15 vibration suppressing effect may be expected at least.



WHAT IS CLAIMED IS;

1. A motor control device having an electric power converter for outputting variable voltage variable frequency alternating current, an AC motor driven with a variable speed by being supplied said variable voltage variable frequency alternating current from the converter, a means for generating a speed reference for said AC motor, and a speed control means for generating a torque reference so that said rotational speed of said AC motor follows said speed reference, comprising

a motor current detecting means, and

a means for controlling said electric power converter based on said torque reference so that a torque current component and exciting current component of said motor current keep a predetermined relation.

2. A motor control device having an electric power converter for outputting variable voltage variable frequency alternating current, an AC motor driven with a variable speed by being supplied from the converter, a means for generating a speed reference for said AC motor, and a speed control means for generating a torque reference for said rotational speed of said AC motor so as to follow said speed reference, comprising

a motor current detecting means,

a torque estimating means for estimating a torque or a value corresponding thereto from detected value from



said motor current detecting means, a torque control means constituted so that an estimated value of the estimating means corresponds to said torque reference, and

5 a means for controlling said electric power converter based on an output from said torque control means so that a torque current component and exciting current component of said motor current keep a predetermined relation.

10 3. A motor control device as defined in at least one of claims 1 and 2, said motor control device characterized in that,

 said predetermined relation is a ratio of said exciting current component to said torque current component determined according to said torque reference.

15 4. A motor control device as defined in claim 3, said motor control device characterized in that,

 said ratio of said exciting current component to said torque current component determined according to said torque reference relates to said speed of said motor or a frequency of said inverter.

20 5. A motor control device as defined in claim 3, said motor control device characterized in that,

 said ratio of said exciting current component to said torque current component determined according to said torque reference relates to a temperature of said



motor.

6. A motor control device as defined in at least one of claims 1 and 2, said motor control device characterized in that,

5 said predetermined relation is a relation of said torque current component and said exciting current component which is necessary for generating said torque in the motor according to said torque reference and is in a range where an input electric power value of the motor
10 becomes small.

7. A motor control device as defined in at least one of claims 1 and 2, said motor control device characterized by further comprising

an exciting current control means operates so that
15 second magnetic flux corresponding to second magnetic flux reference decided based on a ratio of said second magnetic flux of said motor to said torque current obtained from torque reference follows said exciting current reference generated in the motor

20 8. A motor control device as defined in claim 1, said motor control device characterized by further comprising

a load torque estimating means for estimating a load torque of said motor from an rotational speed of the
25 motor, and

a means for adjusting said torque reference based



on a deviation between between an output from the load torque estimating means and an instantaneous torque generated in the motor.

9. A motor control device as defined in claim 8,
5 said motor control device characterized in that

said load torque estimating means is adjusted according to a load change of the motor.

10. A motor control device as defined in claim 2,
said motor control device characterized by further
10 comprising

a load torque estimating means for estimating a load torque of said motor from a speed of the motor, and

a means for adjusting said torque reference based on a deviation between an output from the load torque
15 estimating means and an estimated torque from said torque estimating means.

11. A motor control device as defined in claim 8,
said motor control device characterized in that

said load torque estimating means is adjusted
20 according to a load torque change applied to the motor.

12. A motor control device having an electric power converter for outputting variable voltage variable frequency alternating current, an AC motor driven with a variable speed from said converter, a means for
25 generating a speed reference for said AC motor, and a speed control means for generating a torque reference so



that said rotational speed of said AC motor follows said speed reference, comprising

a motor current detecting means,

a means for detecting said exciting current
5 component and torque current component from a detected current value of the motor,

a means for estimating a secondary magnetic flux generated by an induction motor based on said detected exciting current component,

10 a means for obtaining an instantaneous torque generated in the said induction motor from said estimated secondary magnetic flux and said torque current, and

a means for controlling said electric power converter so that said instantaneous torque corresponds
15 to said torque reference.

13. A converter for converting an AC to a DC, a PWM inverter for inverting the output voltage of said converter into variable frequency variable voltage, a capacitor connected to a direct-current circuit between
20 said converter and said inverter, an induction motor supplied from the PWM inverter, an elevator car which goes up and down by the induction motor, a means for generating a speed reference of the elevator, and a speed control means for generating a torque reference so that a
25 rotation speed angle of the induction motor follows the speed reference, comprising,



a means for detecting an electric current of said induction motor, and

a means for controlling said electric power converter based on said torque reference so that a torque
5 current component and exciting current component of said motor current keep a predetermined relation.

14. a converter for converting an AC to a DC, a PWM inverter for inverting the output voltage of said converter into variable frequency variable voltage, a
10 capacitor connected to a direct-current circuit between said converter and said inverter, an induction motor supplied from the PWM inverter, an elevator car which goes up and down by the induction motor, a means for generating a speed reference of the elevator, and a speed
15 control means for generating a torque reference so that a rotation speed angle of the induction motor follows the speed reference, comprising,

a means for detecting said electric current of said induction motor,

20 a means for estimating a torque or a considerable value corresponding thereto of the motor from a detected value of said electric current,

a torque control means for making said estimated torque correspond with said torque reference, and

25 a means for controlling said electric power converter based on the output of said torque control



means.

15. a converter for converting an AC to a DC, a PWM inverter for inverting the output voltage of said converter into variable frequency variable voltage, a
5 capacitor connected to a direct-current circuit between said converter and said inverter, an induction motor supplied from the PWM inverter, an elevator car which goes up and down by the induction motor, a means for generating a speed reference of the elevator, and a speed
10 control means for generating a torque reference so that a rotation speed angle of the induction motor follows the speed reference, comprising,

a means for detecting said electric current of said induction motor,

15 a means for estimating a torque or a considerable value corresponding thereto of the motor from a detected value of said electric current, and

a means for controlling said electric power converter so that said torque current component and said
20 exciting current component of the said motor current are in a predetermined relation based on a deviation between said torque reference and said estimated torque.

16. A motor control device as defined in claim 12, said motor control device characterized by further
25 comprising

a load torque estimating means for estimating a



load torque of said motor from a speed of the motor, and

a means for adjusting said torque reference based on a deviation between an output from said load torque estimating means and said instantaneous torque.

5 17. An elevator control device as defined in claim 16, said elevator control device characterized in that

said load torque estimating means is adjusted according to a load change of the elevator.

18. A elevator control device as defined in at least
10 one of claims 13, 14 and 15, said elevator control device characterized by further comprising

a load torque estimating means for estimating a load torque of said induction motor from a speed of the induction motor, and

15 a means for adjusting said torque reference based on a deviation between an output from the load torque estimating means and said generated torque of the induction motor.

19. An elevator control device as defined in claim 8,
20 said elevator control device characterized in that

said load torque estimating means is adjusted according to a load change of the induction motor.

20. A motor control device as defined in at least one of claims 19, 10 and 11, said motor control device
25 further comprising,

a means for operating said acceleration reference



by integrating said speed reference.

21. A motor control device as defined in claims 12, said motor control device further comprising,

5 a degree of inclination of said acceleration reference decreases according to a extent which said power supply voltage applied to said converter decreases not more than a predetermined value.

22. a converter for converting an AC to a DC, comprising

10 a PWM inverter for inverting the output voltage of said converter into variable frequency variable voltage,

a capacitor connected to a direct-current circuit between said converter and said inverter,

an induction motor supplied from the PWM inverter,

15 an elevator car which goes up and down by the induction motor, an acceleration reference generating means for said elevator,

a means for generating a speed reference by integrating said acceleration reference,

20 a speed control means for generating a torque reference so that a rotation speed angle of the induction motor follows the speed reference,

a means for detecting said electric current of said induction motor,

25 a means for estimating a torque or a considerable



value corresponding thereto of the motor from a detected value of said electric current, and

a means for controlling said electric power converter so that said torque current component and said
5 exciting current component of the said motor current are in a predetermined relation based on a deviation between said torque reference and said estimated torque.