

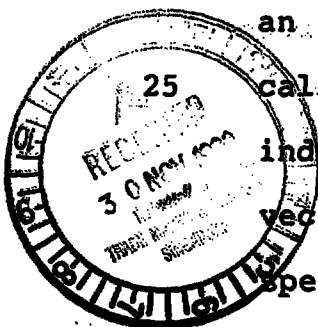
AN ELEVATOR CONTROL APPARATUS

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The present invention relates to a control apparatus for an inverter-driven elevator, more particularly to an elevator control apparatus having an improved function for detecting a present position of a cage of the elevator.

15 In an elevator control, it is one of the important factors that a cage of an elevator can land at the level of a floor accurately, and therefore a great concern has been paid about raising the landing accuracy as much as possible.

20 For this purpose, the speed of the cage is necessary to be controlled accurately. Particularly the high accuracy is required in the speed control during the deceleration of an elevator cage. In order to meet this, an inverter, which is controlled in accordance with a so-called vector control, has been used to control an induction motor for driving an elevator cage, because the vector control can achieve the accurate control of the speed of the induction motor.



Even with the vector control, however, it was still necessary to accurately detect the speed of a cage. Therefore, as disclosed, for example, in United States Patent No. 4,600,088 (issued July 15, 1986), an expensive
5 detector such as a rotary encoder has been employed in order to detect the speed of a motor or the present position of an elevator cage accurately.

An object of the present invention is to provide an elevator control apparatus, in which a position of an
10 elevator cage is easily detected without using an expensive position detector such as an rotary encoder.

According to the present invention there is provided a control apparatus for an elevator serving a plurality of floors, said control apparatus including:

15 (a) an induction motor for driving a cage of the elevator;

(b) inverter means supplied with D.C. power, for converting the D.C. power into A.C. power to supply said induction motor therewith;

20 (c) operation management control means, which receives cage call signals generated in the cage and hall call signals generated in elevator halls of the floors and produces a travelling command including information relating to the present floor position of the cage and the
25 position of the floor to which said cage is travelling to, in order to manage the operation of the cage for serving the floors;

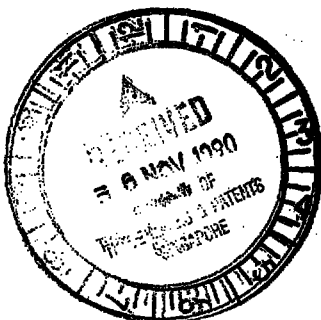
(d) signal processor means, responsive to the

travelling command, in which a detected current of said induction motor is resolved into an excitation component and a torque component, the rotating angular speed of said induction motor being detected on the basis of the torque component, and a control signal being generated to control
5 said induction motor in such a manner that the detected rotating angular speed follows a command for the rotating angular speed determined in accordance with the travelling command; and

10 (e) inverter control means, which in response to the control signal from said signal processor means, produces gate signals for said inverter means;

wherein said signal processor means calculates a present position of the cage on the basis of the detected
15 rotating angular speed of said induction motor and generates the command for the rotating angular speed in accordance with the calculated present position of the cage.

Accordingly, since a present position of an
20 elevator cage is detected from one of the control amounts created in the process of the signal



processing for the vector control. Therefore, any position detector such as an expensive rotary encoder is not needed in the present invention.

5 The present invention will now be described in greater detail by way of example with reference to the accompanying drawings, wherein:-

Fig. 1 is a drawing schematically showing an overall construction of an elevator control apparatus according to an embodiment of the present invention;

10 Fig. 2 is a functional block diagram for explaining the function of a signal processor included in the control apparatus of Fig. 1;

Fig. 3 is a flow chart of a floor height measuring routine, which is executed by the signal processor in Fig. 1 during a preparatory operation of an elevator;

Fig. 4 is a flow chart showing details of a control operation task included in the routine of Fig. 3;

Fig. 5 is a flow chart showing details of a floor height measuring task included in the routine of Fig. 3;

20 Fig. 6 is a drawing for explaining the relationship between a torque produced by an induction motor and a rotating angular speed of the motor;

Fig. 7 is a drawing for explaining the relationship between a rotating angle of the motor and a traveling distance of an elevator cage;

25 Fig. 8 is a flow chart of a normal traveling routine, which is executed by the signal processor in Fig. 1 during a normal operation for service;

Fig. 9 is a flow chart showing details of a V_{TOP} calculating task included in the normal traveling routine of Fig. 8;

Fig. 10 is a drawing for explaining the generation of a speed pattern and modes of the traveling of an elevator cage;

Fig. 11 is a flow chart showing details of a distance calculating task included in the normal traveling routine of Fig. 8;

Fig. 12 is a flow chart showing details of a speed command generating task included in the normal traveling routine of Fig. 8; and

Fig. 13 is a flow chart showing details of a floor height correcting task included in the normal traveling routine of Fig. 8.

Referring to the drawings, an embodiment of the present invention will be explained hereinafter.

In Fig. 1 there is shown an overall construction of an elevator control apparatus in accordance with an embodiment of the present invention. An appropriate power source feeds an inverter 1 with DC electric power. A smoothing capacitor 3 is provided across input terminal of the inverter 1. In the figure, the inverter 1 is shown as a so-called voltage source inverter, however there is no limitation in the type of an inverter used in the



present invention. A current source inverter can be also employed.

The inverter 1 is operated by means of a pulse width modulation (PWM) control method to invert DC power into
5 three phase AC power. The converted AC power is supplied for a three phase induction motor 5 for driving an elevator cage. Further, the voltage of the AC power is controlled on the basis of a vector control method.

There is provided a current detector 4 between the
10 inverter 1 and the motor 5 in order to detect a motor current I_m . Actually, currents I_u , I_v and I_w of three phases U, V and W are detected, although, in the figure, a single current detector is shown and the detected currents are represented by I_m .

15 The torque produced by the motor 5 is transmitted to a traction machine 7 through an appropriate reduction mechanism (not shown). The traction machine 7 drives a main rope 9, one end of which is coupled with a cage 11 and the other end with a counterweight 13, whereby the
20 cage 11 travels up and down within an elevator shaft to serve a plurality of floors.

The cage 11 is equipped with a cage operating panel 15, which generates a cage call signal, when a passenger manipulates it. The cage 11 is further provided with a
25 floor detector 17 and, on the other hand, metal plates 19, 21 are installed in the elevator shaft at such positions as the detector 17 faces them when the cage 11 lands at the respective floors accurately. The floor

detector 17 produces an output signal, when it faces the metal plates 19, 21. Therefore, the output signal of the detector 17 is generated, every time the cage 11 passes a floor.

5 The output signal of the floor detector 17 will be called a position interrupt signal in the following description. The cage call signal and the position interrupt signal are transmitted to a control system as described later through a traveling cable 23.

10 In the elevator shaft, there are further provided a downward limit switch 25 and an upward limit switch 27, which operate to produce output signals when the cage 11 travels down to a downward limit position or up to an upward limit position, respectively, whereby the overrun
15 traveling of the cage 11 is prevented. In elevator halls of the respective floors, there are installed hall button switches 29, 31, which are manipulated by users and produce hall call signals for requesting the service of the cage 11.

20 Further, in the following description, the distance measured from the operating position of the downward limit switch 25 to the floor surface of the respective floors will be called a floor height and represented by F_1 , F_2 ,, F_i , as shown in the figure.

25 The cage call signal and the hall call signal as mentioned above are taken into an operation management controller 33, which totally manages the service operation of the elevator in response to the cage call signals and

the hall call signals. The principal operation of the controller 33 is to generate a traveling command 33a, including information of a present floor and a destination floor, to a signal processor 35. Since various types of controllers are well known as an operation management controller and the present invention has nothing to do with the type thereof, the further description of this controller 33 is omitted. Further, an instruction for carrying out a floor height measuring operation as described later is generated by an operator or a maintenance personnel through the controller 33.

The signal processor 35 is formed by a microcomputer which executes a desired signal processing on the basis of the traveling command 33a from the controller 33, the position interrupt signal from the detector 17, the signals from the downward and upward limit switches 25, 27 and the motor current I_m detected by the current detector 4. The signal processing by the microcomputer will be discussed in detail, referring to Fig. 2 et seq.. As the result of the signal processing, the processor 35 produces an output signal 35a to a control command calculator 37. Further, the microcomputer has an appropriate storage, in which various work tables are defined. Details of the work tables will be explained later.

The calculator 37 at first calculates a reference of the motor current on the basis of the signal 35a. The calculated reference is compared with the detected current

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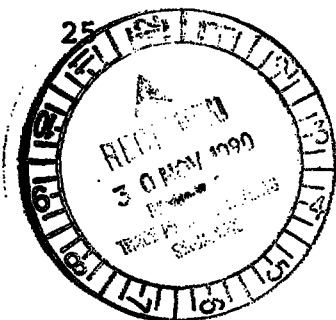
N a destination floor;

n a present floor;

$$F_1, F_2, \dots, F_i$$

value of a floor height of 1st, 2nd,,
i-th floor (cf. Fig. 1);

ΔX_{Nn} a distance between the present floor and the destination floor;



- ΔY_m a minimum distance necessary for a cage to travel at speed V_m ;
- $\Delta \hat{\theta}_r$ a rotating angle of a motor for driving the cage;
- 5 $\Delta \hat{x}$ a cage traveling distance for $\Delta \hat{\theta}_r$; and
- $\hat{x}$ a distance of a present position of the cage, measured from a downward limit switch.

- (2) Work table for the motor control operation
- 10 (called a motor control work table, hereinafter):
- ω_r^* a command for a rotating angular speed of the motor;
- ω_l^* a command for frequencies of a primary voltage applied to the motor;
- 15 I_q^* a command for a torque component of a motor current;
- I_d^* a command for an excitation component of the motor current;
- I_q a torque current component of a detected motor current;
- 20 I_d an excitation component of the detected motor current;
- $\hat{\omega}_s$ a slip of the motor in terms of a rotating angular speed;
- 25 $\hat{\omega}_r$ a rotating angular speed of the motor; and
- I_m a detected value of the motor current.

(3) Work table for the speed command generation
(called a speed command work table, hereinafter):

m a notch for the speed control;
 V_{TOP} a normal traveling speed of the cage;
5 V^* a speed command for the cage;
MOD a mode of traveling of the cage;
 t_a time for an acceleration of the cage; and
 t_b time for a deceleration of the cage.

10 (4) Table for specific data (called a specific data
table, hereinafter):

α acceleration;
 β deceleration;
 $V_1, V_2, \dots, V_m$
15 traveling speed at 1st, 2nd, $\dots$, m-th
notch;
 V_{max} a maximum allowable speed of the cage;
 K_d a gain for converting the rotating angle
 $\Delta\hat{\theta}_r$ into the cage traveling distance $\Delta\hat{x}$;
20 K_s a gain for converting the torque component
 I_q of the motor current into the slip
angular speed $\hat{\omega}_s$; and
 K_ω a gain for converting the speed command V^*
(or the aforesaid traveling speed $V_1, V_2,$
25 $\dots, V_m$) into the command ω_r^* for the
rotating angular speed of the motor.

In the operation described below, detected or
calculated values of the variables are stored in
corresponding areas of these work tables and necessary
data is read out therefrom. Further, symbols of the
5 variables listed above will be also used as reference
symbols representing signals of the respective variables
or their amount.

Now, there is shown in Fig. 2 the function of the
processor 35 in the form of a block diagram, for easy
10 understanding. Therefore, the block diagram of Fig. 2
may be shown in a somewhat different manner from the
actual operation carried out by the microcomputer of the
signal processor 35.

The signal processing of the processor 35 includes a
15 control operation task 41, which is surrounded by a chain
line. Briefly, the task 41 receives the rotating angular
speed command ω_r^* and the detected motor current I_m and
executes the signal processing necessary for the vector
control on the basis of the received signals to produce
20 the output signal 35a.

Although details will be described later, the output
signal 35a is composed of the command I_d^* for the
excitation component of the motor current, a deviation
 ΔI_d between the command I_d^* and its actual value I_d , which
25 is obtained by the calculation as described later, the
command I_q^* for the torque component of the motor current,
and the command ω_1^* for the frequencies of the primary
voltage applied to the motor 5.

The control operation task 41 carries out a coordination transformation 43 with respect to the received motor current I_m in accordance with the following relationship. Further it is to be noted here that the
5 motor current I_m represents the currents I_u , I_v and I_w of the three phases.

$$I_d = i_\alpha \cos \phi + i_\beta \sin \phi \quad (1)$$

$$I_q = i_\beta \cos \phi - i_\alpha \sin \phi \quad (2)$$

10

wherein

$$i_\alpha = I_u - \frac{1}{2}I_v - \frac{1}{2}I_w \quad (3)$$

$$i_\beta = \frac{\sqrt{3}}{2}(I_v - I_w) \quad (4)$$

15

$$\phi = \omega_1 * t + \rho \quad (5)$$

ρ is a constant determined by a phase of the motor current I_m .

20

The thus obtained torque component I_q is multiplied by the gain K_s and converted into the angular speed $\hat{\omega}_s$ of the slip of the motor 5. Thereafter, the subtraction 47 is carried out between the slip angular speed $\hat{\omega}_s$ and the frequency command ω_1^* so that the rotating angular speed
25 $\hat{\omega}_r$ of the motor 5 is obtained.

Next, the calculation 49 of the command I_q^* for the torque component and the frequency command ω_1^* is executed on the basis of the rotating angular speed $\hat{\omega}_r$ obtained as

above and the command ω_1^* thereof, as follows. Further, ω_1^* will be discussed in detail later.

$$I_q^* = k_1 (\omega_r^* - \hat{\omega}_r) \quad (6)$$

$$5 \quad \omega_1^* = \hat{\omega}_r + k_2 (\omega_r^* - \hat{\omega}_r) \quad (7)$$

Among the two commands calculated as above, the command I_q^* for the torque component is directly coupled with the command calculator 37. The frequency command ω_1^* is used in the coordinate transformation 43 and the subtraction 47 and further coupled with the command calculator 37.

The command I_d^* is set at a rated value of an excitation current of the motor 5. A rated excitation current is specific to an induction motor used. In order to control the excitation component of the motor current I_m constant, the comparison 51 is carried out between the excitation component I_d of the detected current I_m and the command I_d^* thereof so that the deviation ΔI_d is obtained.

The command calculator 37 receives the commands I_d^* , I_q^* and ω_1^* and the deviation ΔI_d as mentioned above and obtains the current command by the following calculation.

$$25 \quad \sqrt{(I_d^* + \Delta I_d)^2 + I_q^{*2}} \sin(\omega_1^* t + \eta) \quad (8)$$

wherein

$$\eta = \tan^{-1} \frac{I_q^*}{I_d^* + I_d} \quad (9)$$

5 The signal processing further comprises a floor
height measuring task 53, which measures the floor height
of the respective floors from the operating position of
the downward limit switch 25 during the preparatory
operation taking place after installation of the elevator
10 or when the renewal of the data of the floor height
becomes necessary.

The task 53 is initiated by a signal as shown by a
broken line, which is given by an operator or a
maintenance personnel through the operation management
15 controller 33. Further, the signal from the controller
33 actuates switches 55, 57 to throw them into side a, as
shown in the figure. Thereby, the task 53 provides the
command ω_r^* for the duration of the preparatory operation
through the switch 57, and on the other hand, it also
20 calculates the floor height on the basis of the rotating
angular speed $\hat{\omega}_r$ provided by the control operation task
41. The thus measured floor height is stored in a floor
height table 59 defined in the storage of the
microcomputer.

During a normal operation of the elevator, the
operation management controller 33 throws the switches
55, 57 into side b and produces the traveling command 33a
in response to the cage call signals and the hall call



signals. The traveling command 33a initiates a normal traveling routine. In this routine, a V_{TOP} calculated task 61 is at first executed to determine a normal traveling speed V_{TOP} . The normal traveling speed V_{TOP} depends on the distance between the present floor and the destination floor where the cage 11 should stop next.

When the cage 11 starts to travel, a distance calculating task 63 is initiated by a signal from the task 61 and continues to calculate the cage position $\hat{X}$ on the basis of the angular speed $\hat{\omega}_r$ given from the control operation task 41 through the switch 55. In the execution of the task 63, a signal concerning the floor height from a floor height correcting task 65 is used. The task 65 reads out the data of the floor height from the table 59 in synchronism with the position interrupt signal from the floor detector 17 and conveys it to the task 63 as the signal representing the present position of the cage 11.

A speed command generating task 67 generates the speed command V^* on the basis of the cage position $\hat{X}$. The calculated speed command V^* is converted into the command ω_r^* for the rotating angular speed of the motor 5. The thus obtained command ω_r^* is coupled to the control operation task 41 through the switch 57.

As described above, according to the present invention, the cage position $\hat{X}$ is detected by the calculation which is carried out on the basis of the rotating angular speed $\hat{\omega}_r$ of the motor 5, which is one of

the control amounts created in the process of the signal processing for the vector control of the motor 5.

Therefore, any expensive detector, such as a rotary encoder, is not needed in order to detect the position of the cage 11.

Referring now to flow charts shown in Fig. 3 et seqq., the operation of the signal processor 35 will be explained in detail hereinafter. The explanation will be separately made of a floor height measuring routine executed in the preparatory operation and a normal traveling routine executed in the normal service operation.

In Fig. 3 there is shown a flow chart of the floor height measuring routine. As already described, this routine is carried out in order to detect the floor height by the preparatory operation, for example, after installation of an elevator. If an operator or a maintenance personnel gives an instruction to the control apparatus through the operation management controller 33, the switches 55, 57 are thrown into side a and the floor height measuring routine is started.

At first, at step 301, it is judged whether or not the cage 11 is at a standard position, i.e., whether or not the downward limit switch 25 is operated. If it is not at the position, an area m for the speed control notch in the speed command work table is set at one (step 303) and the downward traveling is instructed (step 305). Thereby, the cage 11 travels downward until the downward limit switch 25 is operated. The traveling speed by the



first notch is 15 m/sec, for example, so that the cage 11 continues to travel slowly and stops when the downward limit switch 25 is operated (step 307).

When the cage 11 stops, the floor height table 59 and the work tables, except the specific data table, are initialized (step 309). Thereafter, the area m for the speed control notch in the speed command work table is set at one again (step 311) and the upward traveling is instructed (step 313), whereby the cage 11 begins the upward traveling for the purpose of the floor height measuring.

At the same time as the departure of the cage 11 from the standard position, a timer is set and starts to count time (step 315). Then, at step 317, the speed V_1 of the first notch is converted into the command ω_r^* for the rotating angular speed of the motor 5. The gain K_ω employed in this conversion is stored in a predetermined area of the specific data table.

Thereafter, at step 319, the control operation task 41 is carried out. A flow chart of the task 41 is shown in Fig. 4. At first, the motor currents I_u, I_v, I_w are taken into predetermined areas in the motor control work table (step 401). Then, at step 403, the motor currents I_u, I_v, I_w are subject to the coordinate transformation as already described and converted into the excitation component I_d and the torque current component I_q . The thus obtained I_d and I_q are stored in the respective areas of the motor control work table.

The excitation component I_d stored in the work table is used for controlling the excitation component of the motor current I_m constant. On the other hand, the torque component I_q is converted into the slip angular speed $\hat{\omega}_s$ at step 405. As apparent from Fig. 6, in which there is shown the characteristic of torque versus slip angular speed of an induction motor, the conversion of I_q into $\hat{\omega}_s$ can be carried out by the relationship of $K_s \cdot I_q$, because the torque is proportional to I_q , and I_q and $\hat{\omega}_s$ are in the linear relationship. The gain K_s is specific to an induction motor used and therefore is stored in advance in a predetermined area of the specific data table.

The thus obtained $\hat{\omega}_s$ is stored in an area defined for $\hat{\omega}_s$ in the motor control work table. Then, at step 407, the subtraction is carried out between the obtained slip angular speed $\hat{\omega}_s$ and the frequency command ω_1^* , which is read out from a predetermined area of the motor control work table. The rotating angular speed $\hat{\omega}_r$ obtained as above is stored in a predetermined area of the motor control work table.

At step 409, the commands I_q^* and ω_1^* are calculated in accordance with the already described relationship on the basis of the above obtained $\hat{\omega}_r$ and the command ω_r^* . The command ω_r^* , which is obtained at step 317, is stored in the motor control work table and read out therefrom for execution of step 409. At step 411, the thus obtained I_q^* and ω_1^* are output to the command calculator 37, together with I_d^* , which is set in advance in the motor



control work table. When these commands are output, the control operation task 41 is completed and the operation is returned to a main routine of Fig. 3.

In the main routine, the operation goes to step 321, at which the floor height measuring task 53 is executed. The task 53 is a task for calculating the traveling distance $\hat{x}$ of the cage 11 and determining the floor height measured from the operating position of the downward limit switch 25. A flow chart of this task is shown in Fig. 5. Before the description of the flow chart, the algorithm of this task will be explained, referring to Fig. 7.

In the figure, the same reference numerals denote the same parts as in Fig. 1. As shown in the figure, the reduction mechanism, which has been omitted in Fig. 1, comprises a first gear 8 of a diameter D_1 coupled to the motor 5 and a second gear of a diameter D_2 coupled to the traction machine 7. Further, a diameter of the traction machine 7 is D_s .

As apparent from Fig. 7, there exist the following relationships in the rotating angle $\Delta\hat{\theta}_r$ of the motor 5 and the traveling distance $\Delta\hat{x}$ of the cage 11, with respect to the duration from time point t_0 to time point t_1 .

$$\Delta\hat{\theta}_r = \int_{t_0}^{t_1} \hat{\omega}_r dt \quad (10)$$

$$\Delta \hat{X} = \frac{D_1}{D_2} \cdot D_S \cdot \Delta \hat{\Theta}_r \quad (11)$$

5 The first formula is changed in a discrete manner,
as follows.

$$\Delta \hat{\Theta}_{r,j} = \sum_{j=1}^{j_0} (\hat{\omega}_{r,j} \cdot \Delta T) \quad (12)$$

10

wherein ΔT : sampling period,

$\hat{\omega}_{r,j}$: the value of $\hat{\omega}_r$ at time point
($t_0 + \Delta T \cdot j$), and

15

j_0 : $(t_1 - t_0) / \Delta T$

Accordingly, both the formulas (10) and (12) are
expressed as follows.

20

$$\Delta \hat{\Theta}_{r,j} = \hat{\omega}_{r,j} \cdot \Delta T + \Delta \hat{\Theta}_{r,j-1} \quad (13)$$

$$\Delta \hat{X} = K_d \cdot \Delta \hat{\Theta}_{r,j} \quad (14)$$



In the formula (14), K_d is represented by $(D_1/D_2)D_S$.
This value is specific an elevator, and therefore it is
stored in a predetermined area of the specific data table
in advance.

Referring now to Fig. 5, the flow chart of the task
53 will be explained. At step 501, the rotating angle

$\Delta\theta_r$ is calculated on the basis of the angular speed $\hat{\omega}_r$ and the previous value of the rotating angle $\Delta\hat{\theta}_r$ (initially, $\Delta\hat{\theta}_r = 0$). Although, as described above, ΔT represents the sampling period, it also means a time interval of the repetition of this calculation, which is generally set at a time smaller than a time constant in the response of the speed control of the elevator, e.g. about ten millisecond.

Further, $\hat{\omega}_r$ is read out from a predetermined area in the motor control work table and $\Delta\hat{\theta}_r$ from a predetermined area in the floor control work table. The thus obtained rotating angle $\Delta\hat{\theta}_r$ of the motor 5 is stored again in the corresponding area of the floor control work table, i.e., the content of the corresponding area is renewed by the newly calculated $\Delta\hat{\theta}_r$.

Then, the traveling distance $\Delta\hat{x}$ is calculated for the rotating angle $\Delta\hat{\theta}_r$ at step 503, and the content of the area for $\Delta\hat{x}$ in the floor control work table is renewed by the newly calculated $\Delta\hat{x}$. At step 505, it is discriminated whether or not the position interrupt signal is produced by the floor detector 17.

If there is no position interrupt signal, the operation ends to return to the main routine of Fig. 3. If the position interrupt signal exists, the content of the area n for the present floor in the floor control work table is increased by one and the result thereof is stored in the corresponding area of the floor control work table again (step 507). The value of $\Delta\hat{x}$ calculated

at step 503 is stored in a predetermined area of the floor height table 59, which corresponds to n obtained at step 507 (step 509). Thereafter, the operation returns to the main routine of Fig. 3.

5 Referring again to Fig. 3, after the floor height measuring task 53 is completed at step 321, it is judged at step 323 whether or not time t reaches ΔT . If the time ΔT does not yet lapse, the judgment operation is repeatedly continued until ΔT lapses. When time t reaches
10 ΔT , the operation goes to step 325, at which it is judged whether or not the upward limit switch 27 is operated. If the switch 27 is not operated, the operation returns to step 315 and is repeated again in the same manner as described above.

15 If the upward limit switch 27 operates, this means that the floor height operation is completed until the highest floor. Therefore, the operation of this routine ends after an instruction for stopping the cage 11 is given (step 327).

20 In this manner, the floor heights of all the floors measured from the operating position of the downward limit switch 25 are detected by repeating the operation from step 315 till step 325 and stored in the floor height table 59.

25 In the following, the explanation will be done of the normal traveling operation. Fig. 8 shows a flow chart of a main routine for the normal traveling operation.

The normal traveling routine is initiated by the traveling command 33a from the operation management controller 33. When this routine starts, the V_{TOP} calculating task 61 is at first executed at step 801. A
5 detailed flow chart of the task 61 is shown in Fig. 9.

In Fig. 9, at step 901, the distance ΔX_{Nn} between the present floor n and the destination floor N is calculated on the basis of the floor height values F_n and F_N of the respective floors which are given from the
10 operation management controller 33 together with the traveling command 33a. The calculated distance ΔX_{Nn} is stored in a predetermined area in the floor control work table. At step 903, the first notch is at first selected and stored in a predetermined area in the speed command
15 work table.

Next, the acceleration time t_α is calculated at step 905, and then the deceleration time t_β at step 907. The acceleration time t_α means a time during which the cage 11 is accelerated with the acceleration α and its speed
20 can be increased up to the speed V_1 of the first notch. Similarly, the deceleration time t_β means a time during which the cage 11 is decelerated with the deceleration β and its speed is decreased down to the speed V_1 of the first notch. The calculated times t_α and t_β are stored
25 in predetermined areas in the speed command work table.

On the basis of t_α and t_β obtained at these steps, the distance ΔY_1 is calculated at step 909. The distance ΔY_1 means a distance in which the cage 11 is accelerated

with the acceleration α until its speed reaches V_1 and thereafter the cage 11 is decelerated with the deceleration β until its speed becomes zero from V_1 . At step 911, it is judged whether or not the thus obtained
5 distance ΔY_1 exceeds the distance ΔX_{Nn} obtained at step 901. If the former is smaller than the latter, notch m is increased by one (step 913) and the operation of step 905 et seqq. is carried out again. This loop operation is repeated until ΔY_m exceeds ΔX_{Nn} .

10 The fact that ΔY_m has become larger than ΔX_{Nn} means that the m -th notch, which has been searched for by the loop operation, is by one higher than its appropriate value. Then, at step 915, the value of notch is decreased by one and the notch $(m-1)$ is stored in a predetermined
15 area of the speed command work table. At step 917, the speed V_{m-1} corresponding to the $(m-1)$ th notch is stored in an area for V_{TOP} in the speed command work table.

Then, it is judged at step 919 whether or not V_{TOP} determined as above is larger than the maximum allowable
20 speed V_{max} of the cage 11, which is stored in a predetermined area in the specific data table. If V_{TOP} does not exceed V_{max} , that value of V_{TOP} is made the normal traveling speed. If, however, V_{TOP} exceeds V_{max} , the latter is used as the normal traveling speed V_{TOP}
25 (step 921).

Returning to Fig. 8, after the V_{TOP} calculating task 61 is completed, the routine for start is executed (step 803). Although details are omitted here, the routine for

start is a routine for preparing the start of the cage
11. The principal function of this routine is to release
the braking force effected during the stop of the cage
11. In the figure, step 803 is executed after the
5 completion of step 801. However, both steps 801 and 803
can be simultaneously initiated. Namely, V_{TOP} can be
calculated, while the start of the cage 11 is being
prepared.

At step 805, an area MOD for the traveling mode of
10 the cage 11 in the speed command work table is set at
one. The traveling mode of the cage 11 will be explained,
referring to Fig. 10, in which there is shown an example
of a speed pattern. As shown in the figure, MOD=1 means
that the cage 11 is being accelerated at the
15 acceleration α . Further, MOD=2 means that the cage 11 is
traveling at a constant speed V_{TOP} and MOD=3 means that
it is being decelerated at the deceleration β .

At step 807, the area of $\Delta\hat{\theta}_r$ in the floor control
work table is cleared, and then, at step 809, the timer
20 is set at zero and begins to count time. At step 811,
the distance calculating task 63 is initiated. As shown
in Fig. 11, the task 63 is the same in the principal
portion as the floor height measuring task 53 already
described. Therefore, the task 63 will be discussed
25 briefly.

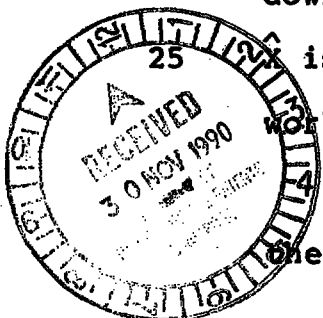
In Fig. 11, at step 1101, the rotating angle $\Delta\hat{\theta}_r$ is
calculated on the basis of the angular speed $\hat{\omega}_r$ and the
previous value of the rotating angle $\Delta\hat{\theta}_r$. The time ΔT in

this step is the same as in step 501 of Fig. 5. Further, $\hat{\omega}_r$ is read out from the predetermined area in the motor control work table and $\Delta\hat{\theta}_r$ from the predetermined area in the floor control work table.

5 The thus obtained rotating angle $\Delta\hat{\theta}_r$ of the motor 5 is stored again in the corresponding area of the floor control work table, i.e., the content of the corresponding area is renewed by the newly calculated $\Delta\hat{\theta}_r$. Then, at
10 step 1103, the traveling distance $\Delta\hat{x}$ is calculated for the rotating angle $\Delta\hat{\theta}_r$ obtained at the previous step, and the content of the area for $\Delta\hat{x}$ in the floor control work table is renewed by the newly calculated $\Delta\hat{x}$.

 Although details will be apparent later, the distance calculating task 63 is repeatedly executed every time the
15 position interrupt signal occurs. Further, as indicated in step 807, the rotating angle $\Delta\hat{\theta}_r$ is cleared every time this task is initiated. Therefore, the traveling distance $\Delta\hat{x}$ means a traveling distance of the cage 11 measured from the floor through which the cage 11 has passed just
20 before. Then, at step 1105, the above obtained $\Delta\hat{x}$ is added to the value F_n of the floor height of the just previous floor, so that the distance $\hat{x}$ of the present cage position measured from the operating position of the downward limit switch 25 is obtained. The thus obtained
 $\hat{x}$ is stored in a predetermined area of the floor control work table.

 After the distance calculating task 63 is completed, the operation returns to the main routine of Fig. 8, and



at step 813, the speed command generating task 67 is initiated. A flow chart of this task 67 will be discussed, referring to Fig. 12.

5 In Fig. 12, at step 1201, it is judged whether or not the value of the traveling mode of the cage 11 is one. If the answer in this step is NO, it means that the cage 11 stops at a certain floor or the value of the traveling mode is either two or three. Then, the operation goes to step 1203, at which it is further judged
10 whether or not the value of the traveling mode is two.

If the answer in step 1203 is also NO, it means that the cage 11 stops at a certain floor or the value of the traveling mode is three. Then, the operation goes to step 1205, at which it is judged whether or not the value
15 of the traveling mode is three. If the answer in this step is again NO, it means that the cage 11 stops at a certain floor. Accordingly, since no speed command V^* is produced hitherto, step 1207 is not carried out. As a result, the execution of this task 67 ends and the
20 operation returns to the main routine of Fig. 8. Further, a flow in step 1207 et seqq. represents the operation, by which the speed command V^* is converted into the command ω_r^* for the rotating angular speed in accordance with the traveling direction of the cage 11. The gain K_ω used in
25 this conversion is stored in the predetermined area in the specific data table.

Returning to step 1201, if the answer in this step is YES, the operation goes to step 1209. As will be

apparent from the description later, this task 67 is repeated every ΔT , and hence step 1209 is repeatedly executed at intervals of ΔT . Thereafter, at step 1209, the speed command V^* is calculated on the basis of the acceleration α and the speed command V^* , which was calculated last time of the repetitive operation (i.e., ΔT before). Further, k_a is a constant for converting the acceleration α into a speed which is attained by the acceleration α during ΔT . Accordingly, step 1209 produces the speed command V^* with respect to time, as this task 67 is repeated every ΔT .

Then, at step 1211, it is discriminated whether or not V^* is equal to or larger than V_{TOP} , which has been already determined by execution of the V_{TOP} calculating task 61. If V^* exceeds V_{TOP} , it means that a point of changing the traveling mode is reached (cf. Fig. 10). Therefore, the area of MOD in the speed command work table is renewed by two (step 1213), and thereafter the operation goes to step 1203.

If V^* is smaller than V_{TOP} , it means that the traveling mode still remains at one. Therefore, the answers in the judgment at steps 1203 and 1205 are NO. In this case, however, the speed command V^* produced at step 1209 is converted into the command ω_r^* of the rotating angular speed at step 1207.

When MOD is judged to be two at step 1203, the operation goes to step 1215, at which V_{TOP} obtained by the V_{TOP} calculating task 61 is stored in the area for V^*



in the speed command work table. Then, the starting point of deceleration (cf. Fig. 10) is determined in accordance with the direction of the traveling of the cage 11. The traveling direction of the cage 11 is discriminated at
5 step 1217.

If the cage 11 travels downward, the following discrimination is carried out at step 1219. At first, a distance necessary for decelerating and stopping the cage 11, which travels at the speed V^* , at the deceleration β
10 is calculated by the relationship of $V^*t\beta/2$. Then, the thus obtained distance is subtracted from the distance $\hat{X}$ of the present position of the cage 11. If the answer in step 1219 is NO, i.e., when the result of the subtraction is larger than the floor height value F_N of the
15 destination floor, the operation goes to step 1205, because the cage 11 does not yet reach the starting point of deceleration.

Since the position of the cage 11 does not reach the starting point of deceleration, the value of MOD remains
20 at two. Therefore the answer of step 1205 becomes NO and the operation goes to step 1207, at which the speed command V^* set at step 1215 is converted into the command ω_r^* for the rotating angular speed of the motor 5. Then, at step 1223, the traveling direction of the cage 11 is
25 discriminated. If the cage 11 travels upward, ω_r^* obtained at step 1207 is utilized as the command, as it is, and if the cage 11 travels downward, ω_r^* is used for the command after it is multiplied by minus one (-1) at step 1225.

Returning to step 1219, if the answer in this step is YES, i.e., when the subtraction result becomes smaller than F_N , it means that the position of the cage 11 reaches the starting point of deceleration. Therefore, MOD is
5 changed to three (step 1227) and thereafter the operation goes to step 1205. At this time, the answer of step 1205 becomes YES, and the operation goes to step 1229, at which the speed command V^* for the deceleration is calculated in the analogous manner to step 1209, but instead of the
10 acceleration α , the deceleration β is utilized in step 1229. Further, k_b is a constant for converting the deceleration β into a speed which is attained by the deceleration β during ΔT .

At step 1231, it is discriminated whether or not the
15 speed command V^* calculated at step 1229 is equal to or smaller than V_1 , which is a speed by the first notch. If V^* is larger than V_1 , the operation goes to step 1207, and when V^* is equal to or smaller than V_1 , the operation goes to step 1207 after V^* is set at V_1 (step 1233).

20 After the speed command generating task 67 is completed, the operation returns again to the main routine of Fig. 8. Then, at step 815, the control operation task 41 is executed. Since this task 41 has been already described in detail, the explanation thereof is omitted
here.

At step 817, it is judged whether or not ΔT has lapsed from the execution of step 809. After the lapse of ΔT , the operation goes to step 819, at which it is



discriminated whether or not the position interrupt signal occurs. If it does not occur, the operation returns to step 809, and the operation as mentioned above is repeated again. Therefore, it will be understood that the
5 operation as mentioned above is repeatedly executed at time intervals of ΔT every time the position interrupt signal occurs.

In the case where the position interrupt signal occurs, the operation goes to step 821, at which the floor
10 height correcting task 65 is carried out. A detailed flow chart of the task 65 is shown in Fig. 13. As apparent from Fig. 8, the task 65 is executed only when the position interrupt signal occurs.

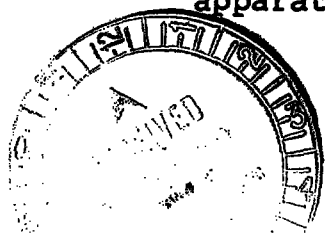
In Fig. 13, at first, the traveling direction of the
15 cage 11 is discriminated at step 1301. If the cage 11 travels upward, one is added to the value n of the present floor when the position interrupt signal occurs, and the result $(n+1)$ of the summation is stored in the predetermined area in the floor control work table as a
20 new value of the present floor (step 1303).

On the contrary, if the cage 11 is in the downward traveling state, one is subtracted from the value n of the present floor, and the result $(n-1)$ of the subtraction is stored in the predetermined area in the work table as
25 a new value of the present floor (step 1305). Thereafter, the floor height value F_n of the floor corresponding to n determined at step 1303 or 1305 is read out from the floor height table 59 (step 1307) and employed as the distance

$\hat{X}$ of the present position of the cage 11 measured from the operating position of the downward limit switch 25.

When the floor height correcting task 65 ends, the operation returns again to the main routine of Fig. 8, and it is judged at step 823 whether or not the cage 11 reaches the destination floor. If it does not yet reach the destination floor, the operation returns to step 807 and is repeated in the same manner as described above until the cage 11 reaches the destination floor. When the cage 11 reaches the destination floor, a routine for stopping the cage 11 is executed at step 825. The principal function of the routine for stop is to open a power circuit and to effect the braking force. Thereafter, the operation of the normal traveling routine ends.

As described above, the present position of an elevator cage is detected by the calculation on the basis of one of the control amounts created in the course of the signal processing for the vector control of an induction motor for driving an elevator cage. Therefore, according to the present invention, any special position detector, such as an expensive rotary encoder, is not needed. Therefore, an economical elevator control apparatus can be achieved.



CLAIMS:-

1. A control apparatus for an elevator serving a plurality of floors, said control apparatus including:

(a) an induction motor for driving a cage of the elevator;

(b) inverter means supplied with D.C. power, for converting the D.C. power into A.C. power to supply said induction motor therewith;

(c) operation management control means, which receives cage call signals generated in the cage and hall call signals generated in elevator halls of the floors and produces a travelling command including information relating to the present floor position of the cage and the position of the floor to which said cage is travelling to, in order to manage the operation of the cage for serving the floors;

(d) signal processor means, responsive to the travelling command, in which a detected current of said induction motor is resolved into an excitation component and a torque component, the rotating angular speed of said induction motor being detected on the basis of the torque component, and a control signal being generated to control said induction motor in such a manner that the detected rotating angular speed follows a command for the rotating angular speed determined in accordance with the travelling command; and



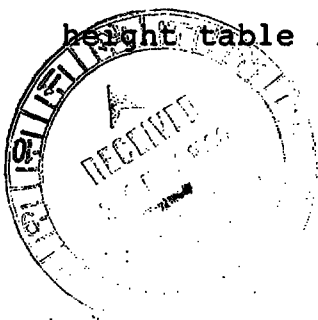
(e) inverter control means, which in response to the control signal from said signal processor means, produces gate signals for said inverter means;

wherein said signal processor means calculates a present position of the cage on the basis of the detected rotating angular speed of said induction motor and generates the command for the rotating angular speed in accordance with the calculated present position of the cage.

2. An elevator control apparatus according to claim 1, wherein said signal processor means obtains a rotating angle of said induction motor by adding up the detected rotating angular speed every given time interval and calculates the present position of the cage on the basis of the above obtained rotating angle.

3. An elevator control apparatus according to claim 1, wherein there is further provided floor detector means for producing a position interrupt signal every time the cage passes a floor, and said signal processor means has a floor height table, in which the calculated position of the cage is stored as a floor height in response to the position interrupt signal.

4. An elevator control apparatus according to claim 3, wherein the present position of the cage is calculated by the floor height read out from the floor height table in response to a position interrupt signal



and a position on the cage calculated on the basis of the detected rotating angular speed after occurrence of the position interrupt signal.

5. A control apparatus for an elevator serving a plurality of floors, said control apparatus being constructed and arranged to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

