

LEVELLING APPARATUS FOR AC ELEVATOR

1 This invention relates to controlling of an AC
elevator driven by an induction motor and more particularly
to a levelling apparatus suitable for improving the stop
position or landing level of the AC elevator at a target
5 floor.

 Generally, DC motors have hitherto been used
widely as drive motors for elevators which are required to
provide highly accurate controlling over a wide range and
give a comfortable feeling to passengers in the elevator.
10 However, the DC drive motor cooperative with a mechanical
rectifying mechanism suffers from various restrictions
thereby. In recent years, therefore, various types of
elevators driven by robust and inexpensive induction motors
of simplified structure have been developed and practiced.

15 Of such elevators with the induction motors, an
elevator system disclosed in, for example, U.S. Patent No.
3,876,918 has been widely used in which speed controlling is
effected by controlling the primary voltage.

 The elevator in this system, because of its nature
20 based on the primary voltage controlling, is implemented in
the form of an elevator without gears or gearless elevator
using, for example, the Ward-Leonard system or the thyristor-
Leonard system and inevitably undergoes restrictions in
performing the following types of controlling:

25 (1) The gearless-drive induction motor, even when

1 used for an elevator of a high speed of 360 m/min, has a
rated revolution of 200 r.p.m. or less. Therefore, when
an elevator of a lower rated speed than 360 m/min is
desired to be controlled near a rated revolution of an
5 induction motor on the basis of the primary voltage
controlling, this induction motor must have a large number
of poles;

(2) The controlling of the induction motor contains
a variety of non-linear factors and the induction motor is
10 difficult to stably control over such a wide control range
as attained by the DC motor; and

(3) In DC gearless elevators, a so-called landing
floor level correction operation is effected whereby a small
difference between the floor level of the elevator car and
15 the floor level of the target floor is detected and
controlled to zero. Under the primary voltage control,
however, such an operation is invalidated since accurate
torque controlling is almost impossible near zero speed.

As described above, while the existing DC gearless
20 elevator can realize very excellent operation character-
istics, the AC elevator driven by the induction motor subject
to the primary voltage controlling is almost impossible to
realize various types of controlling mentioned above.

To achieve the level correction even under the
25 primary voltage controlling, an elevator system as disclosed
in U.S. Patent No. 4,094,385 has been proposed. An
induction motor employed in this system has one type of
winding having a small number of poles to which an AC

1 voltage commensurate with a speed instruction is applied and
the other having a large number of poles to which a DC
voltage attributing to a braking torque is applied. This
permits the induction motor to generate a difference torque
5 between the drive torque and the braking torque, so that the
elevator car can be operated at a level correction speed.
However, since delicate and continuous controlling of the
relationship between the drive torque and the braking
torque is difficult to achieve, it is inevitable that the
10 elevator is operated when the level difference exceeds a
predetermined value and stopped when this level difference
becomes smaller. Consequently, the proposed system, though
being successful in achieving a great improvement in
controlling, fails to provide continuous level correction at
15 a level correction speed commensurate with the level differ-
ence. In addition, the braking torque becomes zero at zero
speed in the proposed system and as a result, a torque for
correcting an amount of unbalance between the elevator car
and the counterweight is difficult to be controlled. For
20 these reasons, the proposed system is disadvantageous in that
it can not actually control the level error and speed to
zero even at the cost of the very complicated and expensive
controlling scheme.

Incidentally, an induction motor control system
25 based on the primary frequency controlling is available and
considered to be superior to the primary voltage controlling
described above. In this slip frequency controlling, the
slip frequency is directly controlled to control the torque

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1 of the induction motor. This control scheme is well known
in the art and details thereof will not be described here but
features thereof will be itemized below.

(a) Precise speed controlling can be attained through
5 the closed loop.

(b) Capability of the motor can be fully utilized to
permit size-reduction of the motor.

(c) Speed controlling over a wide range is possible to
thereby facilitate operations through four quadrants.

10 (d) Stability against variations in load and speed
can be high.

(e) Mitigation of maintenance is possible to thereby
improve adaptability to ambient conditions.

Therefore, the slip frequency controlling solves
15 the problem of the rated speed described in item (1) and in
addition, realizes stable control over a wide range described
in item (2).

In the level correction speed range described in
item (3), however, the slip frequency controlling faces
20 difficulties as below.

During the level correction speed operation, for
example, the door of the elevator car is usually kept opened
and the induction motor is subjected to torque disturbance
which occurs when passengers get on or off the elevator car.
25 In the slip frequency controlling, however, only the slip
frequency and primary current are changed in response to
variations in torque but the phase of current is not
controlled. Consequently, the exciting current component

changes after the torque has changed, with the result that delay in torque response is increased, making it difficult to obtain smooth torque control during the level correction speed operation.

5 Accordingly, slip frequency control has the disadvantage of failing to maintain the comfort of passengers in the elevator car and provide sufficient landing level control, during the level correction speed operation.

10 It should also be noted that induction motor control by vector controlling has recently been developed. Vector controlling, first proposed in U.S. Patent No. 3,824,437 and subsequently discussed in various articles and papers, has now become well known in the art. Vector controlling involves independent control of the torque current and
15 exciting current components fed to the induction motor, thereby realizing stable speed control of the induction motor at a high response.

The present invention seeks to provide a levelling apparatus for an AC elevator which can maintain the comfort
20 of passengers in the elevator car and provide highly accurate levelling in an AC elevator system driven by an induction motor.

According to the present invention there is provided a levelling apparatus for an AC elevator wherein an
25 elevator car is driven by an induction motor to run between a plurality of target floors, said apparatus comprising:

a vector control unit for independently controlling a

torque current component and an exciting current component fed to said induction motor;

level detector means for detecting a level difference between the floor level of said target floor and the floor
5 level of said elevator car;

level correction speed instruction generator means for generating a level correction speed instruction in response to the level difference;

angular speed detector means for detecting a rotation
10 angular speed of said motor; and

means for generating a torque current instruction on the basis of a difference between the output signal of said level correction speed instruction generator means and the output signal of said angular speed detector means, said
15 torque current instruction being used as an instruction for the torque current component of said vector control unit.

Embodiments of the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

20 Fig. 1 is a block diagram showing a levelling apparatus for an AC elevator according to an embodiment of the invention;

Fig. 2 is a graphical representation useful in explaining the operational principle of the vector con-
25 trolling;

Fig. 3 is a graphic representation showing a characteristic of a level correction speed instruction

generator used in Fig. 1;

Fig. 4 is a block diagram showing a levelling apparatus for an AC elevator according to another embodiment of the invention;

5 Figs. 5A and 5B are waveform diagrams useful in explaining the operation of the Fig. 4 embodiment;

Fig. 6 is a block diagram showing still another embodiment of the levelling apparatus according to the invention; and

10 Fig. 7 is a block diagram showing an embodiment of

1 a level difference detector circuit used in Fig. 6.

The invention will now be described by way of examples.

Referring to Fig. 1, there is illustrated a
5 levelling apparatus for an AC elevator embodying the invention. In the apparatus, a vector control unit VC as disclosed in the aforementioned U.S. Patent No. 3,824,437 is well known and only its portion directly related to the invention will be described hereunder.

10 The levelling apparatus comprises a frequency converter 1 for controlling the instantaneous values of the primary currents fed to an elevator drive induction motor 2 and each consisting of a torque current component and an exciting current component, an angular speed detector 3 for
15 detecting the rotation angular speed of the induction motor 2, power source buses 4_1 to 4_3 , DC current transformers 5, 6 and 7 for detecting the instantaneous value of each of the primary currents, a current detector circuit 8 for converting the detection values of the DC current trans-
20 formers 5, 6 and 7 into signal levels commensurate with those of a primary current calculation circuit to be described later, a sheave 9 coupled to a rotor of the induction motor 2, an elevator car 10, a counterweight 11, a main rope 12 trained around the sheave 9 to connect the elevator car 10
25 and the counterweight 11, an elevator speed instruction generator circuit 13, a level difference detector 14 for detecting the difference between the floor level of the elevator car 10 and the floor level of a target floor, a

1 level correction speed instruction generator 15 for convert-
ing the level difference into a signal level of level
correction speed, a flux instruction circuit 16, a speed
control circuit 17 for control which makes the actual speed
5 of the induction motor 2 equal to the instructed speed, a
primary current calculation circuit 18 a torque current
instruction. It from the speed control circuit 17, a flux
instruction I_m from the flux instruction circuit 16 and flux
position signals from a flux position detector 19 to produce
10 an instantaneous reference value i_{α} of an α -axis (x-axis in
the aforementioned U.S. Patent No. 3,824,437) component and
instantaneous reference value i_{β} of a β -axis (y-axis in the
same U.S. Patent) component of the primary current, a three
phase converter circuit 20 receiving the instantaneous
15 values of the α -axis and β -axis components of the primary
current to convert them into three-phase signals, and current
controllers 21U, 21V and 21W for controlling the primary
current value of the induction motor 2 with reference to the
three-phase signals. The flux position detector circuit 19
20 receives a rotation angular speed ω_r of the rotor and the
torque instruction I_t to detect the flux position.

The operation of this embodiment will now be
described.

Primary current I_1 is resolved, on the rotating
25 field of the induction motor 2, into an exciting current
vector component I_m (used as the flux instruction) in a flux
direction and a torque current vector component I_t (used as
the torque current instruction) which is in a direction

1 orthogonal to the flux direction and flows so as to cancel
out a magnetomotive force due to the secondary current.
This relation is indicated by a vector expression as follows:

$$I_1 = I_m + I_t. \dots\dots\dots (1)$$

5 In order to control these orthogonal vectors I_m and I_t
independently, for a fixed I_m , I_t is set to I_{t2} within a
region of larger torque and to I_{t1} within a region of
smaller torque, as shown in Fig. 2, thereby attaining
controlling equivalent to that obtained by the DC motor.
10 This indicates the principle of the vector controlling as
will be known from the aforementioned U.S. Patent No.
3,824,437.

The torque current instruction I_t from the speed
control circuit 17 and the flux instruction I_m from the flux
15 instruction circuit 16 are defined by the coordinates on the
rotating field pursuant to the above-described principle of
the vector controlling. Thus, these instructions are
required to be converted into variables defined by the
coordinates on the stator having orthogonal α and β axes by
20 using rotating field position signals $\sin \omega_1 t$ and $\cos \omega_1 t$
from the flux position detector circuit 19, thus obtaining
 i_α and i_β as outputs from the primary current calculation
circuit 18 which are:

$$i_\alpha = \sin \omega_1 t I_m + \cos \omega_1 t I_t \dots\dots\dots (2)$$

25 $i_\beta = -\cos \omega_1 t I_m + \sin \omega_1 t I_t \dots\dots\dots (3)$

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1 where ω_1 is an angular speed which is represented by the
sum of rotation angular speed ω_r of the rotor and slip
frequency ω_s proportional to the torque instruction I_t .

5 These variables i_α and i_β are converted into the
three-phase primary current having phase currents which are
out of phase from each other by 120° , thus obtaining three-
phase primary currents i_U , i_V and i_W as outputs from the
three-phase converter circuit 20 which are:

$$i_U = i_\alpha + i_\beta \quad \dots\dots\dots (4)$$

10 $i_V = \frac{1}{2}i_\alpha + \frac{\sqrt{3}}{2}i_\beta \quad \dots\dots\dots (5)$

$$i_W = \frac{1}{2}i_\alpha - \frac{\sqrt{3}}{2}i_\beta \quad \dots\dots\dots (6)$$

By supplying these three-phase primary currents serving as
instantaneous reference values to the induction motor, the
controlling performance equivalent to that of the DC motor
15 can be obtained.

As will be appreciated from the foregoing
description, when the speed control circuit 17 produces the
torque instruction I_t in response to the output signal from
the level correction speed instruction generator 15, the
20 level correction speed operation characteristic equivalent
to that of the DC motor can be obtained.

In this case, by setting the characteristic of the
level correction speed instruction such that, as shown in
Fig. 3, the more the level difference approaches zero, the

1 smaller the speed instruction becomes, the difference between the floor level of the elevator car and the floor level of the target floor can be controlled to zero.

According to this embodiment, therefore, torque
5 of the induction motor 2 developing during the very low speed operation inclusive of stopping of the induction motor can be controlled sufficiently smoothly and with high accuracy, to ensure that accuracy of correction for the difference
between the floor level of the elevator car and the floor
10 level of the target floor can be improved and comfortable feeling can be given to passengers in the elevator car during the level difference correction operation.

Referring to Fig. 4, another embodiment of the levelling apparatus of the invention will be described which
15 can give a comfortable feeling to passengers in the elevator car even under the condition that the load torque is externally disturbed during the level correction speed operation.

In the embodiment of Fig. 4, a load detector 30 for
20 the elevator car 10 and a load correction torque instruction circuit 31 are added to the embodiment shown in Fig. 1.

According to this embodiment, therefore, a large change in the speed can be prevented even when the load torque changes as passengers get on or off the elevator car
25 during the level correction speed operation, so that the floor level of the elevator car can coincide with the floor level of the target floor without giving an uncomfortable feeling to passengers in the elevator car.

1 More particularly, as shown in Fig. 5A, when the
external disturbing torque develops in the Fig. 1 embodiment
without ability to correct the external torque, a difference
between the instructed speed and the actual speed develops
5 and the difference attributes to a torque instruction. As
a result, the actual speed undulates as shown in Fig. 5A,
thus giving uncomfortable feeling to passengers in the
elevator car.

 In contrast, with the Fig. 4 embodiment added
10 with the load detector 30 and load correction torque
instruction circuit 31, as shown in Fig. 5B, the torque
instruction can follow the change of torque without causing
time difference and hence undulation of the actual speed
disappears to permit a smooth level correction speed opera-
15 tion.

 Fig. 6 shows still another embodiment of the
invention which features in that a distance pulse generator
44 is provided which generates a distance pulse each time
the elevator car 10 runs a unit of straight distance, and
20 the level difference is detected by counting the distance
pulse.

 Referring to Fig. 6, a rope 43 connected with
elevator car 10 is trained around upper and lower pulleys 41
and 42 disposed along the vertical movement paths, and a
25 rotary disc 45 of the distance pulse generator 44 is
connected to the upper pulley 41. Slits are formed in the
rotary disc 45 concentrically therewith, and a pickup device
46 generates a pulse each time it detects the slit. Thus,

1 the upper pulley 41 and rotary disc 45 rotate in synchronism with the running of the elevator car 10, and the pickup device 46 generates a pulse each time the elevator car 10 runs a unit of distance (1 to 2 mm).

5 A level difference detector circuit 47 receives the pulse from the distance pulse generator 44 and delivers a signal indicative of the level difference from the target floor to a level correction speed instruction generator 15.

Fig. 7 shows details of the level difference
10 detector circuit 47 and the level correction speed instruction generator 15. Referring to Fig. 7, a car position detecting counter 48 counts the pulse from the distance pulse generator 44 and produces a car position signal. A floor level storage 49 stores the floor level of each target
15 floor and produces a floor level signal corresponding to a landing floor. A comparator 50 compares the car position signal with the floor level signal to produce a level difference. Specifically, when the car position exceeds the floor level, the comparator 50 produces a positive value
20 proportional to the difference, and when the car position is below the floor level, it produces a negative value proportional to the difference. The level correction speed instruction generator 15 receives the level difference to produce a descending level correction speed instruction
25 proportional to a value of the level difference when the level difference is positive and an ascending level correction speed instruction proportional to a value of the level difference when the level difference is negative.

- 1 These descending and ascending instructions are illustrated
in a block of the generator 15. The speed instruction
becomes constant for the level difference exceeding a
predetermined value, thereby preventing impartation of
5 anxiety to passengers and occurrence of danger during the
levelling operation at which the door is kept opened and
passengers get on or off the elevator car.

As has been described, according to the present
invention, the landing level of the AC elevator driven by
10 the induction motor can be corrected accurately at the level
correction speed commensurate with the level difference while
giving a comfortable feeling to passengers in the elevator
car.



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CLAIMS:

1. A levelling apparatus for an AC elevator wherein an elevator car is driven by an induction motor to run between a plurality of target floors, said apparatus comprising:

5 a vector control unit for independently controlling a torque current component and an exciting current component fed to said induction motor;

level detector means for detecting a level difference between the floor level of said target floor and
10 the floor level of said elevator car;

level correction speed instruction generator means for generating a level correction speed instruction in response to the level difference;

angular speed detector means for detecting a
15 rotation angular speed of said motor; and

means for generating a torque current instruction on the basis of a difference between the output signal of said level correction speed instruction generator means and the output signal of said angular speed detector means, said
20 torque current instruction being used as an instruction for the torque current component of said vector control unit.

2. The levelling apparatus according to Claim 1 wherein said level difference detector means comprises a distance pulse generator for generating a pulse each time
25 said elevator car runs a unit of distance, a car position detecting counter for counting the pulse to detect the position of said elevator car, and comparator means for

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producing a difference between the car position and a predetermined floor level of the target floor.

3. The levelling apparatus according to Claim 1 or Claim 2 wherein said level correction speed instruction

5 generator means generates a speed instruction which increases with the magnitude of said level difference and becomes constant for said level difference exceeding a predetermined value.

4. The levelling apparatus according to Claim 3
10 wherein said level correction speed instruction generator means generates the speed instruction which becomes positive or negative in accordance with the direction of said level difference.

5. The levelling apparatus according to Claim 1
15 further comprising means for detecting a load on said elevator car, said torque current component being corrected in accordance with the car load.

6. A levelling apparatus for an AC elevator substantially as herein described with reference to and as illustrated in
20 Figs. 1 to 4 and 5B, or Figs. 6 and 7 of the accompanying drawings.
